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ANNUAL REPORT

CanmetENERGY in Varennes

A Government of Canada research centre

Natural Resources Canada | Ressources naturelles Canada

Canada

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Message from **the Director General**

In the context of the climate crisis, the term *energy transition* is on everyone's radar – and with good reason, because the use of fossil fuels and biomass generated about 490 Mt (73%) of greenhouse gas (GHG) emissions in Canada, in 2020[1].

Canada's commitment to decarbonize its electrical grids by 2035 and to meet its GHG emissions reduction targets for its energy system – a 40 to 45% reduction by 2023 and a 100% reduction by 2050 – complicates both the issue and the solutions at hand. GHG emissions from fossil fuels can be eliminated through the electrification of uses, clean electricity, carbon capture, utilization and storage (CCUS), and the use of sustainable biomass.

A massive electrification of uses could double or even triple electricity consumption, requiring ways to produce renewable electricity beyond what is needed to decarbonize existing power grids. CCUS requires cost-effective process scale-up as well as major investments in the industry sector. The sustainable biomass available is variable in nature and in insufficient quantity to replace all fossil fuels. It also requires scaling up processing technologies to adapt them to different markets.

Should a specific path be favoured over others? In what proportions and for what uses? How can we guarantee that the right choices are made in terms of technologies, subsidy programs, investment and regulations, to ensure a just and equitable transition that will preserve the quality of life of all Canadians, particularly when it comes to the environment, economy and public health? These are complex and multidisciplinary issues that affect the entire planet.

The large-scale energy system modelling work being conducted at CanmetENERGY in Varennes, in collaboration with our partners, is helping to identify issues and set targets. More specifically, our work helps address technological and scientific uncertainties associated with energy systems so that government, industry and individuals can make credible science-based decisions to start building now the infrastructure needed to meet targets for 2030, 2035 and 2050.

In 2023, we produced a 2023-2028 science plan that integrates all our research and development (R&D) and deployment activities. This science plan was designed to maximize the impact of our work through a mission-driven model. We also produced an outreach plan to optimize knowledge transfer to our various stakeholders.

In 2024-2025, we will continue to develop our material and scientific capabilities, including our microgrid and high-performance computing infrastructure, while increasing efforts and expanding partnerships in large-scale energy system modelling. Seeing as our human resources are an essential key to achieving our mission, we will redesign our wellness plan and establish a succession plan to ensure the continuity of our quality research.

Jocelyn Millette
Director General

1 https://publications.gc.ca/collections/collection_2022/eccc/En81-4-2020-1-eng.pdf

Who **We Are**

Clearn Energy | Research Innovation | Leadership

The **CanmetENERGY in Varennes (CEV) research centre**, located on Montreal's south shore, is part of Natural Resources Canada's Energy Efficiency and Technology Sector (EETS).

With over 180 researchers, engineers, technologists, managers and support staff, we lead research and development (R&D) activities and deliver programs aimed at developing clean and efficient science and technology for a low-carbon future.

We collaborate with partners from non-governmental organizations, academia, industry, and all levels of government.

We strive to put science at the service of all Canadians.

Our Values

At the core of our decisions and actions lie the excellence and scope of our work, the accountability of public funds and resources, great and efficient teamwork, as well as the well-being, development and motivation of our employees. We value diversity within our team for a healthy, respectful, inclusive and creative work environment.

Our Impact and Scientific Productivity

We use several means to communicate and disseminate our science. The results of our R&D activities are namely:

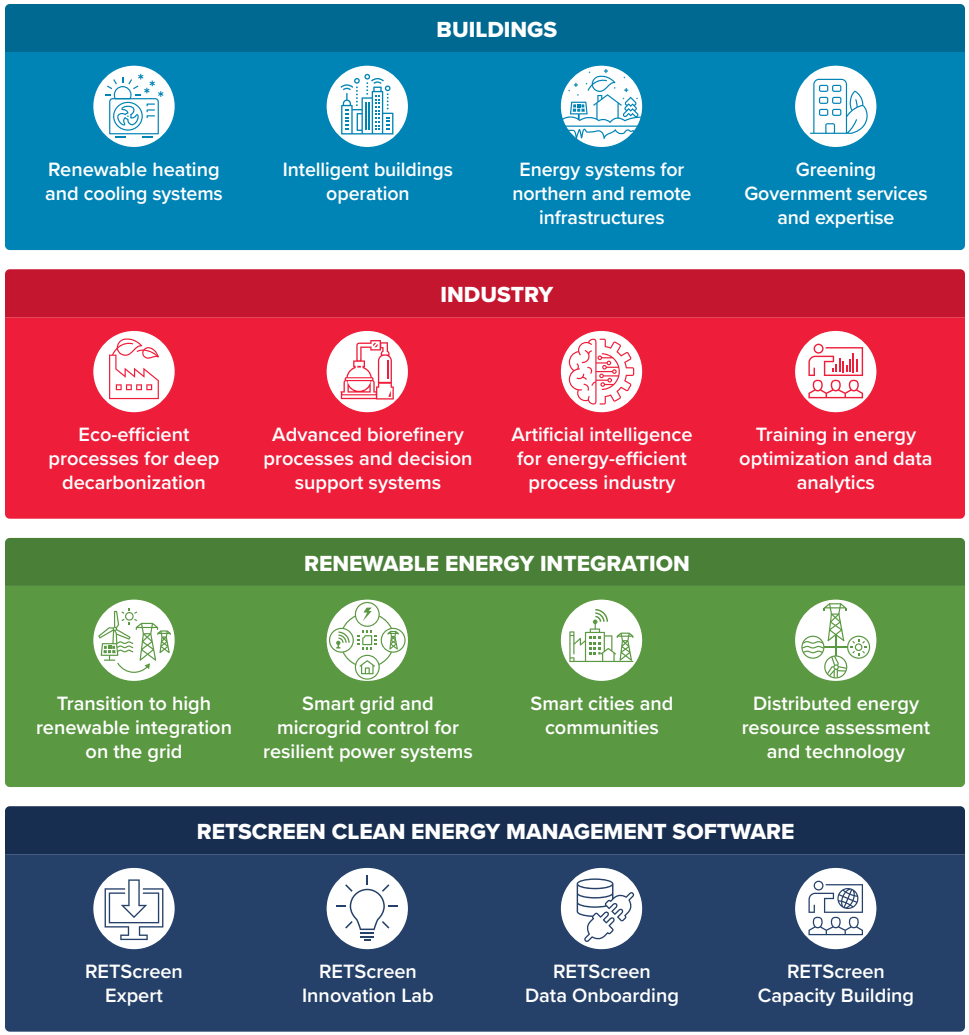
- Presented in international conferences
- Published in reports and scientific journals
- Integrated in several codes and standards
- Included in new patented technologies
- Taught in university courses, workshops and training sessions
- Highlighted in posters, videos, brochures and other promotional material
- Deployed in our software tools, federal government facilities, and remote communities not connected to the power grid
- Shared in television reports, radio interviews, articles published on the Natural Resources Canada website, and posts on our social media platforms

Our work is focused on a successful energy transition and the achievement of GHG emissions reduction targets. Our science and conclusive data enable us to:

- Support government policy decision-making
- Develop national strategies and guidelines
- Provide technical expertise to public deployment programs
- Foster technological innovation in Canada's various sectors

Our Areas of Activity

Our facilities are equipped to develop, test and demonstrate clean energy solutions in real-world conditions to enhance their market uptake. Our activities and expertise in various sectors include:



Structure & **Annual Budget**

Source of Funds

$14.4M
Program of Energy Research & Development (PERD)

$3.6M
Other Government Departments (OGDs)

$2.2M
Vote-Netted Revenue (VNR)

$5.4M
Core Budget (A-Base)

Strategic & Operational	R&D Programs	Deployment
Science Impact Unit 3 employees $0.5M	**Buildings** 20 employees $4.0M	**RETScreen** 23 employees $2.9M
Scientific Outreach 4 employees $0.3M	**Industry** 40 employees $5M	**Greening Government Operations** 10 employees $2.3M
Operations 20 employees $3.2M	**Renewable Energy Integration** 30 employees $3.6M	**Energy Systems for Northern & Remote Infrastructures** 7 employees $2.5M

In $M, including salary, employee benefit payments, and operation & maintenance

Our Green Outlook on the Future...

The 2023-2024 fiscal year unfolded seamlessly. Looking ahead, we see that the delivery of our five-year science plan is well underway. This R&D plan is based on the 13 projects funded under the Program of Energy Research and Development (PERD) / Energy Innovation Program (EIP) for the 2023-2028 funding cycle. It focuses on delivering scientific results to achieve Canada's science and technology (S&T) mandate by providing maximum impact to Canadians.

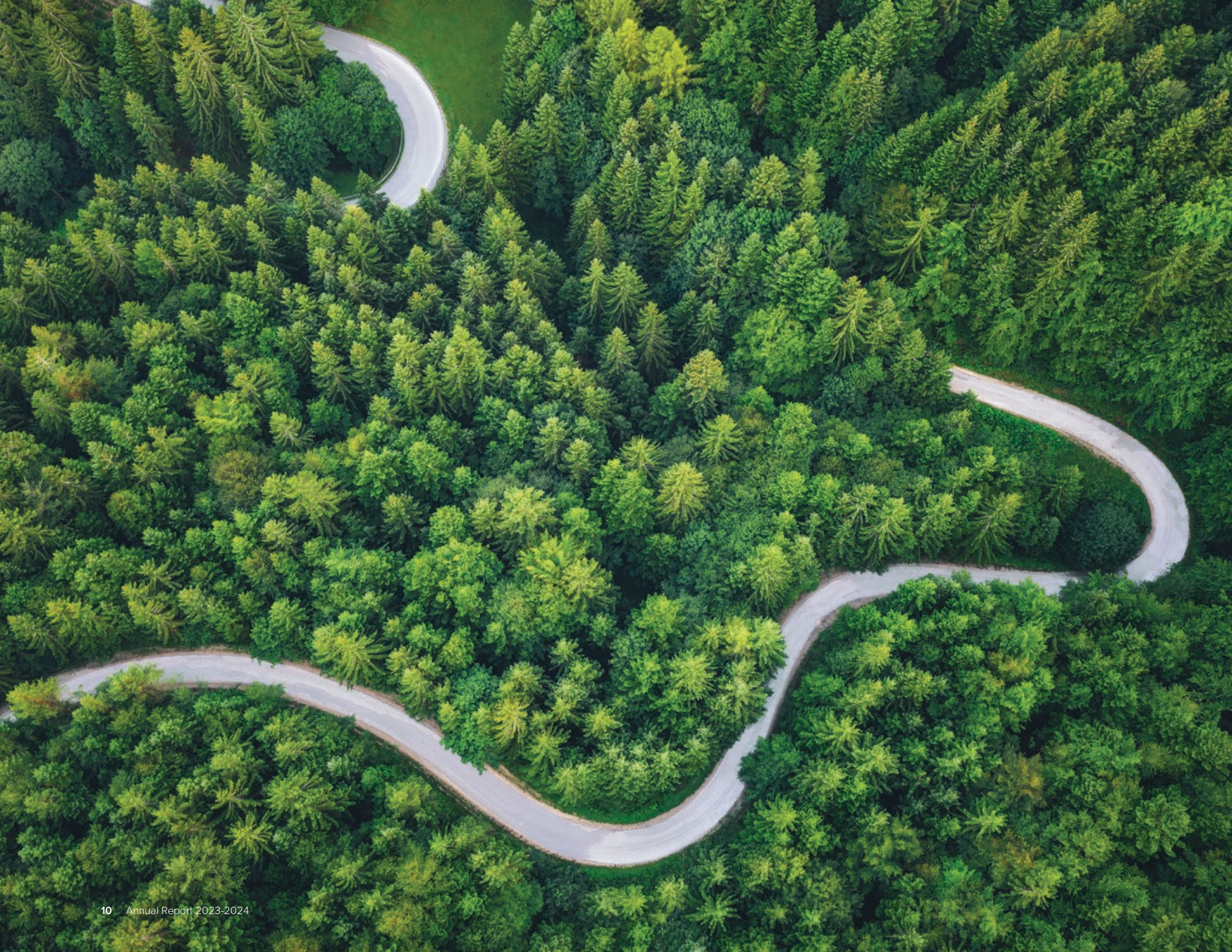
An overview of our scientific activities and results is presented in the following pages of this report. We are proud of what we have achieved over the course of the past year, and we are excited to keep accomplishing our mission in the years to come.

We recognize that we must reduce energy consumption, move from difficult-to-electrify uses to low-carbon fuels, and electrify energy uses while increasing the capacity of power grids and keeping them clean and affordable. To do so, we will:

- Continue to develop our testing infrastructures to equip ourselves with a thermal and electrical microgrid with an approximate capacity of 250 kWe. This infrastructure will enable us to study a massive integration of solar energy, grid forming inverters, protection schemes in configurations with high penetration of renewable energy, load control for stability, and a greater integration of renewable energy sources.
- Develop a greater ability to test and develop cold-climate, air-to-air, air-water, and ground-source heat pumps that use low global warming potential (GWP) refrigerants, such as CO_2.
- Structure and enhance our capabilities in energy system modelling – in terms of software, expertise, and human resources – at the community, provincial and Canadian levels.

To improve collaboration and ensure results that are consistent with the efforts we put in place, we will develop a communication plan tailored to our different stakeholders.

The future looks bright.
And we are working diligently to rise to the occasion.



Overview of our **science and technology activities** carried out during the 2023-2024 fiscal year

Buildings

Our Buildings division carries out R&D activities and deploys energy efficiency, renewable energy integration, and smart electrification solutions and technologies for the decarbonization of buildings. Our activities aim to support Canada in achieving its GHG emissions reduction targets to achieve net-zero emissions by 2050.

Renewable Heating and Cooling

Impact studies of heat pump adoption

Heat pumps play a critical role in the decarbonization of space heating. **Techno-economic simulation studies of implementing cold-climate air-source heat pumps** in the Canadian residential sector were performed to quantify regional benefits, barriers and strategies to increase the adoption of these heating systems.

KEY OUTCOMES

These studies were used to **develop requirements for the Canada Greener Homes Initiative** as well as a **heat pump sizing guide**. They also provided insight into the increase in electric demand responding to inquiries on the additional considerations of decarbonization. The studies were presented at the International Heat Pump Conference (Chicago, May 2023) through a keynote speech that helped disseminate the data.

CO_2 heat pump with ejector

Transcritical CO_2 heat pumps are **increasingly used in a variety of heating and cooling applications in buildings**. Integrating a two-phase ejector as an expander improves the performance of a heat pump, especially at low source temperatures. The ejector is a simple device with no moving parts, which allows high pressure to entrain and compress a lower pressure stream.

KEY OUTCOMES

The experimental test bench results confirmed the ejector's value in **improving the heat pump's performance under certain conditions** (coefficient of performance increased by 18% and capacity increased by 20%). The data also helped validate the thermodynamic and computational fluid dynamics models used to design the ejector and integrate it into a system. Our team of experts now has the knowledge to **support Canadian manufacturers in increasing their competitiveness** by offering more efficient CO_2 systems.

CO_2 Thermal Network

The CO_2 Thermal Network developed by CEV is **expected to greatly improve the way thermal energy is used, recovered and distributed** in commercial and institutional buildings. This innovative technology comprises a single pipe that circulates two-phase (liquid-vapor) CO_2 as a heat carrier fluid. Heat pumps connected to the CO_2 loop provide heating or cooling to the different zones of a building or building cluster.

KEY OUTCOMES

A series of tests performed under various operational conditions **confirmed the technology's value and validated the models used to design** this new concept. Control sequences that strategically allow to obtain the desired performance have been developed. Several discussions are underway with partners for the **transfer of this technology**, which is now patented in both Canada and the United States.

Highlights

- The team working on projects with the Department of National Defence (DND) and Defence Research and Development Canada (DRDC) received recognition and an award for the deployment of remote surveillance power systems in the High-Arctic.
- Our team helped develop or update several codes and standards related to buildings, refrigeration and heat pumps.
- A team member is the Vice-Chair and delegate of the Executive Committee of the International Energy Agency (IEA)'s Heat Pumping Technologies Technology Collaboration Programme (HPT-TCP). We also participate in Annexes 58 & 60 of the HPT-TCP in connection with heat pump technologies.
- Results of the project at the Canadian Space Agency were highlighted by the President of the Treasury Board of Canada during a ministerial announcement in February 2024.

CO_2 vertical thermosiphon to extract ground heat

This passive technology is particularly interesting for **improving building heating efficiency in northern remote communities**. Discussions for demonstration projects are being held with several partners.

KEY OUTCOMES

Test bench results **validated the simulation models** and **confirmed the potential applications of this technology**, particularly in regard to permafrost maintenance with heat recovery to preheat supply air for building ventilation. A collaboration is being developed with Université Laval's Centre for Northern Studies and the National Research Council (NRC).

High-temperature heat pumps for building retrofit

Many buildings in Canada's building inventory use a high-temperature (80-90 °C) heating network, which makes the use of some heat pumps difficult in retrofit projects. Existing, new, and emerging heat pump technologies that make it possible to achieve these temperatures – in a cascade system or by using heat waste – offer a **solution for the electrification of these buildings**.

KEY OUTCOMES

Five feasibility studies were carried out to assess the integration potential of **high-temperature heat pumps in federal buildings**. An agreement was signed with a Canadian company to establish its technology's performance using a low global warming potential refrigerant and to identify the potential for improvement.

> *"Creating climate resiliency requires everyone to do their part and the government is no different. Improving the heating systems in the North and reducing embodied carbon at the Space Agency are some examples of where innovation is leading the way to net-zero, cost-effective and green operations. Through the Greening Government Strategy, we are leading by example in greening our own operations by supporting projects that will move us closer to our goal of net-zero operations by 2050."*
>
> **– The Honourable Anita Anand, President of the Treasury Board**
> (Minister responsible for the Greening Government Fund and the Greening Government Strategy)

Data-Driven Building Operation **for Energy Efficiency, Flexibility and Resiliency**

Advanced controls for greater energy flexibility

Supervisory control strategies were developed to **improve the energy flexibility of building clusters**. Four different strategies – based on supervisory control of room temperature setpoints and domestic water heater setpoints – were developed. The impact of these strategies on a cluster of 2,400 houses was assessed through simulations. This study was carried out as part of a collaboration with Polytechnique Montréal and the International Energy Agency (IEA) Annex 82 – *Energy Flexible Buildings Towards Resilient Low-Carbon Energy Systems*.

KEY OUTCOMES

Simulations revealed that, for the cluster of houses, the **electrical peak power demand could be reduced by 15 to 25%**.

Virtual energy meters

Virtual energy meters are mathematical models that, in the absence of meters, calculate thermal energy use in different building zones to **detect and correct inefficiencies**. Virtual energy meters were developed for air handling units and hydronic perimetric heating systems, and implemented in the building automation system at the CanmetENERGY in Varennes Centre.

KEY OUTCOMES

Energy inefficiencies caused by excessive ventilation and unnecessary fresh air intake were detected. Corrective actions are being implemented.

Technical guide for district heating plants

A technical guide to **optimize the operation of district heating plants** equipped with natural gas boilers was developed for the Department of National Defense (DND). The guide describes how to identify inefficient operation and provide corrective actions, evaluate and track energy performance, and develop optimal supervisory controls.

KEY OUTCOMES

The DND intends to implement data-driven energy efficiency measures in additional military bases, following the promising results obtained in our project financed by the Greening Government Fund.

Simplified software tools

The operation of heating and cooling plants is often far from being optimized, leading to increased energy costs and increased GHG emissions due to heating with natural gas.

KEY OUTCOMES

Simplified software tools facilitating the **energy performance optimization** of cooling plants and the reduction of GHG emissions of heating plants equipped with natural gas and electric boilers were **developed and tested using operational data** from the Canadian Space Agency headquarters (Saint-Hubert, QC) and from a large commercial building (Montréal, QC).

Reducing Diesel Dependency of **Remote Infrastructures**

NATO Operational Energy Concept

The benefits of reducing the diesel dependency of military deployed camps go beyond reducing diesel GHG emissions. They also include improved resilience and reduced fuel convoys as well as quicker mission accomplishment. An **energy management experiment** was conducted in collaboration with Belgium, the UK, the US and the North Atlantic Treaty Organization (NATO)'s Energy Security Centre of Excellence to demonstrate energy efficiency in a deployed camp.

KEY OUTCOMES

The experiment **allowed for the development of the NATO Operational Energy Concept**, which identifies the barriers and next steps NATO members must tackle to better work together. Furthermore, a **20% reduction in diesel fuel consumption** was demonstrated following the NATO harmonized energy metering points with the use of solar photovoltaics, battery energy storage, and diesel generators in a deployed camp setting.

Low power energy solutions for remote surveillance

This project demonstrated that a direct methanol fuel cell with solar photovoltaics, a battery energy storage and a wind system had the **capability of operating autonomously** through the polar night in the Arctic.

KEY OUTCOMES

The results **advanced scientific efforts in the field of power generation and sustainment in the Arctic**. Operating through the polar night was never demonstrated and accomplished before using this type of system and **now provides a new capability**.

Energy efficiency assessments for the Royal Canadian Navy

Several studies were conducted to **improve the operational effectiveness of the Royal Canadian Navy platforms**. The project is in collaboration with Defence Research and Development Canada (DRDC) – Atlantic and the NRC.

KEY OUTCOMES

An energy audit was conducted of the Royal Canadian Navy Halifax class combat ship and, for the first time, a detailed dataset on where the key electrical flows go was measured. The data supported the **development of an energy model** to make energy efficiency recommendations to **reduce fuel consumption and improve decision making** through data analytics. Various vessels were also selected to assess the electrification potential.

Greening **Government Operations**

CanmetENERGY in Varennes and the Office of Energy Efficiency (OEE) are mandated by the Centre for Greening Government (CGG) of the Treasury Board of Canada Secretariat (TBS) to **provide support to federal departments in achieving the GHG emissions reduction targets** set by the Greening Government Strategy. These support services are provided as part of Greening Government Operations. In 2023-2024, our Centre contributed to this program in several ways, namely by:

- **Supporting nine departments and agencies in their decarbonization process** by means of energy performance contracts and existing building commissioning (EBCx) projects, or for the purpose of evaluating and identifying pathways towards energy efficiency and GHG emissions reduction.
- **Developing and implementing tools and guides** on matters such as EBCx and decarbonization planning, in collaboration with the OEE and the DND.
- Exploring with the Correctional Service of Canada (CSC) the potential for a pilot project to **convert organic waste** into biobriquettes for **on-site energy production**.
- Starting a project funded by the Greening Government Fund aimed at demonstrating, through certain pilot projects, the **ongoing commissioning (OCx) approach applied to different types of buildings**, in collaboration with Public Services and Procurement Canada (PSPC), the DND and NRCan.
- Facilitating the adoption of various approaches and technologies by **disseminating information and knowledge** through five conferences and workshops, a training course for university students as well as participation in various technical committees on codes and standards and within industry associations and working groups formed by the TBS-CGG.

Innovative Solution

Two patents were granted for a new technology:

Title:

Single-pipe thermal energy system

Patent in the United States ▶

Patent in Canada ▶

Industrial Systems Optimization (ISO)

Our division offers a broad range of expertise and is uniquely positioned to tackle complex problems related to large-scale energy systems optimization. We provide Canadian energy-intensive industrial sectors with whole-system design tools and knowledge to improve their global efficiency, increase their competitiveness, and reduce their environmental footprint.

Advancing **Science and Technology**

Carbon capture, utilization and storage (CCUS)

In collaboration with CanmetENERGY in Ottawa and different Canadian stakeholders, we are **developing the National CCUS Assessment Framework**. This all-in-one decision support platform aims to help governments and industry better plan CCUS projects while considering costs and technological performance along the entire CO_2 value chain, as well as the impact of policy decisions.

KEY OUTCOMES

A state-of-the-art CCUS value chain optimization model was developed to determine a cost-optimal plan to connect CO_2 emitters with storage reservoirs. This model was successfully used in **CO_2 pipeline network case studies** that include all major industrial emitters and most promising storage locations in Eastern and Western Canada.

High-performance CCUS technologies and systems

Advanced carbon capture technologies that reduce the energy consumption and cost of carbon capture are critical to a widespread deployment of carbon capture and storage. Our team is investigating breakthrough improvements combining efficient solvents with innovative equipment and process configurations that will **significantly improve energy and mass transfer**.

KEY OUTCOMES

Detailed simulations and techno-economic analyses confirmed that promising solvents and new process configurations could reduce **energy consumption and cost by up to 20%** compared to the conventional monoethanolamine carbon capture technology. The integration of high-temperature heat pumps can further improve energy performance while new absorption and stripping systems can dramatically reduce the footprint of the capture unit.

Decision support tool to economically assess carbon capture technologies

Our team is **developing an easy-to-use decision support tool** to quickly and accurately predict the design, performance and cost of carbon capture technologies.

KEY OUTCOMES

Thousands of detailed process simulations were used to **develop and produce powerful machine learning models** for two amine- and cryogenic-based capture technologies. The tool was used to calculate – in less than a second – the capture cost for 70 industrial facilities emitting more than 300,000 tonnes of CO_2/year in Eastern Canada.

Industrial Decarbonization **Powered by Artificial Intelligence (AI)**

Novel approach for intelligent supervisory control

Two complementary strategies are proposed for **intelligent system-wide supervisory control**: the first one uses multiple deep reinforcement learning agents and the other employs machine learning-based economic model predictive control.

KEY OUTCOMES

Preliminary results were obtained on a pulp mill heat recovery network and reboiler using the strategy of deep reinforcement learning agents, showing an energy savings potential of 6%.

AI-based approach for system-wide maintenance decision support

This pioneering AI-based approach harnesses machine learning techniques to construct equipment health indicators, diagnose inefficiencies, predict performance degradation across interconnected equipment, and prescribe actions that maintain desired overall performance.

KEY OUTCOMES

Unlike conventional methods focused on individual equipment, this **innovative strategy considers operational interdependencies**, thus promising greater positive impacts (e.g. increased energy savings, reduced operational costs and higher yield).

An AI-powered simulation-based optimization approach

This new approach uses reinforcement learning agents that interact with simulators to **optimize the operations and energy efficiency design of industrial processes**. This allows to drastically reduce the number of simulations needed by the conventional approach, thereby reducing design time and cost while reaching an optimal solution.

KEY OUTCOMES

The approach achieved 5.5% cost savings in the case of a CO_2 capture process, demonstrating its effectiveness while drastically reducing design time.

Digital forest value chain initiative in the province of Quebec

In collaboration with the Canadian Wood Fibre Centre, we are advancing a research initiative to **develop a forest information ecosystem and a decision support platform**, integrating big data and AI tools to optimize the productivity of forest value chains as well as their performance in terms of energy and GHG emissions.

KEY OUTCOMES

Following several workshops and roundtables with over 60 key provincial stakeholders, a **detailed proposal was developed with 21 projects focused on the digitalization of forest value chains.** Discussions are underway to form partnerships, seek financing and launch projects.

A Partnership for **Improved Decarbonization**

Collaboration agreement with the Quebec provincial government

We have been maintaining a fruitful collaboration on energy transition and decarbonization with the Quebec provincial government for over a decade.

KEY OUTCOMES

The 2020-2023 partnership agreement has enabled a detailed characterization of GHG emissions and fuel consumption of the 100+ largest emitting sites in the province at the operations level. Tools and knowledge were also provided to **identify, assess and implement promising technological solutions** to achieve the decarbonization objectives for the Quebec economy.

Clean Fuels

Assessment of bio-SAF and e-SAF pathways

In collaboration with the SAF+ Consortium, we **model, simulate and assess techno-economic aspects of sustainable aviation fuel (SAF) pathways**: bio-SAF (biomass-to-SAF) and e-SAF (electro-sustainable aviation fuel). A preliminary market assessment of SAF was carried out to determine the potential for SAF production in Eastern Canada.

KEY OUTCOMES

Using CO_2 recovery from industrial sources and forestry residues, five pathways were assessed to produce e-SAF and bio-SAF. An overview of industrial CO_2 emissions for Eastern Canada was conducted highlighting 142 facilities that emit approximately 82 Mt-$CO_{2\text{-eq}}$ per year. These facilities offer opportunities to implement e-SAF production technologies.

Hydrogen

Solid oxide electrolysis cell (SOEC)

The SOEC technology represents a pivotal advancement in the burgeoning hydrogen economy, offering a promising pathway to **produce hydrogen with markedly reduced carbon intensity**. A specific design was proposed to produce 99.9% hydrogen, offering diverse options to improve its energy efficiency and related carbon intensity.

KEY OUTCOMES

A data quality assessment factsheet was developed, which provides comprehensive mass and energy balance used as a basis for life cycle assessment and shared with the National Research Council (NRC) of Canada. Three variants of the SOEC process were developed and the effects on the carbon footprint evaluated.

Multicriteria analysis tool for green hydrogen

A multicriteria analysis tool was developed for the use of green hydrogen in industry. The most important criteria used are GHG reduction per unit of energy input, energy penalty, technical and economic considerations, and the existence of better alternatives or not.

KEY OUTCOMES

Various **potential industrial applications for green hydrogen use** were investigated. A limited number of these applications offer a GHG reduction potential as significant as that of direct electrification, which should be favoured given the limited availability of renewable electricity.

Industrial Decarbonization

This project aims to develop innovative solutions integrating energy efficiency, clean technologies, flexible electrification and the use of low-carbon fuels to accelerate industrial decarbonization and the circular economy.

Pulp and paper sector

A simulation platform was developed to assess several potential configurations for carbon negative kraft mills.

KEY OUTCOMES

Ten new technologies and processes were added to a reference mill, which resulted in several **decarbonization roadmaps** to eliminate fossil fuel utilization.

A simulation platform was developed to assess several potential configurations for carbon negative kraft mills.

KEY OUTCOMES

A case study with a tissue mill was conducted, highlighting the contribution of energy efficiency measures, bioenergy, electrification and hydrogen for the decarbonization of this site, and the overall tissue production in Canada. It was found that the decarbonization of the ten tissue mills in Canada is best achieved with a **combination of high-temperature heat pumps and direct electrification**.

Iron and steel sector

The techno-economic viability of several strategies to achieve **net-zero emissions in steelmaking** was developed, starting from a direct-reduced iron and iron pellet plant baseline to a non-emitting factory in 2050.

KEY OUTCOMES

This **supported the strategic investment plan of our industrial partners** for decarbonizing their operations.

A case study with a steel production facility was conducted, highlighting the respective contribution of energy efficiency, bioenergy, electrification, hydrogen and CCUS for the **decarbonization of this site and the overall iron and steel industry in Canada**.

KEY OUTCOMES

The study results showed that the **decarbonization of steel production facilities is complex** and requires a combination of process changes, advanced energy recovery means, increased steel scrap utilization, process electrification, biocarbon and syngas/hydrogen use, and carbon capture and sequestration.

Decision Support Tools and Methodologies

Driving bioeconomy change

The assessment of bioeconomy transformation is typically done considering a range of criteria that are unique to the values of the company. For this reason, no bioeconomy strategy can be completely de-risked; however, the **use of appropriate decision support tools can assist in mitigating risks**. I-BIOREF has been revamped to expand feedstock database and include sustainability and circularity decision metrics.

KEY OUTCOMES

Thanks to the enhanced capabilities of the I-BIOREF decision-support tool, five showcases were carried out using a multidimensional comparative analysis of technology pathways to produce liquid renewable fuels. These events brought together over 200 participants from academia, government and industry, both nationally and internationally. **I-BIOREF has now become an essential decision-support tool** for designing and evaluating biorefinery or bioeconomy projects as part of the development of industrial biomass-centric clusters.

Arbitrage of limited renewable resources – system-level modelling

The limited availability of renewable resources forces us to prioritize their use where they offer maximum benefits and where there are no better alternatives. **System-level modelling techniques and multicriteria decision-making tools** are needed to develop robust decarbonization pathways, policies and programs.

KEY OUTCOMES

Improved technology models for large-scale E3 modeling platforms now **allow for better arbitrage of limited biomass availability**. These models were also adapted and developed for evaluating electrification potential as well as the most promising hydrogen use in industry.

Software Solutions **Developed by Our Team**

EXPLORE
Multivariate data analysis software for process optimization

I-BIOREF
Software for technical, economic and environmental assessment of biorefinery strategies

INTEGRATION
Software for heat recovery optimization in industrial processes

COGEN
Modelling software to improve the profitability of cogeneration systems

KraftSIM
CADSIM simulation platform for the assessment of new technologies in kraft processes

Free download online ›

Renewable Energy Integration (REI)

Our R&D activities aim to facilitate the integration of more renewable energy into Canada's electricity grid while recognizing sustainability, reliability, and affordability objectives. Our mandate is well aligned with the Government of Canada's commitments to achieving net-zero electricity by 2035, and net-zero emissions in all sectors of the economy by 2050.

Renewable Energy and **Smart Grid Resources and Devices**

Our team assesses the performance of distributed energy resources (DER) and related standards to address issues related to the impact on electric grids of variable renewable energy and the increasing demand for electricity. Through our work, we evaluate and model the performance of both existing and novel solar photovoltaic (PV)-related technologies and power conversion equipment (inverters). In addition to this work, design guidelines and gaps in performance and safety are also addressed.

Standards related to PV/BIPV technologies and to inverters

This project focuses on the adoption and maintenance of standards related to PV and building-integrated photovoltaics (BIPV) technologies and to inverters through various standard committees such as the CSA Group's standard committees. Our involvement contributes to the coordinated **development of DER product and system standards, guides and codes** in Canada.

KEY OUTCOMES

This year, CanmetENERGY chaired a working group that deals with the adoption of Canada's first standard on building integrated PV systems and modules (CSA C22.2 No. 63092). We also chaired the adoption of the new edition of standard CAN/CSA-IEC 61215 on PV module design. This standard ensures that PV modules can **withstand Canadian weather conditions**. It also **safeguards the quality of PV modules** sold in Canada. The standard will soon go to public review and then be published.

Assessment of the technical PV potential of the Canadian building stock

As part of a project on the technical PV potential of the Canadian building stock, our researchers developed a **new statistical method from detailed analyses** of 11 Canadian municipalities, for which high quality LiDAR and building footprint data are available. The method was applied to the stock of residential, commercial and institutional buildings in Canada and can be used, for example, in net-zero pathway studies.

KEY OUTCOMES

CanmetENERGY **published a report entitled "Assessing the photovoltaic potential of the Canadian building stock"** in January 2024. It indicates a potential for 300 GW of rooftop PV, which is roughly double the total electric power capacity of Canada's generation fleet. For Canada as a whole, the analysis shows that rooftop PV could generate 247 TWh per year, equivalent to 76 % of the current electricity needs in residential, commercial and institutional buildings. Technical PV potential on Canadian buildings is considerable, suggesting that rooftop PV could **play a significant role in Canada's energy transition**. To determine the extent to which this potential could be realized, financial criteria and market adoption will need to be considered, as well as the ability of electricity grids to host this capacity.

Improving Technology-Grid Interface and Interoperability **to Support Grid Modernization**

This project focuses on bridging the gaps in terms of integration and connections between grid-edge technologies (e.g. flexible loads) and the grid itself. It focuses on three main R&D areas: facilitation of connections between inverters and the grid, development of methods for DER control and aggregation, as well as mapping and advancement of related grid integration standards.

Smart grid standards

With respect to smart grid standards, this project aims to review standards and fill the gaps related to inverter grid interface and equipment interoperability. It aims to **create a clear picture of the needs for the advancement of key standards** and to dedicate efforts towards it. This effort is aligned with Canadian smart grid standard requirements going to 2035 and beyond.

KEY OUTCOMES

A method was developed to rank the relevancy of contributing to different smart grid standards. This method provides guidance on the level of effort that should be put towards the development and revision of different standards. A vision of required advancements and updates in smart grid codes, standards and regulations is under development. This should enable the **development of a smart grid standard roadmap**.

Inverter-grid interface and grid stability

This project focuses on **facilitating inverter-grid interfaces to improve grid stability**. It addresses the need for the evolution of future inverter grid-support capabilities including the evolution of current grid-following inverters as well as the technical specifications of grid-forming inverters. This project is conducted in collaboration with the International Energy Agency (IEA)'s International Smart Grid Action Network (ISGAN) Working Group 5 on grid-forming inverter research activities and grid code testing using OpenSVP, an open source testing platform.

KEY OUTCOMES

This past year, CanmetENERGY has been **supporting research laboratories** from Ireland, Switzerland and Germany in the implementation of the OpenSVP platform in their test facilities. OpenSVP allows for the testing of DERs according to national grid codes. In addition, **several improvements were made to our Centre's inverter testing facility** with the addition of a battery simulator that will allow for future testing of inverter-based storage units with electric vehicles (EVs) and grid-forming inverters.

Variable Renewable Energy (VRE) Resources and **Electrified Grid-Active Neighbourhoods, Communities and Cities**

This project focuses on strategies to allow operation of distribution grids with a large penetration of VRE. It is based on these mains areas of R&D: the amount of VRE that a distribution grid can accommodate (i.e. hosting capacity); the management, control and protection for the distribution grid and microgrids; and the pathways for both net-zero remote communities and distribution grid modernization.

Distribution system hosting capacity

This project focuses on hosting capacity, meaning the additional amount of DERs and loads that a distribution system can accommodate without requiring infrastructure upgrades. It investigates the assessment methods and their standardization as well as short term approaches to **increase the hosting capacity through resource and load management**.

KEY OUTCOMES

Our team is involved in a working group **developing a guideline for hosting capacity calculation and evaluation metrics** as part of the Institute of Electrical and Electronics Engineers (IEEE)'s P1729 standard – Recommended Practice for Electric Power Distribution System Analysis. This guideline will provide utilities with an easier access to hosting capacity assessment tools.

Varennes Interactive Grid (VARIG)

The Varennes Interactive Grid (VARIG) project aims to develop and demonstrate the operation of a distribution grid with high penetration of VREs and flexible DERs.

KEY OUTCOMES

Many R&D activities progressed this past year including the development of four test cases considering different flexible loads including a community of electric water heaters, CEV's electric boiler, an industrial complex, and an EV fleet. Results will **provide insight on the added value of load flexibility in electric grid planning and operation** to compensate for the fluctuations caused by the variability of PV generation.

Media Visibility

The report *Assessing the photovoltaic potential of the Canadian building stock*, available on NRCan's website, received significant media attention.

The results were used by Radio-Canada to illustrate the potential of PV, which provided an opportunity for us to showcase NRCan's science to the public and to talk about the role of solar energy in Canada.

Conferences & **Events**

- Participated in and contributed to two conferences held by the Energy Modelling Hub (EMH) by presenting on panels related to the integration of DERs in bulk power system modelling. The EMH facilitates the collaboration of Canadian modellers and accelerates the acquisition of knowledge related to net-zero modelling and analysis.
- Participated in the 51st edition of the IEEE's Photovoltaic Specialists Conference, held in San Juan, Puerto Rico; two papers were presented at the conference.
- Participed in the ASHRAE Winter Conference in Chicago; in addition to technical committees, our Centre also contributed to the main program by giving a presentation on capturing the potential of DERs for grid transformation as part of a seminar on strategies for net-zero energy buildings.

Low-Carbon Regional and National Electric Grids and Energy Systems

This project fosters the **development of zero-carbon systems** at the provincial, territorial and national levels. It hones in on three main areas: bulk system stability while integrating large numbers of DERs and inverter-based resources; planning and operation to support electrification and DER opportunities in a new grid paradigm; and Canadian pathways for grid modernization.

This work aims to develop methods and models for improving regional stability, strategies for system operation and planning to support electrification and flexibility while weighing new cooperative roles for transmission and distribution system operators, and grid modernization pathways and scenarios.

Modelling electric grid planning and production

This project focuses on building electric grid planning and production cost models. Through the development of a modelling framework and workflow, CanmetENERGY will be able to **identify the least-cost mix of generation and transmission capacity investment scenarios** for the future Canadian electric grid.

KEY OUTCOMES

Internal modelling capacity to evaluate bulk electric power system pathways is being built with the development of a framework and workflow in the open-source tool Python for Power System Analysis (PyPSA). This modelling capacity is being used to **provide science-based advice to evaluate the feasibility of future electric grid scenarios**.

Smart Renewables Electrification Systems (SRES)

This project aims to assess the capacity of various technologies to provide grid services and their impact on the grid infrastructure. By assessing the performance as well as the flexibility potential of technologies, and identifying knowledge gaps on the effective integration of these technologies into grid systems, SRES provide guidance to policymakers on **effective grid modernization pathways to achieve net-zero targets**.

Information and data acquisition

Information and data acquisition focuses on establishing the current state of R&D through literature reviews, on **acquiring contextual and performance data from energy systems across Canada** and on managing this information in a private and secure manner.

KEY OUTCOMES

Through literature review, our project assessed PV technology research needs for grid support and explored onsite renewable resources for both PV and wind to explore pathways to net zero. The grid-support assessment for PV and wind was classified in different categories such as grid operation, stability and protection. A **system for prioritizing future research initiatives** was developed to enable the team to identify the level of effort according to the urgency and significance of their contribution to achieving net-zero targets.

A Policymaker's Feedback **on Our Work:**

"It is highly appreciated having access to technical experts on power systems and renewables internally at NRCan to obtain science-based advice on electricity grid system questions regarding pathways to decarbonizing the electric grid."

RETScreen® Expert

RETScreen

Our RETScreen division develops and deploys the world-leading RETScreen Clean Energy Management Software platform, which enables low-carbon planning, implementation, monitoring and reporting for buildings, factories and power plants around the world.

The division undertakes **several workstreams to advance NRCan's corporate mandate** to ensure Canada's abundant natural resources are developed sustainably, competitively, and inclusively. These workstreams include:

- The RETScreen Innovation Lab, which collaborates with government and multilateral organizations to co-fund and develop advanced versions of the RETScreen software.
- The RETScreen Data Onboarding service, which delivers onboarding services on a cost-recovery basis, helping large public enterprise customers with their facility-level and portfolio-wide deployment of the platform.
- The RETScreen Capacity Building program, which helps improve the knowledge, skills and capabilities of the 850,000+ energy, facility and sustainability professionals located around the world who use the RETScreen software.

Key highlights of the workstreams during the 2023-2024 fiscal-year include, but are not limited to:

RETScreen **Innovation Lab**

Version 9.1 of the RETScreen Software was released. This updated version includes the following new features:

Benchmark and Feasibility Analysis Modules

- 14 deep emission reduction archetypes incorporating artificial intelligence (e.g. for ice skating arenas, etc.).
- 2 archetypes for auto parts manufacturing plants.
- Multiple fuel heating system model.
- Energy storage, including heating, cooling and electricity storage models.
- Equipment database with file and internet link options.
- Electricity rate calculator based on monthly and time-of-use rates.
- Carbon shadow price and carbon offsets features.
- International electricity and fuels rate database.
- Updated benchmark database (e.g. data centres).
- Cost, GHG emission factors and product databases.

Performance Analysis Module

- "Schedule" filter for data, Measurement and Verification (M&V), etc.
- Paste climate data to Location worksheet feature.
- Direct data connectors for *Managing Energy* and *Measurabl*.
- User-defined meter database to support ISO 50001 implementation, sub-metering and real-time monitoring activities.

Portfolio Analysis and All Modules

- Portfolio-level Virtual Energy Analyzer.
- Portfolio-wide *Net Zero Planning Tool* and *Portfolio Decarbonization Framework*.
- User-defined Waterfall graph.
- "Sustainability – Example" and "Net zero plan – Example" added to My portfolio.
- Translated user manual into Spanish (in addition to English and French).

Members of the RETScreen team received an

NRCan DEPARTMENTAL MERIT AWARD

("Behind-the-Scenes" Category)

RETScreen **Data Onboarding**

The annual Government of Canada's Greenhouse Gas Emissions Inventory prepared by the Treasury Board of Canada Secretariat (TBS), with the support of the RETScreen Team in Varennes, uses the RETScreen Software to **report on the greenhouse gas emissions from federal facilities and conventional fleet operations** (Scope 1 & 2 emissions) and for air travel (Scope 3). This reporting now also includes water consumption and waste production tracking on a pilot basis.

Supported other cost-recovery enterprise customers to implement and maintain RETScreen portfolios:

- Global Affairs Canada (GAC) – **300+ facilities** at foreign missions
- Natural Resources Canada (NRCan) – **29 facilities**
- Canadian Space Agency (CSA) – **15 facilities**

Ongoing cost-recovery support to the Department of National Defence (DND) to implement and maintain a RETScreen portfolio, with **8,000+ military facilities**. A significant deliverable this past year was the completion of the extensive portfolio-wide feasibility analysis for DND: ***2050 Carbon Neutral Portfolio Plan: Canada's Department of National Defence (DND).***

Provided ongoing technical support to numerous energy, facility and sustainability managers at public sector enterprises, who use RETScreen for **portfolio-wide energy and GHG management for thousands of facilities** located across Canada and around the world.

RETScreen **Capacity Building**

Organized **virtual** ***Net Zero Planning with RETScreen Expert*** **training events** in English, French and Spanish in collaboration with the Canadian Institute for Energy Training (CIET), with more than 1,500+ participants attending from across Canada and from many other countries around the globe.

Coordinated **activities with the RETScreen trainers' network**, including the delivery of multiple online training webinars and in-person workshops focused on various customer segments for the RETScreen software (e.g. municipalities, healthcare, clean power generation, primary and secondary schools, etc.).

Supported Infrastructure Canada's $1.5B Green and Inclusive Community Buildings (GICB) Program to **review numerous funding applications** submitted to GICB via the RETScreen Software.

Undertook **outreach activity efforts with various key stakeholders** to encourage a continued software download rate at 40,000+/year and to further build the capacity of the 850,000+ RETScreen users across Canada and around the world.

Provided in-depth technical support to subscribing customers and engaged high value potential customers on an ongoing basis to ensure the **continuous capacity building of key users.**

Targeted outreach activities, including **regular email bulletins** sent to 150,000+ newsletter subscribers, and the completion of **several new training videos.**

1,500+
PARTICIPANTS ATTENDING VIRTUAL TRAINING EVENTS

150,000+
EMAIL NEWSLETTER SUBSCRIBERS

40,000+
CONTINUED SOFTWARE DOWNLOAD RATE, PER YEAR

850,000+
RETSCREEN USERS ACROSS CANADA AND AROUND THE WORLD

Our support teams offer a **wide range of expertise** and are of **valuable service** to our divisions tasked with implementing R&D programs

Operations

Our Operations team supports the delivery of interdependent and national programs by our Centre and its S&T partners. This team is comprised of the following three subgroups:

Engineering & Technical Services | **Infrastructure Management** | **Business Office**

Areas of **Expertise**

- Design and construction of test benches and prototypes for applied science
- Design, construction and delivery of external projects with partners
- Maintenance of test benches and scientific R&D facilities in our pilot pants
- Calibration of scientific measuring instruments
- Technical support for researchers and engineers
- Building maintenance, upkeep and improvement
- Physical security of the premises
- Information technology and management
- Shipping and receiving of goods
- Human resources
- Contracts and finance
- Risk and emergency management

Highlights

- Managed the electrical installation of the microgrid
- Upgraded pilot plants to accommodate future projects
- Reorganized workspaces to accommodate new mechanical and electrical workshops
- Dismantled obsolete projects and test benches
- Delivered new geothermal and CO_2 heat pumps test benches
- Delivered a hybrid energy project for the Arctic with interdepartmental and external partners
- Provided technical support for our scientific projects and prototypes at end sites across Canada
- Standardized our automated and human-machine interface systems to collect scientific data in our databases
- Improved and modified workspaces for a hybrid work environment with a focus on ergonomics and the practical needs of employees
- Repaired or replaced several critical building equipment items such as humidifiers, sump pumps, heating pumps, ventilation systems, etc.
- Managed building condition report initiated by Real Property
- Fully migrated the team's files to MS365 and increased use of Planner and Project for project management
- Supported R&D groups for data migration to MS365
- Migrated multiple servers to a newer version of Windows Server
- Developed a tool for archiving valuable documents
- Verified the compliance of building equipment and protection systems

Science Impact Unit

Positioned within the Director General's Office, our Science Impact Unit (SIU) is composed of science, policy, and engineering experts who provide scientific and corporate support to our research groups to help with strategic planning and to maximize the impact of research results.

The SIU achieves this role by conducting strategic foresight and developing value propositions of our S&T activities. It also provides advice, coordination, and administrative oversight on NRCan agreements developed by our researchers.

Highlights

- Developed a 2023-28+ Science Plan for the Centre built on the value propositions of R&D investments:
  - Decarbonized and optimized industrial operations
  - Flexible, reliable, resilient and clean power grids
  - Energy efficient, dynamic and intelligent buildings
  - Empowered northern and remote community infrastructures
  - Informed evidence-based decision making for policy support
- Liaised regularly with the Office of the Chief Scientist on departmental science planning activities and with the programming staff at the Office of Energy Research and Development (OERD) to coordinate submissions reporting.
- Established an internal working group to position CEV's large-scale energy systems modeling activities. This group aims to identify the most relevant technologies and decarbonization pathways to help Canada achieve its GHG reduction targets and provide support to decision makers on effective energy policies.
- Assisted researchers in structuring contractual R&D and revenue generation agreements with the private sector, universities, international institutions, and other government departments.
- Represented CEV in various departmental working groups, such as:
  - Departmental Science Impact & Technology Transfer Working Group
  - NRCan's International Science, Technology and Innovation Interest Group (STIIG)
  - NRCan's Clean Energy Ministerial Planning Working Group
- Presented the research on social impacts of energy R&D science policy, building on the gender-based analysis plus (GBA+) strategies of the inclusion, diversity, equity and accessibility (IDEA) action plan, as part of the Centre's mandate to embrace diversity and equity, and to foster an inclusive workforce.
- Led NRCan's Foresight Community of Practice (CoP) to develop a strategy for the future of the CoP on how to increase its profile within NRCan.
- Presented CEV in the Cyber Energy Security Policy and Outreach (CESPO) Foresight group (an offshoot of the CoP).

Scientific Outreach

Our Scientific Outreach team provides strategic communication advisory services and puts in place actions towards promoting CEV's science and research. The team helps our scientific divisions maximize the impact of their R&D activities, while offering assistance with knowledge and technology transfer.

Areas of **Expertise**

- Advice on strategic communications for CEV's different divisions
- Development of communication products
- Management of social network platforms
- Dissemination of science and technology
- Arrangements for activities related to media relations
- Translation and revision
- Graphic design, photography and videography
- Document formatting
- Coordination of visits and corporate events

Highlights

- Produced and deployed the 2023-2028 Scientific Outreach Plan
- Participated in the production and promotion of CEV's Annual Report
- Created a communications kit for our Centre's participation in university career fairs
- Revised and translated standardized work objectives for certain positions at our Centre
- Produced technical posters for the presentation of test benches
- Designed the annual brochure for our Industrial Systems Optimization division's activities
- Produced case studies and fact sheets as project deliverables for our Greening Government Operations team
- Assured the linguistic quality of various documents and publications
- Created a communications strategy for increased visibility on social networks
- Produced media pitches during the year with several coverages like radio and TV interviews by our S&T experts

Some of **Our Collaborators**

Federal & Provincial Governments | Crown Corporations

Hydro Québec

Infrastructure Canada

National Defence | Défense nationale

ieso
Connecting Today.
Powering Tomorrow.

Global Affairs Canada | Affaires mondiales Canada

Québec

Canadian Forest Service | Service canadien des forêts

Canada
CNRC·NRC

Canadian Space Agency | Agence spatiale canadienne

Treasury Board of Canada Secretariat | Secrétariat du Conseil du Trésor du Canada

Universities

POLYTECHNIQUE MONTRÉAL
WORLD-CLASS ENGINEERING

Université Concordia University

UNIVERSITY OF WATERLOO

Private Companies

OPAL-RT

CEPTEK

EMERSON

BGI

RioTinto

Agencies | Associations | Organizations

CSA GROUP™

NASA

IEEE

Carrefour de modélisation énergétique | Energy Modelling Hub

ISGAN
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NATO OTAN

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iets

Clean Energy | Research | Innovation | Leadership

Science at the service of all Canadians

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