Current Status and Future Perspectives of Clean Energy Technologies at the NRC

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1. Introduction

Clean energy, low-carbon technologies, GHG emissions reduction and climate change are high priorities for all levels of government in Canada. These priorities are reflected in a multitude of specific policy actions including but not limited to Canada's commitment to the Paris Accord, Mission Innovation, the Sustainable Development Policy, the Pan-Canadian Framework on Clean Growth and Climate Change and numerous clean energy programs administered by departments responsible for Environment and Climate Change (ECCC), Innovation, Science and Economic Development (ISED) and Natural Resources Canada (NRCan).

As the federal government's primary research and technology organization, the NRC mandate is to provide R&D support to public policy formation, innovation in industry and knowledge development. The NRC catalyzes technology development within its own research facilities and by working alongside university, provincial and other federal science-based departments and laboratories.

The NRC is a collaboration focused science and research organization that supports partners from government, industry, and academia with over 3700 scientists, engineers, and technicians across 22 R&D sites across Canada covering a range of economically important sectors from Engineering to Life Sciences. NRC researchers work along the entire technology readiness scale, from fundamental research, to technology development and scale-up, to prototyping and field testing.

2. NRC R&D activities related to clean energy technology

NRC conducts R&D activities across a wide range of clean energy technologies and applications. Key R&D activities dedicated to adjacent areas of clean energy, but not specifically on hydrogen and CCUS discussed in the next section, include:

- Emissions reduction through electrification, concentrating on energy storage technologies for both stationary and transportation applications, and integration of new technologies into grid and vehicle systems
- Development of bioenergy resources through improvement of biomass and organic waste conversion, biofuel upgrading, and certification and integration of sustainable fuels
- Increasing fuel flexibility of conventional power generation technology such as has turbines
- Increase energy efficiency, productivity and clean energy use in mines to reduce emissions and environmental impact
- Use of alternative biofuels and improving efficiency in aircraft, surface and marine vehicles
- Electrification of heavy and long-distance transportation
- Develop, deploy and validate the energy performance of retrofit technologies for commercial and institutional buildings

3. Specific NRC Research activities in hydrogen, CCUS, and related technologies

Canada has plentiful emissions-free and dispatchable hydroelectricity resources, but cold climate, sparse population and long distances create a mix of energy demand that is not amenable to electrification and bioenergy alone. While global energy sector developments focus on electrification and biofuels, the implementation pathways for these technologies do not fully address Canada's unique needs and a gap remains. Canadian emissions remain dominated by the oil and gas, emissions-intensive chemical processing industries, and long distance and heavy transportation sectors. All these sectors rely on fossil fuels. Projections (for example the Senate Committee on Energy, Environment, and Natural Resources, May 2018) suggest that for Canada to meet its COP 21 commitments, a new disruptive and economically viable technology that offers an additional option for GHG emissions reduction in these sectors will be required.

NRC is tackling the emissions reduction gaps identified above through its Materials for Clean Fuels Challenge Program. The NRC has a rich history in supporting hydrogen and CCUS technologies. Examples include the Institute for Fuel Cell Innovation in Vancouver where significant advances in fuel cell technologies were achieved with Canadian, European and Japanese collaborators. The Algal Carbon Conversion Program worked with large industrial emitters in the fossil fuel and cement industries to capture and convert emissions to fuels.

The expertise, experience and facilities developed through that work are being redeployed as a springboard for a renewed focus on hydrogen and CCUS by EME, in launching its new Challenge Program; the Materials for Clean Fuels Challenge Program is a 7-year $57M collaborative research program aimed to develop technology to decarbonize Canada's oil & gas and petrochemical sectors. It brings the National Research Council (NRC) together with academic and small-medium enterprise (SME) collaborators. The program seeks to develop high-risk, high-reward technologies at a low TRL (1-5) towards prototype and demonstration. There is a strong emphasis on catalyst and membranes materials (and associated devices) for artificial photosynthesis and renewable fuels/chemical feedstock production.

The program focuses primarily on three themes – CO_2 conversion, industrial H_2 production, and AI-accelerated materials discovery. The program was recently launched at the end of summer 2019. The following are examples of projects in development at the MCF Challenge Program.

- Emissions-free hydrogen production from natural gas decomposition combined with direct carbon fuel cell technology (2019-2022)
- Low-temperature ammonia electrosynthesis from N_2 and water as a liquid hydrogen carrier. (2019-2022)
- High Performance Membrane Electrode Assemblies for Alkaline Solid Electrolyte Water Electrolysis. (2019-2022)
- Development of ion-exchange membranes tailored for electrochemical CO_2 reduction reaction. (2019-2022)
- Electrochemical CO_2 conversion to ethylene glycol using renewable electricity. (2019-2022)
- CO2 conversion to syngas from bicarbonate solutions coupled with direct air capture. (2019-2022)
- In-situ/operando characterization of CO_2 electrocatalysts under operating conditions. (2019-2022)
- Hybrid bio/electrochemical CO_2 conversion to C3+ alcohols. (2019-2022)

4. NRC International collaboration

4-1 NRC International alliance/networking development

NRC values international collaboration and actively works with international partners through various mechanisms to advance clean technology R&D. The international partnerships are a key aspect of building strategic platforms for future initiatives and opportunities. Recent coordination efforts with international partners in the United Kingdom (UK), Germany and Japan are examples of the NRC's commitment to facilitate this broad, international exposure of its research and researchers.

Additionally, through delivering Canada's associate membership in EUREKA, the NRC provides funding to support Canadian firms and innovators to do business in Europe and beyond.

These relationships provide the framework for NRC collaborative activity in clean energy. For example, NRC represents Canada on technical working groups at the IEA (TCPs on Energy Storage and Hydrogen), Mission Innovation Challenges (Technical lead for Hydrogen and Solar Fuels) and the World Bank Energy Storage partnership. Relationships with the US Department of Energy research laboratories, particularly ARPA-E and the National Renewable Energy Laboratory, are maintained to coordinate NRC work towards clean energy solutions with those in the US.

4-2 NRC International joint R&D activities

Further examples of international collaboration agreements that cover work on clean energy include a project agreement with Chinese Academy of Sciences for the development of efficient carbon supply and high-value algal products, and MOUs with KIAT in Korea, UKRI in the UK, and RWTH Aachen in Germany. NRC is now working within the context of these agreements to explore development of collaborative projects in the areas of carbon dioxide conversion and hydrogen production described in Section 3.

- The development and investigation of high performance membrane electrode assemblies for alkaline solid electrode water electrolysis for hydrogen production, project under development with Helmholtz Institute, Germany.
- The development of a burning for turbine applications for the efficient combustion of gaseous fuels such as H2 enriched blends, with KIMM in Korea.
- The Materials for Clean Fuels Challenge Program is actively pursuing further international collaborative projects with visits to Japan, Germany and the UK in October and November 2019.

5. Future perspectives

The dependence on fossil fuel feedstocks of the energy and chemical industry presents an important emissions challenge for Canada. Liquid fuels remain the densest form of consumable energy and despite penetration of electric vehicles, will be required for freight, flight, and home heating for the foreseeable future. The demand for emissions-heavy petrochemicals such as ethane and naphtha continues to grow given the downstream use of these feedstocks to manufacture consumer goods such as personal care items, food preservatives, fertilizers and furnishings that will be needed in higher quantities to supply a growing worldwide middle class. A less CO_2 emissions intensive alternative to produce fuels and chemical feedstocks must be found in order to mitigate future CO2 emissions.

There is a growing need for low-carbon technology alternatives to current CO2

emissions-heavy processes that produce chemicals and fuels. In 2018, global carbon pricing initiatives were valued at $82B USD and are expected to increase (World Bank - State and Trends of Carbon Pricing, 2018). Concurrently, global societal need for chemicals and fuels continues to grow, especially in developing economies.

The NRC will continue to develop hydrogen and CCUS technologies for uptake and implementation by Canadian industry. In addition to the Materials for Clean Fuels Challenge Program, the NRC is currently engaged in several other clean energy initiatives including the development of a new Advanced Clean Energy program to address energy storage and bio-energy applications.

Research Centres across the NRC continue to conduct further R&D on clean energy technologies, integration and use in transportation, manufacturing and other end-use areas.

Iain Stewart

In 2016, Iain Stewart became the twelfth President of the National Research Council of Canada. He was reappointed for a five-year term in 2018.

Mr. Stewart's most recent career highlights include his role as Associate Secretary at the Treasury Board Secretariat.

As Assistant Deputy Minister, Strategic Policy and other positions, he worked on national science and research policy at Innovation, Science and Economic Development Canada, or ISED.

Previously, Mr. Stewart supported industry and university research through funding programs at ISED and the Atlantic Canada Opportunities Agency and as Assistant Vice-President of Research at Dalhousie University.

Mr. Stewart is a member of a number of federal Deputy Minister committees and the Canada Research Coordinating Committee.