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Ontario's Low-Carbon Hydrogen Strategy

Read our plan to accelerate and sustain a low-carbon hydrogen economy.

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Message from the Premier and Minister

Since taking office, our government has worked to make Ontario the best place to build the industries of the future. By reducing electricity costs, lowering taxes and cutting red tape we have significantly reduced the cost of doing business and seen companies and investment flow into our province as a result.

Under the previous government, the surplus generation from our nuclear and hydroelectric fleets was sold at a loss to competing jurisdictions in the United States. We are aiming to turn that electricity into a Made-in-Ontario opportunity for economic development. By leveraging that electricity for hydrogen production, electric vehicle charging and energy storage we are creating economic growth while lowering rates for families and businesses across the province.

We've rebuilt our manufacturing sector following years of neglect – securing new automotive mandates and major investments in steel production and other sectors that are supporting hundreds of thousands of jobs.

We know that to continue this growth, industries of the future require clean energy. Corporate decisions on where to invest and grow are increasingly influenced by environmental and sustainability goals.

Ontario comes from a position of strength. Our families and businesses have already done the heavy lifting of building one of the cleanest electricity systems in the world, giving us a clean energy advantage. Our government is leveraging this competitive advantage to help create jobs, including through creation of a clean energy credits registry that will allow companies to demonstrate their electricity has been sourced from a non-emitting resource.

Our strategy for a low-carbon hydrogen economy lays out the immediate actions we will take, together with job creators and other partners, in building that advantage. We are confident it will help us attract trade and investments while decarbonizing our energy sector.

Our hydrogen strategy identifies innovative projects that can help secure a clean energy future with hydrogen playing a critical role as a clean and safe energy source, from hydrogen production projects and hydrogen hubs to exploring electricity rate options for hydrogen producers. Our world-class talent and companies with cutting-edge hydrogen technologies, paired with a competitive business climate, can propel that work even further.

When energy is clean, reliable and affordable, our whole province benefits. Our low-carbon hydrogen strategy is just the first step as we seize Ontario's opportunity to grow into the clean manufacturing hub of the future, for the benefit of businesses and people across the province.

We look forward to continuing our work together to shape the future of Ontario's exciting hydrogen sector.

Sincerely,

Doug Ford
Premier of Ontario

Todd Smith
Minister of Energy

Executive summary

Ontario's low-carbon hydrogen strategy sets out a vision for a low-carbon hydrogen economy in our province – one where we can leverage our many strengths to develop a self-sustaining sector in Ontario, evolve our energy system, create local jobs and attract investment while reducing greenhouse gas (GHG) emissions.

Ontario's hydrogen strategy sets out a path where eight concrete and immediate actions are expected to lead to an eight-fold increase in the province's production capacity of low-carbon hydrogen and support the nascent market to meet its potential.

Ontario is well-positioned to become a leader in the low-carbon hydrogen sector. Our province's current advantages include:

- **Open for Business**: Ontario has a highly skilled workforce, global hydrogen technology manufacturers and many established industrial sectors that can support growth of the province's low-carbon hydrogen economy (e.g., cleantech, steel, auto manufacturing and chemicals).
- **Clean, Reliable and Affordable Electricity System**: Ontario's electricity system is among the world's cleanest with very low emissions. In addition, Ontario now has competitive electricity rates for large electricity consumers through a number of programs that could benefit hydrogen producers, particularly by using off-peak electricity.
- **Existing Storage and Pipeline Infrastructure**: Ontario has existing and planned pipeline and storage infrastructure that can be used to store hydrogen and deliver it to homes and businesses. This includes geological storage opportunities and an extensive natural gas distribution network.
- **Enabling Regulatory Environment**: Ontario is prioritizing red-tape reduction to attract investment and create jobs. Ontario's regulatory framework for fuels has already enabled a pilot project to blend hydrogen into natural gas pipelines, as approved by the Ontario Energy Board (OEB) with support from the Technical Standards and Safety Authority (TSSA).
- **Clean Biofuel Resources**: Ontario's rich forest, agricultural and municipal biomass resources could be used to create low-carbon hydrogen or other renewable fuels. This includes using diverting waste streams from these sectors, as well as material from sustainably managed forests and purpose-grown crops.

Ontario also recognizes the importance of working with the federal government and other provinces and territories to advance commercial development of hydrogen. This strategy calls on the federal government to offer tangible supports and partnerships with the province including funding and risk-sharing opportunities, clear and efficient regulations that are harmonized across leading jurisdictions and support for innovation.

To become a leader in the low-carbon hydrogen economy, Ontario's strategy is guided by the following objectives:

- **Generate Economic Development and Jobs**: Capitalize on Ontario's competitive and regional advantages, including our talent, infrastructure and resources, to accelerate growth in Ontario's low-carbon hydrogen economy.
- **Reduce Greenhouse Gas Emissions**: Support our Made-in-Ontario Environment Plan targets to reduce GHG emissions by encouraging the use of low-carbon hydrogen.
- **Promote Energy Diversity**: Consider how low-carbon hydrogen can cost-effectively support Ontario's evolving energy system and build redundancies through electricity storage and clean fuel supply.
- **Promote Innovation and Investment**: Enable opportunities for low-carbon hydrogen use and position Ontario as a leading destination for investment.
- **Strengthen Collaboration**: Work with the private sector, the federal government, municipalities, Indigenous communities, academic institutions and other stakeholders to grow and sustain a low-carbon hydrogen economy in Ontario.

Ontario's strategy is grounded in immediate actions to enable production and expand the low-carbon hydrogen economy in our province:

1. **Launching the Niagara Falls Hydrogen Production Pilot**: Atura Power proposes to produce hydrogen in Niagara Falls using electricity from the Sir Adam Beck hydroelectric generating station as part of its grid regulation services to Ontario's electricity system. The government filed a regulatory exemption to the Gross Revenue Charge (GRC) for electricity used by this project.
2. **Identifying Ontario's Hydrogen Hub Communities**: Atura Power is working to identify additional strategic locations across the province for hydrogen "hubs" where low-carbon hydrogen demand can be matched by low-carbon hydrogen production that leverages existing electricity infrastructure and Ontario's clean electricity grid. The Ministry of Energy will also undertake its own third-party led feasibility study to explore opportunities to establish new low-carbon hydrogen or clean fuel hubs in Ontario.
3. **Assessing the Feasibility of Hydrogen Opportunities at Bruce Power**: Bruce Power will launch a feasibility study to explore opportunities to leverage excess energy from the Bruce Nuclear Generating Station for hydrogen production and support a centre of excellence in the region.
4. **Developing an Interruptible Electricity Rate**: Ontario will be working towards reducing electricity rates to support low-carbon hydrogen production through a proposed Interruptible Rate pilot that would offer large electricity consumers reduced electricity rates in exchange for reduced consumption during system or local reliability events. The Ministry of Energy will also undertake consultations on other electricity rates that could help to further grow Ontario's low-carbon hydrogen economy.
5. **Supporting Hydrogen Storage and Grid Integration Pilots**: Ontario will ask the Independent Electricity System Operator (IESO) to report back on program options to support hydrogen storage and grid integration pilot projects.
6. **Transitioning Industry Through the Use of Low-carbon Hydrogen**: Ontario is taking immediate steps to support the efforts of industry to phase out their use of coal by transitioning to low-carbon processes and hydrogen-ready equipment. For example, Ontario is contributing $500 million in support to the $1.8 billion project by ArcelorMittal Dofasco at its Hamilton facility to replace coal-fed furnaces with a hydrogen-ready electric arc furnace (EAF). This project will reduce GHG emissions by about three million tonnes annually.
7. **Consulting on an Ontario Carbon Sequestration and Storage Regulatory Framework**: Ontario is proposing changes to the *Oil, Gas and Salt Resources Act* and the *Mining Act* frameworks to enable carbon storage activities on Crown land. Carbon sequestration offers the opportunity to produce low-carbon hydrogen using natural gas.
8. **Supporting Ongoing Hydrogen Research**: Ontario is supporting two independent hydrogen research projects in partnership with Natural Resources Canada to advance hydrogen development in the province.

Ontario is ready to do our part so we can attract investment and good-paying jobs in science, technology, engineering and the skilled trades.

Working together with Ontario businesses and industrial partners, the federal government, municipalities, Indigenous communities, academic institutions and other key stakeholders, we are going to connect Ontario with global markets to develop an economically sustainable low-carbon hydrogen sector.

By leveraging our talent, infrastructure and resources, we will seize this opportunity and unleash our fullest potential by becoming a world-class hub for low-carbon hydrogen innovation.

Introduction and need for action

What is Hydrogen

Hydrogen is the first element on the periodic table. It is colourless and odourless and makes up about 75% of mass in the universe. But energy is required to break the bond it has with other elements to release it from the materials where it is naturally found, for example in water (H_2O), to create pure hydrogen gas (H_2).

There are various feedstocks and ways to "break the bonds" to make hydrogen, such as with electricity, 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.

Globally, most hydrogen is made from natural gas through a process called steam methane reformation, which is currently the cheapest way to make hydrogen but has a higher carbon footprint. Hydrogen made from natural gas could potentially be paired with carbon capture, utilization and storage (CCUS) to keep most of the carbon dioxide from its production from entering the atmosphere. Hydrogen made from clean electricity or biomass results in zero or near-zero greenhouse gas (GHG) emissions over its lifecycle. This is relevant in Ontario since our world-class electricity grid is one of the cleanest, with most electricity generated from carbon-free nuclear or hydroelectric sources.

Low-carbon hydrogen (e.g., made from clean electricity) currently represents only 0.5% of the global market share.[1] 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.[2]

Currently, producing low-carbon hydrogen is costly in Ontario in part because of the cost difference between producing hydrogen using electricity versus using natural gas. Given that specific challenge, and the opportunity of promoting the production and use of low-carbon hydrogen to help decarbonize our energy system, Ontario is interested in exploring technologies and business models that can improve cost-competitiveness of producing low-carbon hydrogen.

Hydrogen is a proven safe form of fuel and subject to the same strict standards of safety as other gaseous fuels in Ontario. In fact, some of hydrogen's properties make it safer to handle and use than other fuels. According to the U.S. Department of Energy, hydrogen is non-toxic, and because hydrogen is much lighter than air, it dissipates rapidly when it is released, allowing for relatively rapid dispersal of the fuel in case of a leak.[3]

> **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, utilization and storage.
> - 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.

Seizing the Opportunity

Companies across the globe are putting capital towards reducing industrial emissions, shifting to zero-emission transportation vehicles and finding new low-carbon ways of heating our homes and businesses. Addressing climate change by lowering our GHG emissions presents Ontario with new opportunities for economic development rooted in the emerging global demand for low-carbon and net zero.

Meeting climate change targets and reducing overall GHG emissions is a challenge for all jurisdictions. Ontario is committed to action on climate change, including reducing GHG emissions to 30% below 2005 levels by 2030.

There are a number of technologies and pathways to help Ontario meet its targets. For practical and cost-effectiveness reasons, different low-carbon technologies are better suited for specific applications in the near term. In some cases, electrification makes sense; in others, clean fuels will provide the flexibility needed to abate emissions.

The province's Made-in-Ontario Environment Plan speaks to the important role that hydrogen can play as a low-carbon fuel that can support low-carbon vehicle adoption (e.g., public transportation, forklifts, heavy-duty trucks), decarbonization of space and water heating for homes and businesses and helping industry to decarbonize their processes and meet compliance obligations under Ontario's Emissions Performance Standards program.

Since 2018, Ontario has already embarked on a wide range of initiatives that include low-carbon technologies:

- Lowering the carbon footprint of industrial processes such as reducing the use of industrial coal in the steel industry;
- Introducing industrial Emissions Performance Standards;
- Building zero-emission electric vehicles;
- Developing Canada's first grid-scale small modular reactor and investigating future hydroelectric opportunities in Ontario's North;
- Integrating more electricity storage and distributed electricity generation resources into the provincial electricity grid;
- Supporting new transmission infrastructure to connect more businesses to Ontario's clean grid;
- Blending renewable content into gasoline, diesel and natural gas; and
- Increasing production of biogas and renewable natural gas for space and water heating, transportation and other applications.

Ontario is also leveraging and maximizing the province's existing energy infrastructure to ensure successful and cost-effective application of clean technologies across the province.

As we cast an eye to the future, clean fuels like low-carbon hydrogen present an opportunity to expand Ontario's clean energy advantage, remain a leader in manufacturing and meet climate and clean energy goals.

Ontario already has a strong foundation to grow Ontario's low-carbon hydrogen economy. Through this strategy, we will showcase opportunities and actions across government and outside of it that are helping to build momentum and support for Ontario's hydrogen economy in the near term and into the future.

Ontario's Hydrogen Economy – Setting the Stage

Ontario has conducted extensive consultations for more than a year in developing Ontario's Low-Carbon Hydrogen Strategy, including hearing from industry, academia, environmental groups, Indigenous communities and the public.

We have a lot more work to do. Growing our low-carbon hydrogen sector in Ontario will take time. We will continue to closely collaborate with the private sector, academics, municipalities and industry to refine our actions and advocate the federal government for investment. We will leverage Ontario's existing advantages and work within the broader framework that is being created on the national level.

This document sets the stage. It lays the foundation that will help Ontario create the right climate for businesses to take the lead.

> **Consultation to Develop Ontario's Low-Carbon Hydrogen Strategy**
>
> Ontario engaged in several types of targeted and broader public consultation on low-carbon hydrogen to help inform the development of Ontario's Low-Carbon Hydrogen Strategy:
>
> - **Clean Technology Sector Engagement**: As part of the Ontario Jobs and Recovery Committee's work, the government consulted with the clean technology sector, including hydrogen stakeholders, in spring 2020. The purpose was to understand COVID-related disruptions and how government could support the sector to continue to grow and prosper beyond the immediate recovery.
> - **Low-Carbon Hydrogen Discussion Paper**: The government posted a discussion paper to the Environmental Registry of Ontario for public consultation in fall 2020. The purpose of the discussion paper was to begin a dialogue and seek input to better understand the needs of the sector, the challenges of supporting a complex hydrogen market, and ways to enable the private sector to expand adoption of hydrogen and support regional growth.
> - **Stakeholder Webinars**: Ontario hosted two webinars in January 2021 to broaden the reach and obtain additional feedback from stakeholders, and shared information with Indigenous communities. Ontario received 145 comments from 140 organizations and individuals on the hydrogen discussion paper, including comments from industry, academia, environmental groups and the public.
> - **Hydrogen Strategy Working Group**: Ontario established the Hydrogen Strategy Working Group that met nine times from February to June in 2021 and was made up of 23 industry and academic experts who provided advice on how to use hydrogen across various sectors and help Ontario compete in the global hydrogen market.

Provincial interests – the case for low-carbon hydrogen

Environment and Economy

Using hydrogen as a fuel and feedstock (i.e., raw material used for industrial processes) has re-emerged as an exciting and potential long-term way to address climate change while providing clean energy and creating opportunities for economic growth. This is especially important since 2019, when about 75% of Ontario's GHG emissions came from energy usage (such as for transportation, buildings and industry) and about 15% from industrial processes and product use. While electrification may provide a low-carbon alternative for some applications, hydrogen could be that alternative for others.

To take advantage of the potential of low-carbon hydrogen, we need to act now to scale up existing technologies and encourage investment.

Many countries and subnational jurisdictions around the world have established or are creating plans to support market ramp-up of low-carbon hydrogen to help address climate change, secure their energy supply and support economic growth. In recent years, Canada and a number of other countries and regions, including Germany, the United States, Australia, the European Union, Japan and Spain and jurisdictions like British Columbia, Alberta, California and New South Wales, Australia have issued hydrogen strategies or plans.

Natural Resources Canada (NRCan) modelling shows that hydrogen could make up about 30% of the country's fuels and feedstock by 2050, create about 350,000 jobs and remove up to 190 megatonnes of GHG emissions per year, with both domestic and international market opportunities.[4]

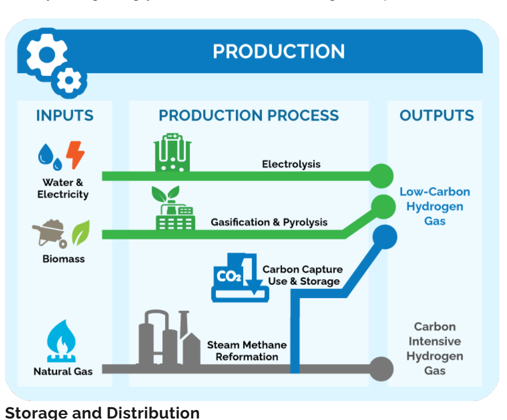
By 2050, Ontario's share of these projected benefits could include over 100,000 jobs and GHG emissions reductions of 50 megatonnes per year, according to preliminary estimates. This reduction in GHG emissions would be equivalent to about a quarter of the province's 2005 emissions or removing 15 million cars off the road.

Low-Carbon Hydrogen Supply Chain

Production

Energy is needed to separate hydrogen from other elements to create pure hydrogen gas. Today, most hydrogen is produced using natural gas through a process called steam methane reformation, which results in a more carbon intensive hydrogen gas. This is often referred to as "grey" hydrogen. Lower-carbon hydrogen can be produced from natural gas using steam methane reformation that incorporates carbon capture, utilization and storage (CCUS) to reduce the carbon emissions associated with hydrogen production. This is often referred to as "blue" hydrogen. Low-carbon electricity (e.g., nuclear, hydroelectric, wind, solar) can be used for electrolysis to produce low-carbon hydrogen or biomass and renewable natural gas can be converted into hydrogen through processes such as gasification and pyrolysis. This is called "green" hydrogen.

Using electricity generated from non-emitting sources to produce hydrogen may also help with the affordability of electricity in Ontario. For example, increasing electricity demand during off-peak hours when demand for electricity is lowest provides a new customer base for Ontario's low-carbon electricity, allowing existing system costs to be shared across a large consumption base.



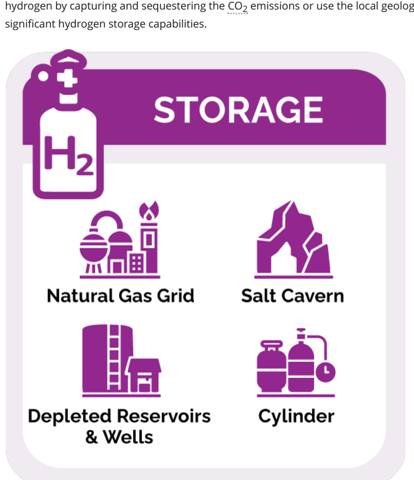
Storage and Distribution

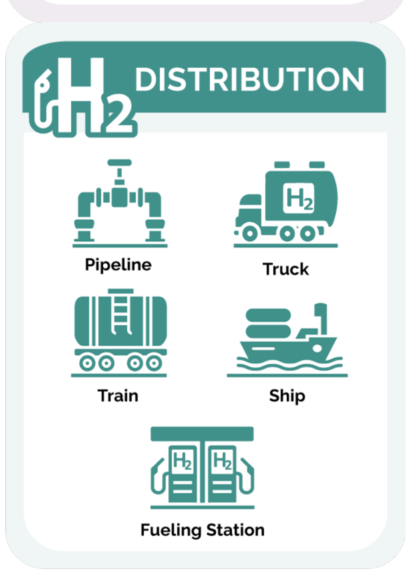
Once produced, hydrogen can be stored in gaseous form in high pressure cylinders and in liquid form in insulated tanks. It can also be stored in gaseous form in natural gas pipelines, salt caverns and depleted reservoirs. It can then be transported in tanks on trucks, trains and ships or transmitted or distributed through the existing natural gas system or dedicated pipelines.

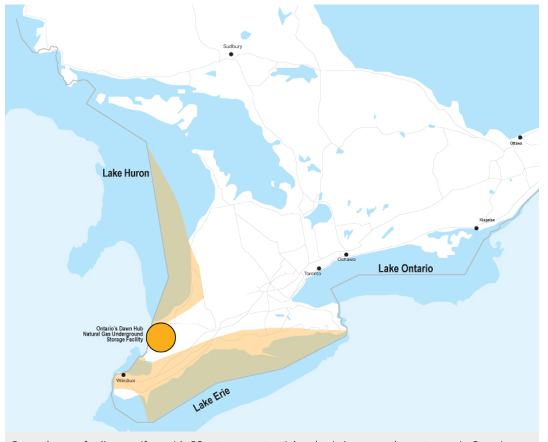
Ontario is currently home to one of the largest natural gas storage facilities in North America, referred to as the Dawn Hub, which is located in southwestern Ontario. Ontario's unique Dawn Hub is also the second most physically traded natural gas hub in North America.

The Dawn Hub is a series of underground depleted cavernous natural gas reservoirs that are filled each summer when demand for natural gas is low and natural gas is cheaper and discharged in the winter to serve increased heating demand. This allows optimum utilization of pipeline capacity into Ontario, lowers natural gas prices for Ontario families and businesses, and ensures the province has the energy it needs throughout the winter. Each year Ontario stores approximately 35% of its total winter natural gas demand in the Dawn Hub storage facilities.

In a similar manner, Ontario's geology may provide opportunities for large scale low-carbon hydrogen production or storage. Advancement of carbon dioxide (CO_2) storage opportunities may allow for industrial producers of hydrogen (e.g., petroleum refiners) to use natural gas to manufacture blue hydrogen by capturing and sequestering the CO_2 emissions or use the local geology to provide significant hydrogen storage capabilities.







General area of saline aquifers with CO_2 storage potential and existing natural gas storage in Ontario

Source : Geological Sequestration of Carbon Dioxide: A Technology Review and Analysis of Opportunities in Ontario, Ontario Ministry of Natural Resources, 2007.

In 2007, a review of sequestration opportunities for CO_2 in Ontario undertaken by the Ontario Ministry of Natural Resources suggested that, from a geological perspective, the most suitable geology for CO_2 storage may be located in an area of Southern Ontario underlain by sandstones that act as saline aquifers.

Ontario is engaged with the federal government to advance work under the federal *Hydrogen Strategy for Canada* in collaboration with other provincial and territorial governments. This includes research to better understand Ontario's opportunities for underground CO_2 storage as well as working on codes and standards for the storage and distribution of hydrogen.

Usages

At present, the main uses for hydrogen in Ontario are in petroleum refineries and for fertilizer production. Additionally, at least two large companies in Ontario – Canadian Tire and Walmart – are using hydrogen-powered forklifts in their warehouses because they are already cost competitive when operated for 24 hours a day. Since hydrogen-powered forklifts only emit water, they support indoor air quality for workers. This equipment has also improved productivity and reduced greenhouse gas emissions.

There are several uses where low-carbon hydrogen could replace natural gas, diesel, gasoline, coal or high-carbon hydrogen. It can be converted to electricity through a fuel-cell in electric vehicles to power trucks and heavy machinery. It can be used by industry as fuel for industrial processes or as feedstock to produce other products like fertilizer, ammonia, renewable diesel or refinery products. It can also be used to create low or carbon-free heat for buildings and communities, and for large scale long-term electricity storage and balancing services to support the electricity grid (i.e., helping adjust to real-time variations in electricity supply and demand).

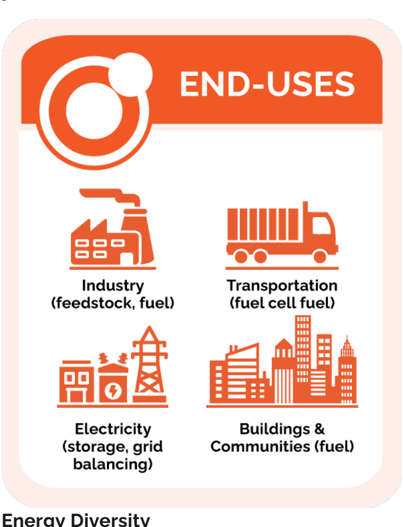
There is already a pilot project being led by Enbridge Gas and Cummins to inject hydrogen into natural

gas pipelines in Markham, adding up to 2% hydrogen by volume into the gas stream for 3,600 customers.

Hydrogen could have applications to decarbonize heavy industry. For instance, hydrogen could be used to remove oxides from iron ore (instead of coke or coal in a blast furnace) in steelmaking. Hydrogen would support the province's initiatives related to the phase-out of industrial coal and the government's support for clean steelmaking investments.

Major transportation routes could be leveraged to support the development of hydrogen transportation corridors that provide demand nodes for Ontario hydrogen production.

Low-carbon hydrogen use in these applications can complement other low-carbon fuels and technologies such as battery electric vehicles, heat pumps and renewable fuels like renewable natural gas.



Energy Diversity

Energy diversity is a key advantage of Ontario's energy sector contributing to its reliability, flexibility and resilience.

Ontario's clean electricity grid is powered primarily by a combination of nuclear, hydroelectric, other renewable electricity and natural gas, providing reliable and flexible electricity supply from a diversity of sources. Similarly, Ontario's broader energy system (i.e., supporting transportation, industrial, home heating and other applications) includes a diverse mix of fuels such as natural gas, petroleum fuels and biofuels. Different fuel sources and energy solutions make sense in different circumstances. A diverse energy mix allows end-users to find solutions that best meet their needs.

Low-carbon hydrogen is an important part of Ontario's path to decarbonizing its energy system and can also support continued energy diversity in a low-carbon Ontario.

For example, low-carbon hydrogen can serve as a complementary fuel source in the evolving transportation sector. By 2030, it is expected that one out of every three automobiles sold will be electric. Ontario's automotive sector is a key part of that transformation.

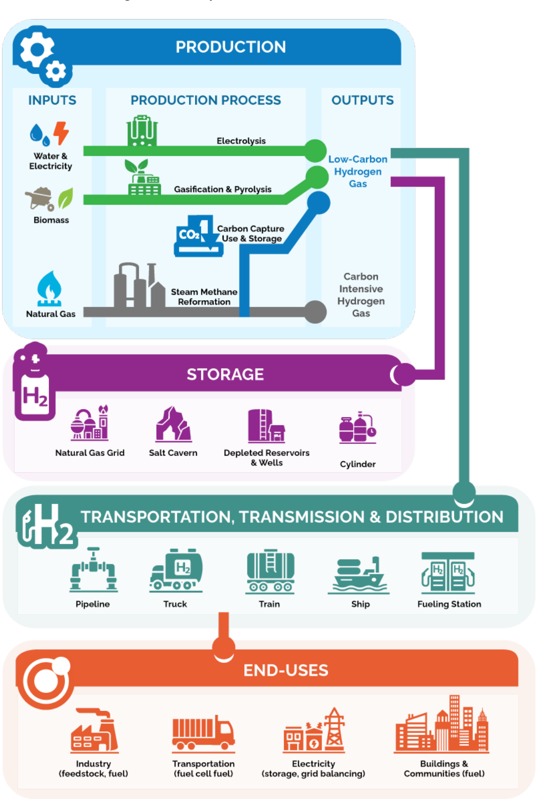
Hydrogen fuel cell vehicles have attracted interest, particularly for heavy-duty vehicle applications. For example, hydrogen fuel cells tend to be favourable for long-distance trucking applications given their comparability in range and fueling times with conventional diesel trucks. Hydrogen fuel cells also offer a smaller onboard battery pack compared to battery-electric vehicles and can support increased payload capacity. Hydrogen fuel cell applications may be more easily scalable to fleet and long-haul operations, such as transit buses, transport trucks, ships and trains, allowing for more efficient use of energy infrastructure.

Low-carbon hydrogen fuel cell powered vehicles can also complement transportation vehicles powered by lower-carbon ethanol and bio-based diesel blends. In this way, low-carbon hydrogen contributes to the diversity of transportation fuel options in Ontario, promoting energy diversity and resilience.

Low-carbon hydrogen can also be used in a complementary way to renewable natural gas (RNG), another low-carbon fuel that is critical to meeting the province's environmental goals. RNG is an important driver of economic growth in rural communities, generating value through organic waste recovery in Ontario's agrifood sector. As identified in the Made-in-Ontario Environment Plan, RNG and hydrogen can be key drivers for fuel-switching in sectors alongside electrification.

Like RNG, low-carbon hydrogen can be blended with natural gas in existing natural gas networks, reducing its carbon footprint. Similar to RNG, hydrogen can also be blended into natural gas-fired electricity generation facilities where feasible, helping lower the carbon footprint of these peaking units when they are required. Low-carbon hydrogen and RNG complement each other as low-carbon fuels with locational and production diversity.

Low-carbon hydrogen can also play a role in linking the electricity grid to the natural gas distribution grid, such as converting off-peak electricity from the provincial power grid into hydrogen that can be blended into the natural gas distribution system.



Ontario's Energy Mix

In 2017, about 28% of Ontario's energy use was natural gas and 16% was electricity. Hydrogen has the unique potential to help solve major energy challenges including clean energy storage, green transportation and linking the electricity and natural gas distribution grids.

Generation	Type	Percentage of total
Refined petroleum products	1,452 PJ	48%
Natural gas	852 PJ	28%
Electricity	481 PJ	16%
Biofuels	129 PJ	4%
Others	121 PJ	4%

Source: Canada Energy Regulator

Ontario's competitive and regional advantages – key considerations for hydrogen deployment

Open for Business

Ontario has many advantages that will help advance a globally competitive low-carbon hydrogen economy for consumers in Canada and around the world. Ontario has a world-class clean electricity system, highly skilled workforce, global hydrogen technology manufacturers and innovative companies that are working to advance low-carbon hydrogen technology.

Ontario's location within the Great Lakes region is beneficial for trade with the United States and overseas markets including Europe and Asia, which could include trading low-carbon hydrogen and associated technologies in the future. Ontario is uniquely positioned to deliver the cutting-edge low-carbon hydrogen equipment and services needed to meet the demand of the global market.

Certain regions in Ontario have opportunities to advance low-carbon hydrogen, for example:

- **Niagara Region**: run-of-the-river hydroelectricity and electricity grid regulation services that can be used for large-scale hydrogen production;
- **Bruce-Huron Region**: large-scale clean electricity generation and geological storage;
- **Windsor-Quebec Corridor**: busiest freight corridor in North America;
- **Windsor and Sarnia-Lambton Region**: refineries and chemical production transformation, gaseous fuel storage and underground caverns for subsurface hydrogen storage;
- **Northern Ontario**: feedstock from sustainably managed forests;
- **Greater Toronto Area**: large density of end-users, such as vehicle fleets and heavy-duty trucking;
- **Hamilton**: major steel producers and manufacturing hub;
- **Southern Ontario**: heavy industry transformation; and
- **Resource recovery across Ontario**: feedstock from landfills as well as food and organic waste processing facilities.

Ontario has a solid foundation for innovation with a world-class education system and research ecosystem. Ontario's universities and colleges are recognized globally and include several institutions that work on hydrogen and fuel cell related research.

Ontario is committed to providing services and programs to individuals and businesses that can be leveraged to support a low-carbon hydrogen economy in the province:

- Ontario launched a second round of the Skills Development Fund in September 2021. The fund encourages applicants to submit proposals that will address employer challenges to hiring and training workers during the COVID-19 pandemic, including priority sectors such as advanced manufacturing, life sciences and technology, which can include hydrogen technology.
- Ontario launched the 2021-22 Pre-Apprenticeship Training Program Call for Proposals in December 2021. The program introduces individuals seeking a career in the skilled trades to the technical training needed for apprenticeship in a specific trade, including those related to hydrogen technology. The goal of the program is to increase the number of new entrants to apprenticeship programs, while addressing skilled trade shortages in high-demand trades.
- Ontario has a number of programs and services for enterprises that can be leveraged to support low-carbon hydrogen in Ontario. Examples include services that provide business opportunity analysis and market insights, client-centric advice and facilitation, site selection and export assistance.
- In addition, Ontario has regional economic development funds that can support low-carbon hydrogen in Ontario. This includes the Eastern Ontario Development Fund, the Southwestern Ontario Development Fund and the Northern Ontario Heritage Fund Corporation's funding programs.

Ontario also provides several income tax incentives to encourage business investment and job creation. These incentives include:

- The Ontario Research and Development Tax Credit, Ontario Innovation Tax Credit and the Ontario Business-Research Institute Tax Credit for qualified expenditures on scientific research and experimental development performed in the province;
- Paralleling federal measures that allow businesses to accelerate write-offs of investments made in most depreciable assets. These measures include an immediate 100% write-off for manufacturing and processing machinery and equipment, specified clean energy equipment and zero-emission vehicles; and
- The Regional Opportunities Investment Tax Credit for certain capital investments in designated regions of the province.

Ontario's industrial sectors are already exploring measures to reduce their carbon footprint. Adopting low-carbon hydrogen could further help industry reduce its GHG emissions and aligns with programs like Ontario's Emissions Performance Standards (EPS). The EPS program is a key commitment of the government to reduce GHG emissions from large, industrial emitters with a system that is tough but fair, cost-effective and flexible to the needs and circumstances of our province.

Some Ontario regions have taken steps to champion their area as potential hydrogen hubs. For instance, Sarnia-Lambton has highlighted the region's cluster of current and potential low-carbon hydrogen producers and users (e.g., in the petroleum refining and chemical sectors), energy and infrastructure assets, research capabilities and skilled workforce as attributes that position this region to be a key player in the low-carbon hydrogen economy. Ontario's support for clean steelmaking in Hamilton also provides an opportunity for companies, research centres and workers in that region to begin partnering on hydrogen hub opportunities.

Other regions have potential as low-carbon hydrogen hubs and Ontario has engaged in preliminary research to evaluate potential opportunities, along with the federal government's Hydrogen Strategy, which is also looking to identify potential hubs for Canada.

Ontario has many established industrial sectors that can support growth of the province's low-carbon hydrogen economy. This includes businesses with experience in cleantech, steel, auto manufacturing and chemicals. These businesses are ready to collaborate and deliver innovative solutions for the future of low-carbon hydrogen in Ontario. Two such sectors, chemicals and autos, are profiled below.

Chemical Manufacturing

With 40% of the country's total production, Ontario is a chemical manufacturing powerhouse. The chemical sector has a longstanding presence in Ontario and has played a vital role in the province's economy.

From a burgeoning sector that mass-produced synthetic rubber in Sarnia-Lambton during Canada's World War II efforts, the sector has grown to become the largest in Canada, providing 26,000 direct jobs to Ontarians (in 2020)[5], and is the fourth largest exporting manufacturing sector in the province. With over $16 billion in sales, the sector's value chain includes the production of ethanol fuel from biomass feedstock, as well as commodity chemicals, synthetic resins, a wide range of specialty chemicals and plastics as well as a leading producer of chewing gum.

The sector's products are direct enablers of other key sectors in the province, including automotive, aerospace, health and life sciences, food packaging and electronics. As the sector continues to focus on environmental sustainability, the province's chemical manufacturers are investing in technologies that contribute to waste and carbon emission reductions, as well as the evolving circular economy.

Sarnia-Lambton is also a major player in the production of fertilizer and ammonia. Ammonia is comprised of three parts hydrogen and one-part nitrogen. At present, ammonia production is one of the largest industrial uses of hydrogen, though the vast majority of it is grey hydrogen. Low-carbon hydrogen presents an opportunity to decarbonize ammonia production.

In addition to being used to produce fertilizer, ammonia can also be used as a chemical carrier to enable the cost-effective transport of hydrogen within Canada and to export markets across the continent and beyond. Ammonia's higher volumetric energy density compared to hydrogen gas, enables hydrogen to be transported and stored using existing ammonia transportation infrastructure, which is already highly developed including pipelines, railways, ports and distribution facilities across Canada, North America and the globe.

Ammonia is also a fuel in its own right. It can be used directly for power generation in ammonia-fired turbines, engines and marine vessels. As well, the International Maritime Organization has identified ammonia and hydrogen as key fuels for a decarbonized shipping industry.

Automotive Sector

Ontario is North America's second largest vehicle producer, with a sector that includes world-leading vehicle assemblers, parts manufacturers and research centres. As the only subnational jurisdiction with five original equipment manufacturers that, despite the global pandemic and supply chain issues, produced nearly 1.4 million vehicles in 2020, Ontario is well-positioned to manufacture the next generation of low-carbon vehicles, including hydrogen fuel cell vehicles.

The Government of Ontario's auto sector strategy, Driving Prosperity, aims to strengthen and build on leadership in automotive assembly and parts production as well as technology innovation and adoption. Over the next decade, global sales of electric vehicles (EVs) are forecasted to grow exponentially. Ontario's automotive plan includes maintaining and growing Ontario's auto sector by building at least 400,000 electric vehicles and hybrids by 2030.

Ontario's automotive sector is going through a transformation to produce green vehicles. Recent landmark investments from global automakers totaling around $4 billion firmly establish Ontario as a hub for EV manufacturing and Ontario companies are at the forefront of developing zero-emissions technologies including fast-charging batteries, connected charging infrastructure, battery recycling and EV powertrains. Recent, transformative investments in Ontario include:

- $1.8 billion by Ford to produce electric vehicle battery packs and five new electric vehicle models in Oakville, including historic investments of $295 million each from the governments of Ontario and Canada;
- $1.5 billion by Stellantis to upgrade its Windsor Assembly Plant and build electric vehicles; and
- $1 billion by GM to produce the BrightDrop all-electric delivery van in Ingersoll, the first produced by a mainstream automaker in Canada.

Hydrogen Investments

Ontario is also a world leader in hydrogen technology development. The world's first commercial hydrogen powered trains, North America's first hydrogen-blended natural gas project in Markham and the commercialization of large-scale hydrogen production systems all rely on hydrogen technologies developed by Ontario-based companies.

These early-stage investments in hydrogen technology reflect Ontario's desirability as a jurisdiction for research and development, innovation and manufacturing.

Cummins & Hydrogen Optimized

Cummins' Fuel Cell and Hydrogen Technologies group is based in Mississauga, Ontario following its acquisition of Hydrogenics in 2019. Since the acquisition, Cummins has dramatically scaled up its Mississauga operations, more than doubling its headcount and expanding its facilities. Cummins is also the leading developer of large-scale proton exchange membrane (PEM) water electrolyzer equipment for the production of low-carbon hydrogen. Enbridge Gas and Hydrogenics built the first large scale low-carbon hydrogen facility in Markham, Ontario, which was commissioned in 2018.

For over 20 years, Cummins has developed high performance fuel cell power modules for many equipment manufacturers and integrators including transit buses in China, Class 8 trucks in California and Europe, and in the world's first fuel cell electric train, the Coradia iLint, developed by French train manufacturer Alstom.

Hydrogen Optimized, located in Owen Sound, Ontario, develops and commercializes large-scale hydrogen production systems. Their RuggedCell water electrolyzer converts clean electricity into low-carbon hydrogen for industrial, chemical, utility and energy end users. The recent operation of a 50,000 ampere RuggedCell unipolar electrolyzer represents a breakthrough in large-scale hydrogen production technology and a direct pathway toward the commercialization of single electrolysis modules up to 100 megawatts (MW).

These companies and other Ontario businesses are already leading the world and place Ontario at the forefront of clean energy technologies and development.

Clean, Reliable and Affordable Electricity System

Ontario is well positioned to be a significant contributor in low-carbon hydrogen production using its abundance of clean electricity. The province's clean electricity grid is powered primarily by a combination of nuclear, hydroelectric, other renewable electricity sources and natural gas.

Today, Ontario's electricity system is among the cleanest in the world with the majority of electricity generation coming from non-emitting sources. Due to the nature of the electricity system, surplus generation occurs when electricity production from baseload facilities exceeds demand. This typically occurs overnight when demand for electricity is at its lowest and generation is the cleanest. The province can maximize this surplus electricity, including from nuclear, hydroelectric and wind generation, by utilizing it to produce hydrogen and potentially storing it to generate electricity during times of system need.

Ontario is undertaking several initiatives to ensure that consumers in Ontario continue to have access to clean, reliable electricity, including:

- Asking the Independent Electricity System Operator (IESO) to evaluate a moratorium on the procurement of new natural gas generation in Ontario and develop an achievable pathway to phase out contracted natural gas generation and move to zero emissions in the electricity system, while maintaining reliability and affordability. As part of this work, the IESO is giving consideration to the possibility of maintaining natural gas generating facilities but replacing natural gas with clean fuels such as hydrogen and renewable natural gas or the development of utility-scale carbon capture and storage;
- The development of a clean energy credit (CEC) registry and trading system that would allow consumers to ensure that their electricity consumption comes from 100% emission free energy resources to fulfil their corporate, environmental and sustainability goals and promote the development of clean energy supply in Ontario;
- Completed the demolition of the last coal-fired generating station in Ontario, Lambton Generating Station, in February 2022; and.
- Re-contracting Ontario's biomass generation facilities and enabling storage and distributed energy resources in the province, while investigating opportunities for future hydroelectric power generation in Northern Ontario.

The Ontario landscape has changed in the past few years. In addition to its clean energy advantage, Ontario now has competitive electricity rates for large electricity consumers through programs like the Industrial Conservation Initiative (ICI) and the Northern Industrial Electricity Rate Program (NIERP). In 2021, Ontario introduced the Comprehensive Electricity Plan (CEP), which included shifting funding from the electricity rate-base to the province for a portion of non-hydro renewable energy contract costs, which are above market and not competitive. The CEP is forecasted to reduce rates for industrial consumers by about 15% and for mid-sized commercial consumers by about 17% in 2022 by removing the above-market costs of electricity generating contracts for wind, solar and biomass from electricity bills.

Most large Ontario electricity consumers participate in the ICI and can reduce their electricity costs by avoiding consumption during periods of peak system need, which helps avoid the need to build energy generation infrastructure only to meet short periods of peak demand. The ICI program is especially well-suited to hydrogen production, as consumers with flexible consumption profiles can achieve electricity rates among the lowest in North America.

For example, under current system conditions, an ICI participant that is directly connected to the high-voltage transmission grid and that does not consume electricity during peak hours could achieve all-in electricity costs of about $35 per megawatt-hour or lower (based on 2021 rates), which is well below rates in competing jurisdictions.

Ontario's Clean Electricity Generation

In 2020, about 94% of Ontario's electricity came from non-emitting sources, including nuclear, hydroelectric, biomass, wind and solar. Natural gas generation is required to help meet temporary supply gaps due to the refurbishment of Ontario's nuclear fleet and provide back-up generation when the sun is not shining and the wind is not blowing.

Fuel Type	Percentage of total generation
Nuclear	57%
Hydroelectric	24%
Wind	9%
Natural Gas	6%
Solar	2%
Bioenergy	1%
Other	1%

Ontario's Nuclear Advantage

Ontario is a leader in nuclear energy. About 95% of Canada's nuclear generation occurs in Ontario. In 2020, nuclear electricity generation accounted for about 60% of Ontario's electricity mix. Only five countries have a higher share of annual electricity generation from nuclear power than Ontario. The refurbishments of the Bruce and Darlington nuclear generating stations will secure a long-term supply of reliable and emission-free energy for decades to come.

Ontario is also leading the way in nuclear innovations such as Small Modular Reactors (SMRs), which could provide scalable clean energy across Canada and around the world. Ontario has been collaborating on SMR development with Saskatchewan, New Brunswick and Alberta through a Memorandum of Understanding (MOU). Under the MOU, the provinces were tasked with developing a Strategic Plan with a path forward for the advancement of SMRs across Canada.

Some designs for SMRs that may be considered are well-suited for producing high-temperature steam for hydrogen production. In addition, the Province supports Ontario Power Generation's plan to build a grid-scale SMR at the Darlington nuclear site – which would be its first new reactor since 1993 – and is planning for it to be operational as early as 2028. The Darlington SMR would help meet Ontario's growing demand for clean electricity that can be leveraged for the production of clean hydrogen.

Existing Storage and Pipeline Infrastructure

Ontario has existing and planned pipeline and storage infrastructure that can be used to store hydrogen and deliver it to homes and businesses, as it is currently being used to transport and store natural gas and RNG. Leveraging existing assets to the extent possible will help offset the need to build new storage and distribution facilities. Existing natural gas assets include:

- **Natural Gas Distribution Network**: Ontario's natural gas pipeline network currently supplies about 3.5 million homes and 340,000 businesses in the province. Ontario is also working to expand natural gas access to thousands of households and businesses across northern, rural and Indigenous communities.
- **Salt Layers**: Southwestern Ontario has geologic salt layers potentially suitable for creating large salt caverns deep underground that are currently a typical storage method for liquid hydrocarbons and hydrogen. Ontario currently has 73 active storage caverns in the Windsor and Sarnia area serving the petrochemical industry, which could be evaluated for conversion to hydrogen storage.[6] Within North America, there are three hydrogen salt storage caverns that have been in operation since 1983.
- **Underground Natural Gas Storage**: Ontario has the second largest underground natural gas storage capacity in Canada at about eight billion cubic metres.[7] This underground storage uses depleted oil and gas reservoirs.

In the future, as low-carbon hydrogen production and use increases in the province, existing underground hydrocarbon and liquified petrochemical storage facilities could be explored for potential use to store blended natural gas and hydrogen where feasible. Additional research will be required to confirm the suitability of Ontario's existing underground storage assets to new applications.

Home heating is one of the largest contributors to a household's GHG emissions. By blending low-carbon hydrogen into the natural gas system, residential customers can reduce their carbon footprint while keeping their existing furnaces, water heaters and other gas appliances. Blending projects are happening around the globe and are safe, effective ways of leveraging low-carbon hydrogen. Ontario is already home to an exciting pilot project that is blending hydrogen into the natural gas distribution system – the Low-Carbon Energy Project in Markham. The federal government, natural gas pipeline companies and natural gas distributors are reviewing codes and standards to assess hydrogen blending limits in natural gas pipelines.

North America's First Utility-Scale Power-to-Gas Facility

In 2018, Enbridge Gas and Hydrogenics (subsequently purchased by Cummins Inc.) developed and built the Markham Energy Storage Facility, which converts Ontario's clean electricity from the provincial power grid into low-carbon hydrogen. From 2018 to 2021, Ontario's IESO contracted with the facility to help maintain electricity grid reliability by providing regulation services to help balance electricity supply and demand.

Enbridge Gas recently put into service the Low-Carbon Energy Project which is blending hydrogen into the natural gas system on a pilot basis, offsetting a portion of fossil natural gas with hydrogen. This utility-scale facility, commissioned on October 1, 2021, is the first of its kind in North America and will:

- Replace up to 2% by volume of natural gas for 3,600 homes and businesses; and
- Reduce GHG emissions by up to 120 tonnes a year.

According to Natural Resources Canada, natural gas blend ratios of up to 20% hydrogen are being trialled around the world, with limited impact on infrastructure and end-use appliances.[8]

In Europe, hydrogen blending has been started in Germany, France and the United Kingdom, with a demonstration project in Scotland set to deliver up to 100% hydrogen for a small number of homes.[9]

An Enabling Regulatory Environment

Ontario is prioritizing red tape and burden reduction to create an open for business climate that attracts investment and creates jobs. The government's goal is to make life better for people and remove regulatory roadblocks for businesses and reduce their costs by $400 million.

To date, Ontario has taken actions to modernize, streamline and remove out-dated or duplicative processes and regulations to the tune of a reduction of 2% per year.

This work has already been successful in the clean fuels sector by unlocking the value of RNG resources, particularly by streamlining approvals for on-farm biogas anerobic digestors in 2020 to increase RNG production in Ontario.

Ontario and the Technical Standards and Safety Authority (TSSA) have also been proactive in developing regulations and codes to support the safe adoption and use of hydrogen:

- Ontario worked with the TSSA to modernize operational compliance obligations for hydrogen refueling stations by updating the Operating Engineers regulation (O. Reg. 219/01) that adopts a risk-informed framework to enable the use of modern technology and updates operating engineer certification and requirements without compromising public safety. This change was introduced as part of a package of measures announced alongside the *Better for People, Smarter for Business Act* in 2020.
- Ontario in collaboration with the TSSA adopted the Canadian Hydrogen Installation Code in 2007. Ontario's Fuel Industry Certificates includes a hydrogen certificate to support fuels safety in Ontario, which is the first of its kind in Canada.

Ontario has worked with industry and environmental groups to update "Guideline A-5: Atmospheric Emissions from Stationary Combustion Turbines" to include provisions for the use of hydrogen in stationary combustion turbines. This update aligns with federal guidelines, incorporates industry best practices, and reduces overall air emissions that contribute to air pollution, such as nitrogen oxides, from individual combustion turbine systems.

Clean Biofuel Resources

Ontario's rich forest, agricultural and municipal biomass resources could be used to create low-carbon hydrogen or other renewable fuels. This includes using diverted waste streams from these sectors, as well as material from sustainably managed forests and purpose-grown crops.

Ontario's sustainably managed Crown forests can supply approximately 30 million cubic metres of wood annually. As outlined in Ontario's Draft Biomass Action Plan, Ontario's forest sector is highly integrated. For example, mill by-products from one facility are the feedstock to produce energy for another and fuel Ontario's northern fleet of biomass electricity generators, which helps reduce waste and promotes a circular economy. The existing forest products manufacturing infrastructure provides for a solid foundation to leverage future investments for the development of new bioproduct and revenue streams while avoiding added pressure on landfills.

Bioenergy production from low-grade forest biomass can support existing and new uses of wood waste, including emerging uses such as production of RNG from the methane captured as organic material decomposes, and producing low-carbon hydrogen.

As other sectors of the economy move to transition away from fossil fuels and toward more circular and sustainable alternatives, the forest sector can provide valuable supply chain benefits to participants in the emerging green economy. This has the potential to contribute to the Northern Ontario economy and support forestry sector jobs.

Currently, about 3.5 million tonnes of food and organic waste is generated in the province every year, some of which is captured and cleaned to produce RNG for injection into the natural gas grid.

RNG from food and other organic waste could then be used to produce low-carbon hydrogen. Alternatively, dry organic waste could be used to produce low-carbon hydrogen directly.

CHAR Technologies

In October 2021, CHAR Technologies Ltd. started surveying and testing at the proposed site of its woody biomass-to-RNG High Temperature Pyrolysis (HTP) project near Kirkland Lake, Ontario. This project may potentially produce 500,000 gigajoules per year of RNG and 10,000 tonnes per year of CHAR's proprietary CleanFyre bio-coal. The company has a letter of interest signed in July 2021 for biomass supply to the project, and an exclusive letter of interest signed in September 2021 with a Canadian gas utility for long term RNG off-take. CleanFyre from the proposed Kirkland Lake facility will be earmarked for future sale to the steelmaking and metal smelting industries.

CHAR is expanding its activities in the United States as well. The company has a definitive agreement for a project with Hitachi Zosen Inova to develop an HTP to hydrogen system at their existing San Luis Obispo anaerobic digestion facility in California. The HTP system is being developed to produce up to one million kilograms of green hydrogen per year.

StormFisher and ZooShare Biogas

The StormFisher London Biogas Facility and the Toronto-based ZooShare Biogas Plant are both converting thousands of tonnes of organic waste into biogas for electricity and to upgrade biogas to RNG for heating and fuel transportation.

StormFisher partnered with Enbridge Gas to upgrade the biogas produced in their facility to RNG to inject in the Ontario natural gas system. Over 70,000 tonnes of organic waste from restaurants, grocery stores, municipalities and other organizations are converted to about three million cubic metres of RNG annually using an anaerobic digestion process. The RNG diverts waste from landfills and eliminates over 8,000 tonnes of GHG emissions. The digested organics are then used to produce fertilizer. The StormFisher London Biogas Facility received the 2021 Project of the Year award from the Canadian Biogas Association for its RNG production system accomplishments.

The ZooShare Biogas Plant, Canada's first biogas plant to use zoo animal waste as the primary biogas feedstock, turns food waste and Toronto Zoo animal waste into renewable power for the Ontario grid. ZooShare converts 2,000 tonnes of zoo animal waste and 15,000 tonnes of food waste into renewable power for about 250 homes. This reduces GHG emissions by up to 20,000 tonnes per year. At the end of the biogas production process, the remaining solid waste is used as a nutrient-rich fertilizer to grow food. ZooShare began to generate power to the grid on April 1, 2021.

In regard to hydrogen opportunities, biogas can be used as a low-carbon feedstock for hydrogen production or to generate clean electricity which can produce hydrogen using electrolysis technology.

Working cooperatively with the federal government

Ontario will continue to work with the federal government as well as with other provinces and territories to collectively advance the hydrogen economy across Canada.

The *Hydrogen Strategy for Canada*, launched in December 2020, aims to make hydrogen a central part of Canada's goal of achieving net-zero emissions by 2050, while building up Canada as a global leader in clean renewable fuels. The federal hydrogen strategy includes an ambitious near- to long-term framework for actions.

The proposed *Roadmap to 2050* in the federal hydrogen strategy covers a wide range of policies and activities, such as:

- Using the proposed Clean Fuel Standard to drive near-term investment in the sector;
- Incentivizing regional hydrogen hubs;
- Enabling larger scale hydrogen production for relevant industrial applications; and
- Deploying large-scale hydrogen technologies.[10]

In addition, the federal hydrogen strategy emphasizes the importance of developing strategic partnerships and of collaborating across multiple levels of government in order to align programs and policies and to identify areas for federal/provincial/territorial (FPT) collaboration. Ontario is already participating on intergovernmental hydrogen working groups established by the federal government. There is work underway to create about 16 intergovernmental working groups to collaborate on different aspects of hydrogen development, including natural gas, nuclear energy, hydrogen hubs, codes and standards, mining and transportation.

The federal government is also undertaking further studies to advance its own hydrogen strategy (e.g., identifying export markets, off-grid opportunities, harmonizing codes, standards and modelling, co-location of hydrogen and nuclear assets) that will help to inform the FPT work that is already unfolding.

Participation in these working groups allows Ontario to reflect the province's interests, for example, by seeking its fair share of federal funding and aligning approaches to low-carbon hydrogen development where appropriate. Ontario is also promoting its existing low-carbon hydrogen strengths, needs and opportunities to the federal government to leverage potential resources.

Ontarians have done their part in our electricity system by paying for the phase-out of coal. To meet our climate change goals, we need the federal government to play a role in Ontario's low-carbon economy, including the commercial development of hydrogen.

To make hydrogen a success in Ontario will require the federal government to offer a full suite of tangible supports and partnerships, including:

- Funding and risk-sharing opportunities;
- Clear and efficient regulations that are harmonized across leading jurisdictions; and
- Support for innovation.

We also call on the federal government to ensure that ample funding is available for Ontario companies to engage in research and demonstration projects for the production, storage, distribution and end-use of hydrogen as well as exporting hydrogen to global markets.

Ontario's low-carbon hydrogen future

Core Objectives

Ontario's vision for the low-carbon hydrogen strategy is to develop a self-sustaining low-carbon hydrogen economy in Ontario that would create local jobs, attract investment and reduce GHG emissions.

Ontario's strategy lays out a framework that builds on our existing strengths and our government's broader commitment to reducing barriers, driving innovation and encouraging collaborative partnerships.

The core objectives of Ontario's strategy are to:

- **Generate Economic Development and Jobs**: Capitalize on Ontario's competitive and regional advantages, including our talent, infrastructure and resources, to accelerate growth in Ontario's low-carbon hydrogen economy.
- **Reduce Greenhouse Gas Emissions**: Support our Made-in-Ontario Environment Plan targets to reduce GHG emissions by encouraging the use of low-carbon hydrogen.
- **Promote Energy Diversity**: Consider how low-carbon hydrogen can cost-effectively support Ontario's evolving energy system and strengthen reliability through electricity storage and clean fuel supply.
- **Promote Innovation and Investment**: Enable opportunities for low-carbon hydrogen use and position Ontario as a leading destination for investment.
- **Strengthen Collaboration**: Work with the private sector, the federal government, municipalities, Indigenous communities, academic institutions and other stakeholders to grow and sustain a low-carbon hydrogen economy in Ontario.

Through this strategy, the province will showcase additional areas of work across government and outside of it that are helping to build momentum and support for Ontario's low-carbon hydrogen economy in the near term and into the future.

Immediate Actions

Ontario is taking immediate and meaningful steps through eight specific actions to enable production and expand the low-carbon hydrogen economy. Through these actions, Ontario's hydrogen strategy is expected to increase the amount of annual production capacity of low-carbon hydrogen eight-fold in the province and support the nascent market to meet its potential.

Action 1: Launching the Niagara Falls Hydrogen Production Pilot

The Ontario Government is supporting Atura Power's proposal for the province's largest low-carbon hydrogen production facility. Atura Power is a wholly owned subsidiary of Ontario Power Generation (OPG).

Atura Power proposes to build, own and operate this facility in Niagara Falls, Ontario, which would be a catalyst for the low-carbon hydrogen economy in Ontario. Atura Power has completed a feasibility study and preliminary design for the Niagara Hydrogen Centre. The facility plans to include a 20 MW electrolyzer that is capable of providing grid balancing services and use low-cost off-peak electricity to produce low-carbon hydrogen. With this local hydrogen supply, it is anticipated that the Niagara facility can be a prominent low-carbon hydrogen hub for heavy-duty trucking, municipal mobility and heavy industrial consumers in Ontario.

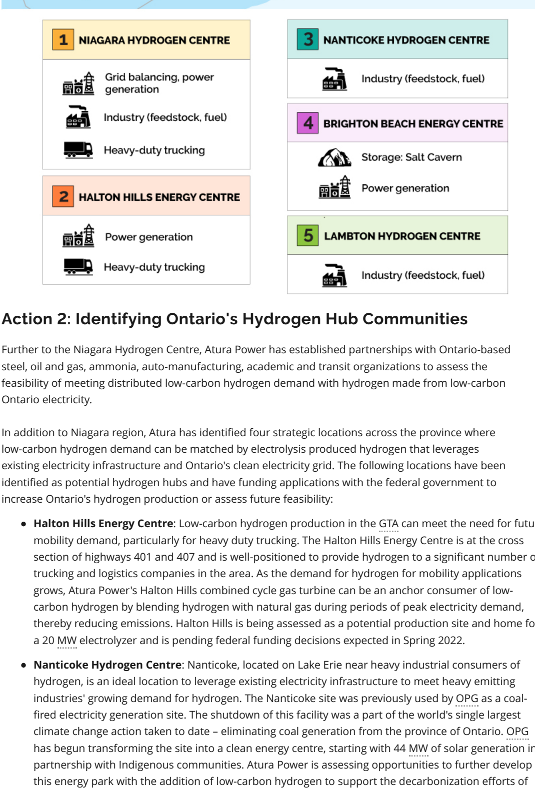
The proposed facility would be a source of low-carbon hydrogen that can be used in the merchant market for hydrogen as well as blending with natural gas in natural gas combustion turbines (to be performed in the near term at Atura Power's facilities). The low-carbon hydrogen produced at the Niagara facility would support emission reductions equivalent to taking more than 4,000 cars off the road.

The main source of electricity for the electrolyzer would be the nearby Sir Adam Beck Hydroelectric Generating Station on the Niagara River. Hydrogen produced via electrolysis at this location has an exceptionally low life-cycle carbon intensity. The Niagara facility location allows direct access to Highway 405, which connects the northern portion of the I-90 in New York with the Queen Elizabeth Way (QEW) and the Greater Toronto Area (GTA). This area has a strong industrial base, and the location enables efficient access to the 400 series highway network and end-users in the GTA and upstate New York.

The benefits of near-term low-carbon hydrogen production at the proposed Niagara facility include local and provincial economic development through investment, jobs and developing the first large-scale low-carbon hydrogen hub in Ontario. Atura Power is advancing the detailed design and conducting long-lead procurement for the electrolyzer that will support a final investment decision for the facility in summer 2022. The final investment decision will depend on the outcome of federal funding submissions made to the Natural Resources Canada Clean Fuels Fund. If successful, the facility is expected to achieve commercial operations by the end of 2023.

Ontario is supporting the proposed hydrogen production facility in Niagara through a regulatory exemption to the Gross Revenue Charge (GRC). The regulation, filed in January 2022, provides GRC property tax and waterpower rental charge savings from 2024-33 for electricity generated at the Sir Adam Beck station used specifically for hydrogen production while providing electricity grid regulation under prescribed conditions. The proposed Atura Power project and the Province's actions will enable better utilization of the Niagara Falls hydroelectricity resource, while being capable of providing electricity grid frequency regulation to produce low-cost, low-carbon hydrogen. The Province is supportive of innovative solutions like the Niagara Hydrogen Centre that maximize Ontario's low-carbon electricity resource utilization and kick-start the low-carbon hydrogen economy.

With the addition of the 20 MW electrolyzer, Ontario's potential for low-carbon hydrogen production capacity would expand eight-fold. Currently, the Markham Power-to-Gas facility has a capacity of 2.5 MW for hydrogen production. The addition of this new facility will increase Ontario's installed electrolyzer capacity to 22.5 MW.



Action 2: Identifying Ontario's Hydrogen Hub Communities

Further to the Niagara Hydrogen Centre, Atura Power has established partnerships with Ontario-based steel, oil and gas, ammonia, auto-manufacturing, academic and transit organizations to assess the feasibility of meeting distributed low-carbon hydrogen demand with hydrogen made from low-carbon Ontario electricity.

In addition to Niagara region, Atura has identified four strategic locations across the province where low-carbon hydrogen demand can be matched by electrolysis produced hydrogen that leverages existing electricity infrastructure and Ontario's clean electricity grid. The following locations have been identified as potential hydrogen hubs and have funding applications with the federal government to increase Ontario's hydrogen production or assess future feasibility:

- **Halton Hills Energy Centre**: Low-carbon hydrogen production in the GTA can meet the need for future mobility demand, particularly for heavy duty trucking. The Halton Hills Energy Centre is at the cross section of highways 401 and 407 and is well-positioned to provide hydrogen to a significant number of trucking and logistics companies in the area. As the demand for hydrogen for mobility applications grows, Atura Power's Halton Hills combined cycle gas turbine can be an anchor consumer of low-carbon hydrogen by blending hydrogen with natural gas during periods of peak electricity demand, thereby reducing emissions. Halton Hills is being assessed as a potential production site and home for a 20 MW electrolyzer and is pending federal funding decisions expected in Spring 2022.
- **Nanticoke Hydrogen Centre**: Nanticoke, located on Lake Erie near heavy industrial consumers of hydrogen, is an ideal location to leverage existing electricity infrastructure to meet heavy emitting industries' growing demand for hydrogen. The Nanticoke site was previously used by OPG as a coal-fired electricity generation site. The shutdown of this facility was a part of the world's single largest climate change action taken to date – eliminating coal generation from the province of Ontario. OPG has begun transforming the site into a clean energy centre, starting with 44 MW of solar generation in partnership with Indigenous communities. Atura Power is assessing opportunities to further develop this energy park with the addition of low-carbon hydrogen to support the decarbonization efforts of local industry. Execution of the feasibility study with partners will commence in summer 2022, subject to successful funding award decisions from the federal government.
- **Brighton Beach Energy Centre and Hydrogen Salt Cavern Storage**: Brighton Beach, located in Windsor, is one of the few locations in Ontario with suitable geology for underground salt cavern storage of hydrogen. Atura Power, in conjunction with a local industry partner, is proposing a feasibility study to assess hydrogen production and large-scale sub-surface storage of hydrogen in salt caverns. Understanding the potential to expand or convert existing salt caverns, or develop new salt caverns for hydrogen storage, is an important component in hydrogen's decarbonization potential. As the hydrogen demand is established in the region, Atura Power's Brighton Beach combined cycle gas turbine can consume the hydrogen, reducing emissions during peak generation periods. The feasibility study is subject to funding award decisions from the federal government, and if successful, the project will commence as early as summer 2022.
- **Lambton Hydrogen Centre**: The project proposed in the Lambton-Sarnia region is located at a former OPG coal-fired generation site. In February 2022, the smokestacks and powerhouse of the decommissioned Lambton Generating Station were safely imploded by OPG. The safe decommissioning and demolition of this facility represents an opportunity for new beginnings for this site as a clean energy centre. Atura Power is investigating the opportunity to produce large-scale low-carbon hydrogen at this site and serve heavy industry in the Sarnia-Lambton area in support of a local hydrogen hub. A feasibility study application for this site has been submitted to the federal government for funding and, pending award, will commence in summer 2022.

The Ministry of Energy will also undertake its own third-party led feasibility study to explore opportunities to establish new low-carbon hydrogen or clean fuel hubs in Ontario to give Ontario business a competitive edge by enhancing their abilities to develop and adopt low-carbon technologies.

Action 3: Assessing the Feasibility of Hydrogen Opportunities at Bruce Power

The Bruce Nuclear Generating Station is Ontario's largest nuclear facility and the largest operating nuclear plant in the world. Bruce Power will explore opportunities to leverage excess energy from the Bruce station (i.e., energy that is not currently being transmitted to the electricity system) for hydrogen production. This includes excess steam, diverted steam to address system manoeuvres, or incremental output as part of Bruce Power's *Project 2030* to achieve 7,000 MW peak electricity generation at the site.

As a first step, Bruce will launch a Hydrogen Opportunities Study in 2022. The study will be led by Bruce Power in collaboration with Greenfield Global, Hydrogen Optimized and Ontario's Ministry of Energy to determine opportunities for hydrogen production using this excess energy and to recommend how this unique asset could become a centre of excellence for hydrogen production and a key hydrogen hub for the province. The project will be conducted in partnership with the Hydrogen Business Council and is expected to be completed in early 2023.

In addition, the Bruce Power Centre for Next Generation Nuclear at the Nuclear Innovation Institute is also exploring opportunities for Bruce Power's assets to maximize the impact they'll have on Canada's clean energy future. This includes three main activities:

- Leveraging investments being made in CANDU nuclear reactor technology through Ontario's refurbishment program to further clean innovation in other sectors of the economy;
- The Breakthrough Energy Program conducts research and policy work into small modular reactor technology as well as evaluates the long-term opportunities for fusion energy generation; and
- Bruce Power is exploring opportunities into the next 50 years for its assets to be optimized, enhanced, leveraged and extended.

Action 4: Developing an Interruptible Electricity Rate

Ontario is committed to exploring the use of surplus electricity, such as spilled hydropower or curtailed wind power, by hydrogen producers that are able to operate with flexibility. Providing reduced rates for this intermittent surplus electricity could provide an economic benefit to hydrogen producers with no negative impact for existing ratepayers. Although electricity rates in our province are competitive and continue to attract investment, some eligibility requirements to the ICI program create barriers for hydrogen producers. We are exploring potential changes while avoiding any negative impact to other ratepayers.

Ontario is working towards the launch of an Interruptible Rate pilot that would offer large electricity consumers reduced electricity rates in exchange for agreeing to reduce consumption during system or local reliability events, as identified by the Independent Electricity System Operator (IESO). Ontario is consulting with stakeholders on this proposal through a posting on the Regulatory Registry. Agreements like these could reduce the costs required to build new energy generation infrastructure by using existing production more efficiently.

In addition, the Ministry of Energy is undertaking consultations on other electricity rates that could help to further grow Ontario's low-carbon hydrogen economy.

Ontario is also exploring potential Gross Revenue Charge exemptions for other hydroelectric facilities, specific to the use of surplus hydroelectric generation for hydrogen production.

Action 5: Supporting Hydrogen Storage and Grid Integration Pilot Projects

Hydrogen producers are very well suited to provide electricity system benefits and have previously worked with the IESO to provide ancillary services such as grid frequency regulation.

The Ministry of Energy will ask the IESO to report back on potential program options to support hydrogen electricity storage and grid integration pilot projects as Ontario's electricity system continues to evolve. These projects will help to improve our experience and understanding of the potential benefits and limitations of hydrogen in supporting Ontario's provincial electricity grid.

Action 6: Transitioning Industry Through the Use of Low-Carbon Hydrogen

We are taking immediate steps to support the efforts of industry to phase out their use of coal by transitioning to low-carbon processes and hydrogen-ready equipment.

In February 2022, Ontario announced an investment in ArcelorMittal Dofasco (AMD), Canada's largest producer of flat-rolled steel. This investment will support a $1.765 billion project with hydrogen-ready equipment to convert the steel production process and phase out coal-fired steelmaking at its facilities in Hamilton, Ontario.

Together, with the government's significant investment in AMD in Hamilton and in Algoma Steel in 2021 to shift away from industrial coal to clean Ontario electricity, these projects alone will reduce the province's greenhouse gas emissions by up to six million tonnes – a significant step, closing over 30% of the remaining gap between now and the Made-in-Ontario Environment Plan emission reduction target for 2030.

These projects are equivalent to taking almost two million passenger vehicles off the road.

Action 7: Consulting on an Ontario Carbon Sequestration and Storage Regulatory Framework

Carbon sequestration offers the opportunity to produce low-carbon hydrogen using natural gas.

The Ministry of Northern Development, Mines, Natural Resources and Forestry (NDMNRF) regulates the drilling and operation of wells used for activities such as the exploration and production of oil and natural gas, the underground storage of hydrocarbons and some compressed air energy storage projects under the *Oil, Gas and Salt Resources Act* and the *Mining Act*.

Recently, Ontario businesses have been interested in pursuing new underground geologic storage projects, such as the storage of carbon dioxide, which were not contemplated when these regulatory frameworks were developed. The result has been an unregulated business environment that is a barrier to advancing new technologies and business opportunities in our province.

In that context, NDMNRF is proposing that changes be made to the *Oil, Gas and Salt Resources Act* and the *Mining Act* frameworks that would clarify the regulatory framework under which carbon storage is permitted and allow the ministry to grant authorizations to use Crown land for carbon storage activities. It would also add the ability for NDMNRF to enter into agreements with companies that want to use wells to explore, test, pilot or demonstrate new technologies, such as carbon storage.

The government is committed to ensuring that potential projects like carbon storage can continue to progress, while recognizing that flexibility is currently needed to develop and test these technologies that are new to Ontario. These measures would ensure businesses have a path to enable their pilot or demonstration projects with the appropriate oversight and accountability, and would foster flexible, adaptable approaches, while protecting public and environmental safety.

Action 8: Supporting On-going Hydrogen Research

Ontario is supporting two independent hydrogen research projects in partnership with Natural Resources Canada to advance hydrogen development in the province:

- H2GO Canada is undertaking a comprehensive, techno-economic evaluation of the province's low-carbon hydrogen supply opportunities and the principal end-use applications, around which sustainable markets can be developed. This study will lay the foundations for priority project developments by identifying highest value-creation potentials among numerous clusters and hubs of prospective hydrogen activity.
- Closely associated and integrated with the hydrogen value chain study described above, the related opportunities of seasonal storage of hydrogen and permanent sequestration of CO_2 within Ontario's geological prospects will be evaluated and mapped by H2GO Canada from a commercial utility perspective.

Another independent project led by H2GO Canada is Hydrogen Village, which is a resource centre providing information, education and assistance to individuals and organizations seeking to develop hydrogen projects, or to adopt and use hydrogen technologies in their lives, businesses and communities. Hydrogen Village launches in Spring 2022 with three inaugural program streams to engage audiences in the Greater Toronto and Hamilton Area, including workshops for fleet managers on the use of hydrogen as a vehicle fuel, promotional ride-and-drives in a fuel cell electric vehicle and an online course for self-directed learners on the basics of hydrogen systems.

Path forward and future areas of work

Ontario's low-carbon hydrogen strategy showcases actions that are helping to build momentum and to support sustained growth in Ontario's hydrogen economy in the near term and into the future.

The strategy will build on the ongoing dialogue with stakeholders to better identify barriers to growing the low-carbon hydrogen economy in the province and to better support Ontario businesses.

Ontario, in collaboration with the private sector, the federal government, municipalities, Indigenous communities, academic institutions and other stakeholders will continue to support the development of Ontario's hydrogen economy. These future areas of work include:

- Additional actions to support Ontario's low-carbon hydrogen supply chain, including potential business supports, infrastructure and enabling more end-use applications;
- Identifying and addressing regulatory barriers and gaps for hydrogen production, storage, distribution and integration into Ontario's electricity and natural gas systems;
- Assessing production pathways and adoption scenarios to accelerate low-carbon hydrogen technology scale-up, commercialization and deployment;
- Raising public and industry awareness of the benefits of low-carbon hydrogen, promoting Ontario's leadership in the hydrogen sector to the global market and building strategic partnerships across Canada and internationally; and
- Other considerations to increase the use of low-carbon hydrogen when and where it makes sense in an Ontario context.

Evaluating new pilot and demonstration projects will also allow Ontario to calibrate its strategy and enable future government direction. For example, we can further explore options to use hydrogen to support IESO initiatives to improve electricity grid stability and support additional clean generation and advance work on establishing hydrogen hubs in Ontario.

This future work will provide Ontario with insights that will help chart a course to the future for Ontario's low-carbon hydrogen economy and will focus on economic and environmental opportunities that will have the most impact for Ontarians. This is a future where the sector is cost-effective, economically competitive and driving clean economic growth.

Developing low-carbon hydrogen will be a key part of Ontario's efforts to electrify and decarbonize its economy over the near-term while charting a path ahead for decades to come. As low-carbon hydrogen and other clean fuels become a more prominent part of Ontario's energy system, the Province will consider how the electricity grid and clean fuels can work together to contribute to the energy transition. This will also help inform Ontario's development of its process for long-term energy planning.

Conclusion

Ontario's low-carbon hydrogen strategy is all about clearing the path and laying the groundwork to support the private sector to take the lead in growing the low-carbon hydrogen economy.

This work is crucial to supporting Ontario's transition to a low-carbon economy, continuing the rebuild of the province's manufacturing and industrial base, and supporting good-paying jobs of the future.

By supporting private sector innovation in this clean technology now, we will ensure that our energy system, environment and our economy can continue to thrive for generations to come.

Ontario is ready to do our part so we can attract more well-paying jobs in science, technology, engineering and the skilled trades; jobs where people can be proud that they are contributing to a more sustainable and prosperous province.

Working together with Ontario businesses and workers, the federal government, municipalities, Indigenous communities, academic institutions, and other key stakeholders, we are going to connect Ontario with global markets to develop an economically sustainable low-carbon hydrogen sector.

By leveraging our talent, infrastructure and resources, we will seize this opportunity and unleash our fullest potential by becoming a world-class hub for low-carbon hydrogen innovation.

Appendix – Future Actions

1. **Generate Economic Development and Jobs** – Capitalize on Ontario's competitive and regional advantages, including our talent, infrastructure and resources, to accelerate growth in Ontario's low-carbon hydrogen economy.

Future Actions

Review Regulatory Barriers and Gaps While Ensuring Public Safety

Ontario will identify and assess regulatory barriers and gaps related to environmental approvals for low-carbon hydrogen projects including approvals for generating hydrogen from waste.

Ontario will ensure that its codes and standards for hydrogen storage, handling and transportation continue to support public safety as the adoption of low-carbon hydrogen increases across the province.

Enable Hydrogen Adoption Through a Streamlined, Client-Focused Approach to Investment Attraction

Ontario will provide a "one-stop" approach to low-carbon hydrogen companies and adopters to help them find services and programs that are most relevant to their needs. This will ensure Ontario continues to be a top-tier destination for investment and business growth.

Explore Options for Hydrogen Equipment

Ontario will work with the natural gas sector and industry associations to explore the current status and next steps for manufacturing higher hydrogen mix-ready heating equipment and identify hydrogen retrofitting options for existing natural gas-only equipment.

2. **Reduce Greenhouse Gas Emissions** – Support our Made-in-Ontario Environment Plan targets to reduce greenhouse gas emissions by encouraging the use of low-carbon hydrogen.

Future Actions

Harmonize Hydrogen Carbon-Intensity Performance with Other Jurisdictions

Ontario will continue to use the modelling tool currently used by the federal government to assess the GHG emissions of hydrogen production pathways throughout their lifecycle, known as GHGenius.

In the longer term, Ontario will work with federal and other provincial governments on a standardized approach to assessing lifecycle GHG emissions for hydrogen, with a focus on approaches that align with target export markets.

Raise Public Awareness of the Environmental Benefits of Low-Carbon Hydrogen

Ontario will share educational information with the public, including Indigenous communities, to increase knowledge of low-carbon hydrogen's environmental benefits and how its use can reduce emissions while growing the economy.

Build Industry Understanding of Low-Carbon Hydrogen

Ontario will share technical information, including from research studies, with industry to support the production and use of low-carbon hydrogen in industrial sectors when and where it makes sense as the best pathway to meeting their decarbonization goals.

3. **Promote Energy Diversity** – Consider how low-carbon hydrogen can cost-effectively support Ontario's evolving energy system.

Future Actions

Review Potential Barriers to Hydrogen Use in the Energy Sector

Ontario will assess potential barriers to the use of hydrogen as a fuel for electricity generation and the inclusion of low-carbon hydrogen and renewable natural gas in Ontario's natural gas distribution system, while ensuring appropriate standards and best practices are in place.

Identify Opportunities for Clean Energy Through Natural Resource Planning

Ontario's ongoing planning related to resource recovery, forest sector and critical minerals recognizes the potential production or use of low-carbon hydrogen in the province. This includes the Food and Organic Waste Policy Statement, the Forest Sector Strategy and proposed Forest Biomass Action Plan, as well as the Critical Mineral Strategy Framework Discussion Paper.

Identify Opportunities for Clean Energy Through Future-Ready Transportation Infrastructure

Ontario released draft transportation plans in 2020 for Southwestern Ontario and for Northern Ontario. Each plan includes an action to support future-ready transportation infrastructure by reviewing locations for alternative fueling stations (including electric and hydrogen) for public use that will support potential private sector commercial partnerships and competitiveness.

The transportation plans for the Greater Golden Horseshoe, Eastern Ontario and the entire province

are under development and will consider how best to support future-ready infrastructure.

4. **Promote Innovation and Investment** – Enable opportunities for low-carbon hydrogen use and position Ontario as a leading destination for investment.

Future Actions

Pursue Federal Support for Nuclear Energy to Facilitate Hydrogen Production

Ontario is calling on the federal government to allow nuclear projects to access all federal funding programs and incentives designed to accelerate the development and deployment of clean energy technologies, including those that are currently limited to renewable energy sources such as wind and solar. Nuclear energy can play a key role in hydrogen production due to the production of reliable baseload electricity and steam for use in high-temperature electrolysis.

Develop Industry Guidance Materials with Stakeholders

Ontario will work with stakeholders to develop guidance materials to reduce knowledge barriers related to hydrogen equipment. The guidance materials will seek to encourage the industrial and commercial sectors to consider opportunities to adopt hydrogen as a fuel where existing applications are known and well understood (e.g., hydrogen-powered forklifts).

Ontario will also consider information sessions to increase awareness of new applications for hydrogen and other clean fuels to improve industrial competitiveness as investors consider their environmental and sustainability goals.

Explore Innovative Procurement Strategies

Ontario will explore how its government procurement strategies can be leveraged to promote the use of innovative low-carbon technologies. This could include identifying opportunities for the purchase of low-carbon hydrogen equipment and vehicles where applicable.

5. **Strengthen Collaboration** – Work with the private sector, the federal government, municipalities, Indigenous communities, academic institutions and other stakeholders to grow and sustain a low-carbon hydrogen economy in Ontario.

Future Actions

Ongoing Stakeholder Engagement and Partnership Opportunities

Building on the success of public consultations and the Hydrogen Strategy Working Group, Ontario will continue to meet with hydrogen sector stakeholders to gather information on additional pilot projects and research opportunities to help advance Ontario's low-carbon hydrogen economy. Ontario will also seek input on how to best promote collaboration among the private and public sectors to deliver innovative solutions for the future of low-carbon hydrogen in the province.

Engage Hydrogen Companies in Existing Export Initiatives

Ontario will engage hydrogen technology companies in interprovincial and international export trade missions and shows to promote the province's capabilities, increase foreign direct investment and create opportunities for export-ready businesses.

International Collaboration

Ontario will continue to participate on a hydrogen working group under the Canada-Germany Energy Partnership signed by the federal government in March 2021. The partnership recognizes the importance of international collaboration in achieving Canada's and Germany's targets of net-zero emissions by 2050.

Canada and Germany have established a High-Level Steering Committee, co-chaired at the Deputy Minister level, to foster the energy transformation through exchanges on policy, best practices and technologies as well as through cooperative activities and projects focused on:

- Energy policy, planning and regulations;
- Resilient electricity systems that can integrate high levels of renewables;
- Energy efficiency;
- Sector coupling and low-carbon fuels; and
- Innovation and applied research.

The hydrogen working group will report to the Steering Committee on the challenges and opportunities of hydrogen trade between Canada and Germany.

Ontario will also engage with jurisdictions leading in low-carbon hydrogen to share best practices, collaborate on areas of mutual interest, promote current actions and attract future investment.

This includes building on existing partnerships and creating new opportunities to collaborate with jurisdictions like the U.K., France and Mexico.

Hydrogen Strategy Working Group Members

- Atura Power
- Canadian Hydrogen and Fuel Cell Association (CHFCA)
- Canadian Steel Producers Association (CSPA)
- Cummins
- dynaCERT Inc.
- Emerald Energy from Waste
- Enbridge Gas
- EPCOR Utilities Inc.
- Evolugen
- GE Gas Power
- H2GO Canada
- Hydrogen Business Council of Canada
- Hydrogen Optimized
- Independent Electricity System Operator (IESO)
- Nuclear Innovation Institute
- Ontario Clean Technology Industry Association (OCTIA)
- Ontario Environment Industry Association (ONEIA)
- Ontario Power Generation (OPG)
- Ontario Public Transit Association
- Ontario Trucking Association
- Ryerson University
- Toyota
- Transition Accelerator
- TC Energy

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.

Carbon capture, utilization, and storage (CCUS): Carbon capture use and storage is a process that captures carbon dioxide emissions (for example, when producing hydrogen from natural gas) that either uses or stores it, preventing it from temporarily or permanently entering the atmosphere.

Combustion: The process of burning something, that is, the chemical reaction involving 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 gas. It is the reverse of the chemical reaction that takes place in a fuel cell.

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

Emissions-free electricity: A form of electricity that emits no greenhouse gases (see Greenhouse gas) or air emissions when produced. This includes renewable generation sources, like wind and solar and non-renewable sources, like nuclear.

Feedstock: Refers to the raw material used for industrial processes.

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 controlled process involving heat, steam and oxygen to convert carbon-based raw material such as coal or biomass to hydrogen and other products, without combustion.

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 suite of products and services procured 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 hydrogen: hydrogen that has few greenhouse gas emissions from its production and upstream processes, such as extraction and production of fuels used.

Original equipment manufacturer: A company whose goods are used as components in the products of another company, which then sells the finished item to users.

Gigajoule (GJ): A unit of energy; for example, the heat generated, or energy expended.

Pyrolysis: The process of using heat to decompose the chemical composition of materials such as biomass producing fuels and char.

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, biomass).

Small modular reactor: A nuclear reactor that is smaller than traditional nuclear power plants.

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

ISBN: 978-1-4868-5994-8

Updated: April 07, 2022
Published: April 07, 2022

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Footnotes

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- [2] ^ IHS Markit, 2020
- [3] ^ U.S. Department of Energy, Safe Use of Hydrogen
- [4] ^ Hydrogen Strategy for Canada, p.69.
- [5] ^ https://www.investontario.ca/chemical-and-biochemical
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