ONTARIO’S HYDROGEN STRATEGY CONSULTATION

Government of Ontario consultation on the province’s first ever hydrogen strategy • University of Toronto Submission •
Pelayo Garcia De Arquer, left, and Cao-Thang Dinh examine a wafer which lowers the amount of electricity required to split water into hydrogen and oxygen.
Ontario’s Low-Carbon Hydrogen Strategy is a welcome first step to integrating and growing the economic potential of hydrogen gas as part of the province’s Environment Plan. As Canada’s leading university and a national and global leader in sustainability, the University of Toronto shares Ontario’s commitment to addressing climate change while boosting economic recovery. We are pleased to submit our initial responses and offer the expertise of our researchers as the province explores the creation of Ontario’s first hydrogen strategy.

U of T makes a significant contribution to strengthening Ontario’s ecosystem of research on sustainable energy sources. Leading researchers at the university are working on cleaner energy technology and biofuels – including in the labs of Aimy Bazylak, Canada Research Chair in Thermofluidics for Clean Energy, Olivera Kesler, Professor of Mechanical Engineering, Ted Sargent, Professor of Electrical and Computer Engineering, Professor Bradley A. Saville, principal investigator in the Bioprocess Engineering Lab, and David Sinton, Canada Research Chair in Microfluidics and Energy.

These researchers are developing two important parallel technologies that fit into Ontario’s hydrogen strategy. They are advancing water electrolyzers for efficient and low-cost production of green hydrogen from electricity, as well as developing new high-performance and scalable carbon dioxide electrolysers that can be used to generate low-carbon hydrogen from steam methane reforming. In addition, partnering with industry provides U of T researchers with a strategic, fast-paced route to accelerate the development of energy technologies for commercialization and societal benefit.

U of T is also preparing the next generation of students to design efficient energy solutions for existing infrastructure with programs in Sustainable Energy, Environmental Engineering and Energy Systems Engineering. With almost three-quarters of engineering students participating in extensive professional experience programs, U of T graduates hit the ground running, solving the problems of today and tomorrow.

“Our researchers’ strength across the full breadth of areas of scholarship fuels an extraordinary range of cross-disciplinary collaborations – work that is vital to developing creative and sustainable solutions for the challenges facing Canada and the world.”

— University Professor Ted Sargent, U of T’s vice-president, research and innovation and strategic initiatives
2 SUMMARY OF RECOMMENDATIONS

Establish stakeholder advisory tables. Co-operation among industry, post-secondary institutions and government is necessary to develop, implement and communicate regulatory and safety frameworks. At the same time, networks between academia and industry can build receptor capacity among companies and offer early insights into market opportunities that can be exploited through deployment of advanced research.

Support a dynamic, diversified industry. The hydrogen industry can benefit the entire province. As the hydrogen economy grows, new jobs will be created in established companies that are investing in hydrogen transport and distribution, as well as in start-ups working on emerging solutions to energy storage and security. Other jurisdictions, such as Australia and Europe, are strategically designating hydrogen hubs to leverage existing energy networks and industrial hubs into new economic opportunities.

Integrating the goals of the hydrogen strategy with Ontario’s Regional Development Program can further link education programs to regional needs for skills development and connect remote communities to central knowledge hubs for commercializing research.

Commit to supporting hydrogen research & innovation. National research funding reinforces fundamental inquiry at universities. Provincial funding streams that encourage alignment with regional development goals and industry partnerships can strengthen the relationships between research, industry and talent development and recognize the potential of the hydrogen economy.
Ontario’s decision to evaluate the elements of a hydrogen strategy is well-timed. Jurisdictions in Canada and around the world are embarking on similar consultations, seeking to participate in an industry that is projected to provide as much as a quarter of the world’s demand for energy by 2050.

Hydrogen can be an important lever to help reach the province’s goal of a 30% reduction in greenhouse gas emissions below 2005 levels by 2030. In addition, as the framework suggests, collaborations between government, industry and researchers can spur clean energy innovation and create jobs across the province.

By engaging postsecondary institutions early in the consultation process, the province can advance emerging technologies and enhance the capacity of the province’s companies and labour force in high-productivity sectors.

This response paper recognizes that the province is at the beginning of an exciting journey. The university’s submission provides suggestions toward a strategy that can guide development of the industry, attendant infrastructure and an appropriate regulatory and safety regime.

Researchers at the University of Toronto have identified several elements across three domains that could be the focus of targeted investments to meet the goals of emissions reductions, growth of a dynamic energy industry and establish Ontario as a globally competitive source for hydrogen energy.

Low-carbon hydrogen production

- Develop efficient, low-cost, scalable, and durable electrolyzers that advance the state-of-art for both water splitting (to accelerate the value proposition of green hydrogen production from electricity), and for CO₂ conversion (to achieve cost-competitive carbon capture and utilization that enables low-carbon hydrogen produced through conventional steam methane reforming).

- Target research to focus on more effective fuel cell and electrolyzer technologies to provide transportation infrastructure with zero emissions and clean as well as sustainable and reliable energy storage that eliminates Ontario’s dependence on neighbouring jurisdictions with negative pricing scenarios.

- Scale-up and deploy these technologies to meet Ontario’s demand for low-carbon hydrogen. These include:

  Decarbonizing the agriculture sector through green ammonia. Hydrogen can be used to make low-carbon fertilizer to aid carbon mitigation of the approximately 5% of provincial emissions that come from this sector.
Decarbonizing natural gas electricity production. Approximately 15% of the province’s electricity needs are met by Natural Gas combustion. Hydrogen can be used as a green alternative.

Decarbonize heavy industry. Ontario’s heavy industry accounts for approximately 24% of the province’s greenhouse gas emissions. Hydrogen can be used to replace fossil fuels that are used to produce high-grade heat in heavy industry processes.

Decarbonize heating. 35% of Canada’s homes are heated with natural gas furnaces. Hydrogen can be blended with or displace natural gas to provide a low-carbon alternative.

Further research is needed to understand the optimal pathways to refine hydrogen to increase its capacity to be carried through existing natural gas infrastructure.

Hydrogen storage and infrastructure

- Explore the electrical energy storage benefit of electricity-to-hydrogen as well as the physical storage and transportation benefits of hydrogen-to-ammonia.

- Integrate hydrogen as long-duration energy storage to facilitate integration of renewable energy into power grids.

Hydrogen policy

- Establish regional and globally connected nodes that facilitate collaboration between government, industry and researchers and increase capacity for innovation throughout the province.

- Establish a regulatory table that tracks and engages global safety and regulatory standards.
Extraordinary research strengths and innovation in sustainable energy sources inspire the institution’s work on the development of hydrogen as an energy source. Basic research encompasses thermofluids for energy and advanced materials, smarter power grids, electrolyzer design, and energy markets and regulatory frameworks, the latter through courses at the Rotman School of Management.

The Faculty of Applied Science & Engineering is home to significant expertise in addressing and mitigating climate impacts. Ranked in the top 10 engineering schools among North American public universities, the Faculty has approximately 70 sustainability experts across energy, aerospace, power grid analysis, transportation, and geochemistry. The Myhal Centre for Engineering Innovation and Entrepreneurship, which boasts sustainable design strategies to maximize energy efficiency, houses some of U of T’s flagship cleantech and renewable energy research hubs, including the Centre for Global Engineering, the Institute for Sustainable Energy, and the Institute for Water Innovation.

With over 100 spinoff companies launched in the past two decades, a doubling of industry-sponsored research funding in the past five years, and start-ups that have raised over $95-million since 2012, the Faculty is a hub of collaboration on industry-relevant real-world challenges. One recent success story is CERT, a carbon-tech company that converts carbon dioxide into carbon-based fuels and feedstocks using only water and electricity, enabling decarbonization of manufacturing industries and hydrogen production from fossil fuels. CERT is a top 10 finalist for the $20-million Carbon XPRIZE and a winner of $1.4-million in the Breakthrough Energy Solutions Canada program.
These are some of the highlights of the Faculty’s expertise in hydrogen:

**Hydrogen storage**

Aimy Bazylak, Canada Research Chair in Thermofluidics for Clean Energy, leads research and learning on sustainable energy technologies, which is diffused and integrated throughout engineering programs for undergraduate and graduate students.

*Professor Bazylak’s Thermofluids for Energy and Advanced Materials (TEAM) Laboratory* focuses on the study and utilization of microfluidic and nanofluidic transport phenomena to achieve unique material designs and water management techniques for clean energy technologies. Professor Bazylak leads a team of experts specializing in polymer electrolyte membrane (PEM) fuel cells and electrolyzers that produce hydrogen and carbon neutral fuels. Hydrogen is used as a fuel to produce on-demand power through low temperature fuel cells. Her work on materials discovery and advanced operando imaging have attracted key industry partnerships in Canada and abroad.

**Smarter Grids:** The Centre for Power and Information is a multidisciplinary centre that is addressing the infrastructure of energy transmission and storage. CPI is researching solutions that integrate renewable energy and storage into existing power grids (such as storage of solar or wind power in hydrogen cells), cyber and physical security, and power electronic converters. **CPI director and Professor Deepa Kundur** is educating a new generation of engineers on designing smarter grids, harnessing information technology to power systems to enable competitive and efficient electricity transmission and supporting the integration of cleaner energy sources such as green hydrogen into power grids.

**Electrolyzer Innovation**

Catalysts developed in the labs of **Professor Ted Sargent** (Canada Research Chair in Nanotechnology) and **Professor David Sinton** (Canada Research Chair in Microfluidics and Energy) are being used to reduce the materials cost for green hydrogen production, and to produce commodity chemicals such as ethylene from the conversion of carbon dioxide that could be used as a cost-effective strategy for carbon capture and conversion to enable low-carbon hydrogen production from existing fossil fuel combustion processes.

These research labs are further developing technology to scale CO₂ electrolyzers for increased economic viability and environmental impact, having recently
demonstrated the world’s largest CO$_2$ electrolyzer at 40,000 cm$^2$ for the COSIA Carbon XPRIZE.

Talent

The research opportunities in sustainability and energy available at U of T enrich the education of the ~2,000 undergraduate and graduate students who earn their engineering degrees each year. In addition, students at the Rotman School of Management gain a competitive business perspective on energy markets through dedicated courses and programs for start-ups in the energy industry at the Creative Destruction Lab. CDL’s model of intense mentorship, networking and STEM innovation has been adopted by CDL – Rockies, a Calgary-based hub devoted to energy.

Protecting and growing made-in-Ontario innovation

One of the goals of a made-in-Ontario hydrogen strategy is catalyzing the industry for economic growth. As an industry at the beginning of its potential, hydrogen will present commercialization opportunities for researchers and companies that drive new technology. The U of T has recently launched an intellectual property course that prepares all students and faculty to consider how to best protect their innovative ideas while turning them into products and processes, a valuable foundation of knowledge for a growing sector.

U of T is setting a model for responsible climate stewardship in the BPS. By 2030, the University’s Low-Carbon Action Plan will lead to a 37% reduction in U of T’s carbon levels from 1990 levels and net-zero by 2050. At the heart of the plan is the largest geoexchange system in a Canadian city, installed under King’s College Circle. The project will allow for the storage of heat in the summer for deployment in winter.
Continued and sustained dialogue and collaboration is required to achieve the vision outlined in Ontario’s Low-Carbon Hydrogen Strategy – one in which a successful provincial hydrogen economy leads to vibrant new companies and jobs. Formal consultative tables that identify areas for industry research and create new networks can provide highways of knowledge exchange between industry and researchers and increase awareness of the opportunities in this industry.

**Stakeholder tables** promote an integrated approach to industry, workforce and community development. Multiple perspectives can also provide feedback on the competitive impact of regulatory or safety regulations, offer valuable information on developments in other jurisdictions and accelerate agreement on made-in-Ontario approaches.

The feedback below responds to the questions identified by the province to be of primary interest which are aligned with expertise at the University of Toronto.

**Topic 1: The vision for Ontario’s hydrogen strategy**

**What is the relevance and what are the key outcomes of a hydrogen strategy in Ontario?**

Ontario’s interest in developing a made-in-Ontario hydrogen plan marks an important entry by Canada’s most populous province into a national field marked by **distinct regional advantages**. For example, **Alberta’s geology positions it well to produce blue hydrogen while sequestering** the carbon dioxide emissions. Alberta can also leverage existing oil and gas infrastructure and knowledge and talent networks. **Quebec’s abundant hydro power** allows government to incentivize industry leadership to reach targets for hydrogen production.

Similarly, Ontario’s approach must reflect the province’s current strengths and build a strategy that is **complementary to provincial and global markets**.

Some of the key opportunities that can be realized through a provincial hydrogen strategy include:

**Workforce development.** Canada’s federal hydrogen strategy estimates that **up to 350,000 jobs** can be generated across the country by 2050. With **approximately ~4,000 graduates** in engineering, math and physical sciences programs in 2019, U of T is a ready training ground for a generation that is dedicated to making a cleaner world.

**Maximizing the opportunities for cross-border co-operation.** The University of
Toronto is a co-founder of the Great Lakes Higher Education Consortium, a collaboration with higher education institutions in the University of Illinois system that will address socioeconomic and environmental issues in the Great Lakes region. With the incoming U.S. administration committed to making unprecedented investments in developing hydrogen as an important source of clean energy technologies, such research partnerships position Ontario at the forefront of cutting-edge knowledge, talent, investment and innovation in North America.

**Lower-cost hydrogen in the future.** The cost of green hydrogen currently exceeds other sources of clean energy. But multiple jurisdictions are implementing regulatory measures that will increase the return on hydrogen investments. Combined with research on improving the efficiency of hydrogen production, the cost of hydrogen energy is expected to decline in coming years. A provincial hydrogen strategy gives Ontario a seat at international discussions on how to accelerate that process. As Massimo Mondazzi, COO of global energy company, Eni, recently told this year’s International Forum of the Americas, “an energy transition requires many steps.” It is in Ontario’s interest to be engaged in each step.

**Topic 2: Supporting the Environment Plan by reducing greenhouse gas emissions through low-carbon hydrogen**

*What are the key technology, regulatory and business opportunities and how can Ontario set realistic goals?*

The varied approaches outlined above suggest that as has been the case in jurisdictions such as Australia and the European Union, a range of regulatory mechanisms and frameworks will have to be reviewed and aligned in developing Ontario’s framework. Considerations will include standards for workforce development and training, transportation requirements, safety issues such as the concentrations of hydrogen in gas networks, and the adoption of “hydrogen-proof” or “hydrogen-ready” considerations in planning processes for infrastructure projects.

Closing gaps in regulatory and safety frameworks will remove barriers to the full development of the hydrogen industry, as noted by the U.S. Department of Energy in its Hydrogen Strategy, released July 2020.

A full consultative review of the experience of other jurisdictions in reaching agreement on hydrogen strategies can allow Ontario to benefit from prior work and introduce a forward-looking strategy.

**Topic 3: Generating economic development and jobs**

*How can the hydrogen industry help develop regional prosperity and facilitate innovation and job creation?*

Regional nodes have been proposed in multiple jurisdictions to facilitate learning.
and accelerate the transfer of knowledge and expertise among partners in the private sector, research and training institutions, Indigenous organizations and end users such as municipal transit authorities. Further, such nodes can be connected to further expand knowledge exchange.

Existing networks can provide a starting point for the development of hydrogen-focused regionally-connected collaboration. Multiple agreements are currently in place that engage municipal, provincial and federal governments in research networks and include industry as key players. Among them are Ontario’s Regional Development Program, FedDev Ontario, Mitacs, and agreements such as Toronto’s Post-Secondary Partnerships.

**Topic 5: Reducing barriers + enabling action in order to attract investment and create a level playing field between technology options**

*How can Ontario’s relationship with partners overcome barriers to growth?*

Hydrogen currently supplies ~5% of global energy. Building dedicated transportation pipelines, bringing efficient energy storage solutions to market and facilitating industry and workforce growth and transformation requires a combination of research and policy innovation. Establishing stakeholder consultation tables will provide consistent channels to share information, spot challenges and seize opportunities for market penetration in Canada and abroad.

One such model can be seen in the *Canadian Energy Systems Analysis Research (CESAR)*, a network of university researchers based at the University of Calgary and working with private sector research partners.

CESAR demonstrates an important secondary benefit of industry-academic networks. The network translates sector expertise to the public, serving to stimulate awareness and demand among end users for an emerging technology. Canada is also engaged in a global initiative to accelerate clean energy innovation through *Mission Innovation*.

Including post-secondary researchers in hydrogen and clean energy-focused networks (such as *Queen’s University* and *the University of Waterloo*) can extend Ontario’s line of sight into the future of this technology and identify which avenues are most likely to yield favourable returns. Equipped with a longer horizon, government can better communicate labour force needs and allocate support for workforce transitions.

As Canadian jurisdictions prepare to prosper in the hydrogen economy, the University of Toronto will be a valuable partner in bringing innovation and expertise to industry and governments. Together with other Ontario universities and research agencies engaged in hydrogen innovation we look forward to contributing to the development of Ontario’s hydrogen strategy.
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