National Research Council Canada

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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. 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 research activities in renewable energies, next generation energy management system with batteries, 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 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.

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.

NRC is tackling some of the emissions reduction gaps identified above through activities under a number of programs:

- Materials for Clean Fuels (MCF) Challenge Program

  The MCF Challenge Program, launched in summer 2019, 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 (1-4) 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:
  - CO2 conversion (5 active projects)
  - Industrial H2 production (9 active projects)
  - AI-accelerated materials discovery (2 active projects)
- Vehicle Propulsion Technologies (VPT) Program

  The VPT Program, launched in 2012, has 27 researchers and funding of C$5 million per year, on average. The program hosts NRC R&D activities aimed at assisting industry and policy development in vehicle electrification and clean transportation sectors by focusing on technology development needs related to:
  - Advanced Electric Motors (6 active projects)
  - Batteries (23 active projects)
  - Hydrogen Applications (10 active projects)
  - Alternative Fuels (3 active projects)
- Advanced Clean Energy (ACE) Program

  The ACE Program, currently being launched and incorporating the activities of previous NRC programs, is a 7-year program with a total budget of C$50 million and 30 to 40 FTEs at NRC. The program focuses on key enablers for electrification and alternative fuels to accelerate emissions reduction and the transition to a clean energy economy, to support Canada's commitment to zero emissions by 2050. Alignment of these activities with the global priorities identified by the IEA creates opportunities to work with Canadian and international partners towards common goals. The ACE research priorities are:
  - Energy Storage Materials and Devices (4 active projects)
  - Low Carbon Fuels (7 active projects)
  - Zero Carbon Fuels (projects in early planning stage)

- Green Aviation Research

  Canada is a major global player in aviation with a strong supply chain ranging from aircraft and engine OEMs to major international airlines. In support of Canada's and the Industry's carbon reduction targets, NRC's Aerospace Research Centre, with an approximate total of 340 staff members and yearly budget of $55M, presently undertakes key R&D activities to support the de-carbonization of the sector through focused R&D in two main thematic areas:
  - Advanced Aircraft: E.g. Novel aircraft configurations, ultra-efficient engines, lightweight structures and advanced materials (4 active projects)
  - Clean Energy Sources: E.g. Electrification, and Sustainable Fuels (7 active projects)

4. International collaboration

4-1 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, and NRC plays a central role to connect the key stakeholders in domestic and international innovation ecosystems. In 2019, NRC opened its first international offices in Japan and in Germany to facilitate closer interactions and collaborations, and reflecting a growing commitment to facilitate broad, international exposure of its research and researchers. As we opened our Japan office at the same time that the 2019 RD20 was held, NRC and AIST also signed an MOU on research cooperation, with several opportunities for collaborative projects now being explored. Other MOUs facilitate our work with key international partners such as UKRI in the U.K., RWTH Aachen and DLR in Germany and KIAT in Korea.

Additionally, through delivering Canada's associate membership in EUREKA, the NRC provides funding to support Canadian firms and innovators to undertake co-innovation projects with Europe and beyond. NRC worked with NEDO just recently in a EUREKA Globalstars (consortia) call for proposal to support collaborative R&D projects between Canadian SMEs and Japanese corporations.

As other examples of international collaboration, 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 International joint R&D activities

The following ongoing projects involve international collaborators (institutes taking part in RD20 marked in **bold**):

- Low-temperature ammonia electrosynthesis from N2 and water: Imperial College London, UK
- High Performance Membrane Electrode Assemblies for Alkaline Solid Electrolyte Water Electrolysis: Helmholtz-Institut Erlangen-Nürnberg for Renewable Energy, Germany
- Artificial intelligence accelerated materials discovery for platinum-group-metal-free acid-stable oxygen evolution reaction catalysts: Carnegie Mellon University, USA
- Materials assessment and quality control of fuel cell technologies for surface transport applications: **Fraunhofer ISE (Germany)**, **NREL (USA), CEA (France)**, HySA (South Africa)
- Process development including membrane manufacturing and conditioning/additives impact for fuel cell technologies: NREL (USA), 3M (USA), Solvay (Italy)

- Energy Storage Model Development with IEA ECES Annex 32: IEA ECES Member Countries
- Enabling the manufacturing of advanced solid-state batteries: **AIST (TBC) (Japan)**
- Advanced manufacturing and design solutions for electric motors: Boeing (USA)
- Low Emission Burner development for turbine application: Korean Institute of Machinery and Materials (Korea)
- Engine Inlet Velocity Profile Effects: GKN Aerospace Engine Systems (UK)
- Alternative Fuels to 100LL: Federal Aviation Administration (USA)
- National Jet Fuel Combustion Project: International consortium including FAA (USA), engine OEMs, more than 10 universities from USA and UK, and DLR (Germany)

5. Future perspectives

Canada is developing a plan to achieve net-zero emissions by 2050 and will set legally-binding, five-year emissions reduction milestones. The government will increase clean electricity, invest in greener buildings and communities, accelerate the electrification of transportation, and adopt nature-based climate solutions.

A 2019 analysis shows that in 2030, Canada's emissions are projected to be 227 million tonnes (Mt) below what was projected in 2015. This is a historic level of emissions reductions. Policies and measures now in place, including those introduced in the last year, are projected to achieve a level of emissions 28 million tonnes lower by 2030 than 2018's projections.

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. 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 launch of the 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.

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Before joining the NRC in 2018, Dr. Laaksonen-Craig was the Assistant Deputy Minister for British Columbia government's Climate Action Secretariat in the Ministry of Environment and Climate Change. She also held a number of Executive Director and Director roles in the Ministry of Forests, Lands and Natural Resource Operations.

Prior to joining the BC government in 2007, Dr. Laaksonen-Craig worked as an assistant professor at the University of Toronto's Faculty of Forestry, as the Assistant Director of the University of California Forest Products Laboratory, and as a researcher for the Finnish Forest Research Institute.

Dr. Laaksonen-Craig holds a master's degree in Forestry from the University of Helsinki and a Ph.D. in Wildland Resource Science from the University of California at Berkeley. Dr. Laaksonen-Craig has been an Adjunct Professor at the University of Toronto's Faculty of Forestry since 2007.