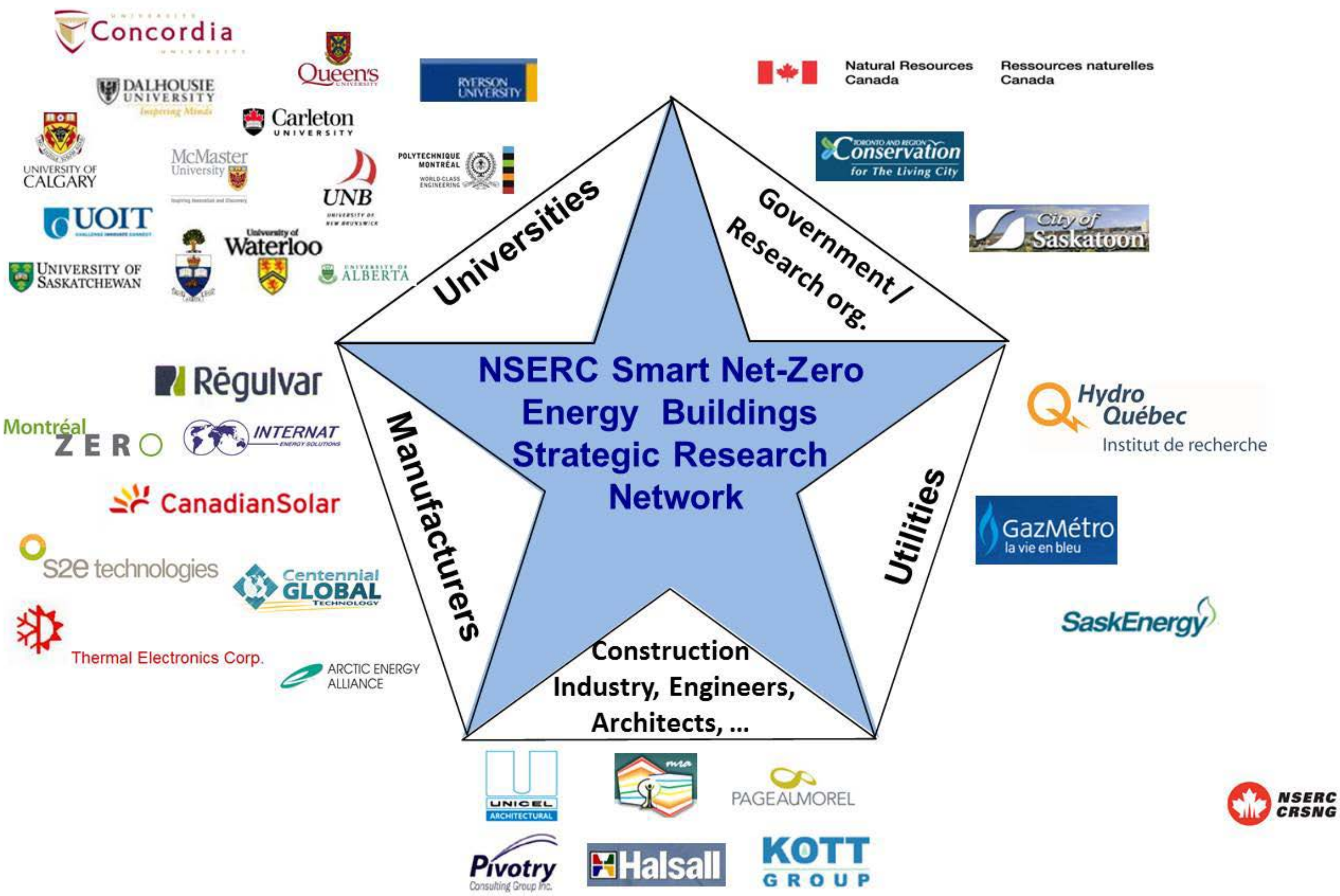
NSERC Smart Net-Zero Energy Buildings Strategic Research Network

Réseau de recherche stratégique du CRSNG sur les bâtiments intelligents à consommation énergétique nette zéro

Partnerships



www.solarbuildings.ca

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SNEBRN Executive Summary

Approximately one third of Canada's GHG emissions are attributed to building energy consumption. Buildings also account for about 53% of Canada's electricity consumption. They are largely responsible for the peaks in electricity demand associated with space heating, cooling, lighting and appliances. These peaks, if not reduced and shifted in time, will impose additional requirements to build new power plants. Without a major transformation in the way we design, build, and operate buildings, Canada cannot expect to meet its goals for reductions in greenhouse gas (GHG) emissions and for clean air in its cities. Mechanisms that allow the building to act as a net energy generating system and also shift peak demand can provide the basis for this transformation. At the same time, a comparison of the Canadian construction industry with that in other industrialized nations, points out the urgent need for Canadian innovations. This convergence of the need for innovation and the requirement for drastic reductions in energy use and GHG emissions provides a unique opportunity to transform the way we conceive buildings and their energy systems. This Network is a vital step along the way to achieving these goals. It links researchers from academia, industry and government in a united effort to develop the technologically advanced smart net-zero energy buildings (NZEBs) of the future. *A net-zero energy building is defined as one that, in an average year, produces as much energy (electrical plus thermal) from renewable energy sources as it consumes*.

The NSERC Smart Net-zero Energy Buildings strategic Research Network (SNEBRN), funded for 2011-2016 under the strategic research networks program of NSERC, partly builds on a previous network: the NSERC Solar Buildings Research Network (SBRN), which completed its program at the end of 2010. The Network has a total of about 30 researchers from 15 Canadian universities. In addition, there are partners from government and industry. Major partners include the CanmetENERGY laboratory of Natural Resources Canada and Hydro-Québec (Laboratoire des technologies de l'énergie). Industry partners include s2e and Kott Group, Régulvar (automation), Unicel (curtain walls) and Canadian Solar (PV manufacturer). SNEBRN is developing a strategy to effectively transfer the knowledge gained to designers, manufacturers, builders, and utilities. Estimated cash support from partners is about $2 M and there is also significant in-kind support. The amount from NSERC is about $5.2 M. Support from NRCan and other partners is expected to bring the total budget of the Network to about $7 M.

The **vision** of SNEBRN is to perform the research that will facilitate widespread adoption in key regions of Canada, by 2030, of optimized NZEB energy design and operation concepts suited to Canadian climatic conditions and construction practices. We aim to influence long-term national policy on the design of net-zero energy buildings and communities in association with our partners. The Network is training about 100 highly qualified personnel, thereby providing the leaders who will go on to join universities, industry and government and provide further innovations and work to overcome the barriers to our vision. **The main network goal is to develop optimal pathways for achieving zero average annual energy consumption at both the building and neighbourhood levels**. This will be achieved through combinations of dynamic building methods that integrate a number of technologies: building-integrated solar systems, high performance windows with active control of solar gains, short-term and seasonal thermal energy storage, heat pumps, combined heat and power technologies, and smart controls. We aim for simultaneous reduction of energy demands and shifting of peak loads through techniques such as predictive control at the building and neighbourhood scales. The Network is organized into five Themes, each Theme having two internationally-recognized researchers as co-leaders:

1. Integrated solar and HVAC systems for buildings (Steve Harrison / Ian Beausoleil Morrison).
2. Active building envelope systems and passive solar concepts (David Naylor / Paul Fazio).
3. Mid-to long-term thermal storage for buildings and communities. (Marc Rosen / Michel Bernier).
4. Smart building operating strategies (Andreas Athienitis / Radu Zmeureanu).
5. Technology transfer, design tools and input to national policy (Alan Fung / Sophie Hosatte).

The following describe a new state-of-the-art solar simulator-environmental chamber located at Concordia and a demonstration project – the JMSB building-integrated photovoltaic/thermal (BIPV/T) system.

SOLAR SIMULATOR - ENVIRONMENTAL CHAMBER

The Solar Simulator - Environmental Chamber laboratory is a unique facility located at Concordia University in downtown Montréal, Canada. It was built with a $4.6-million grant through the Knowledge Infrastructure Program jointly funded by the Government of Canada and Québec's Ministère du développement économique, de l'innovation et de l'exportation (MDEIE).

This unique facility enables accurate and repeatable testing of solar systems and advanced building envelopes under standard test conditions with full simulated sun and indoor plus outdoor conditions. It consists of two major systems:

1. **A large scale solar simulator** (Figure 1) is designed to reproduce natural sunlight in order to test various solar systems such as photovoltaic modules, photovoltaic/thermal modules such as the JMSB solar system (Figure 2), solar air collectors, solar water collectors and a **range of building-integrated solar systems**.

<u>Specific capabilities of solar simulator (testing at room conditions)</u>

- Consists of 8 special metal halide (MHG) lamps with an artificial sky to remove infrared radiation from lamps (lamps individually controlled and dimmable); meets the specifications of the relevant standards EN 12975:2006 and ISO 9806-1:1994.
- Collimation: approximately 80% of the emitted radiation lies in the range in which the incidence angle modifier of a regular flat plate collector varies by no more than 2%
- Test specimen size: up to 2.4 m x 3.2 m
- Less than ± 10% homogeneity (typically 5%), under 1-sun (depending on test specimen size)
- Customized solar air collector testing platform (able to test systems such as the JMSB BIPV/T system)

Figure 1. Concordia solar simulator testing BIPV/T air collector in horizontal position.

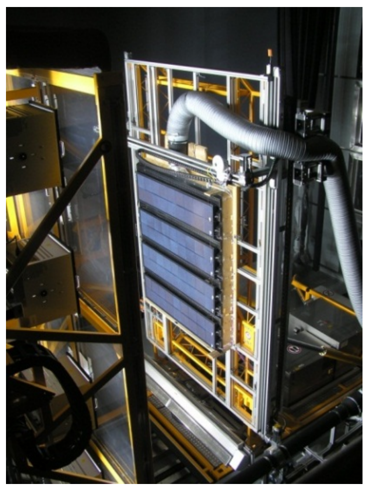

Figure 2. JMSB building-integrated photovoltaic/thermal system tested in vertical position.

Figure 3. Concordia mobile solar simulator with the two-storey high environmental chamber.

2. **A two-storey high environmental chamber with a mobile solar simulator lamp field** (Figure 3) that is used to test building technologies under controlled environmental conditions, by simulating exterior/interior microclimates (from arctic to desert).

<u>Specific capabilities of environmental chamber</u>

- Test building envelope components, such as advanced wall systems that may include solar energy utilization components, under a range of conditions from Arctic to desert
- Develop test methods and design standards for predictable relative hygrothermal performance and durability of different building envelope systems under various climatic conditions
- Test wall systems and rooms up to 7 m high, for hygrothermal and energy performance, including solar electricity and useful heat generation
- Temperature test range: -40° to 50°C , under specific conditions
- Temperature stability can be maintained within 1°C
- Relative humidity range between 20% – 95% (depends on temperature)
- Specially designed windows that allow through sunlight produced by a 6-lamp mobile solar simulator

JMSB BUILDING-INTEGRATED PHOTOVOLTAIC/THERMAL (BIPV/T) SYSTEM

A NSERC SOLAR BUILDINGS RESEARCH NETWORK DEMONSTRATION PROJECT

Funded by TEAM Demonstration Program of NRCan through CanmetENERGY Varennes

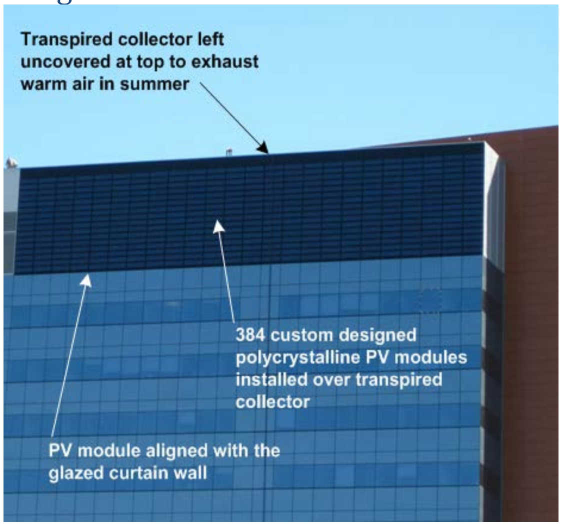

Fig 1. (a) Street view of JMSB solar system

(b) Close-up of the system

The John Molson School of Business (JMSB) building-integrated photovoltaic/thermal (BIPV/T) system is the first such system fully integrated with the building envelope, the heating and ventilation system and the architecture. The system (Fig. 2) consists of:

1. Custom photovoltaic panels, integrated on an Unglazed Transpired Collector (UTC) - a dark corrugated porous cladding
2. Unglazed Transpired Collector (UTC) - dark corrugated porous cladding through which fresh air is drawn into an insulated cavity (plenum) and then into the building as preheated ventilation air during the heating season.

The BIPV/T façade is close to south-facing and part of the building mechanical room, making this an optimal system. The 288 m² system generates solar electricity (up to 25 kilowatts) and solar heat (up to 75 kW of ventilation fresh air heating).

A variable speed fan draws solar-heated air through the pores of the UTC cladding which account for a porosity of about 1% (see Figure 2). Heat loss from the building is also by the air plenum. Dark-framed PV modules are mounted directly against the UTC cladding, covering about 70% of the total surface. In addition to the electricity generation, heat is actively drawn from the back of the PV modules (Figure 3) and the exposed UTC, contributing to heating the ventilation air, while cooling the panels. The system is being continuously monitored and **peak combined solar energy utilization efficiencies of up to 55%** have been measured.

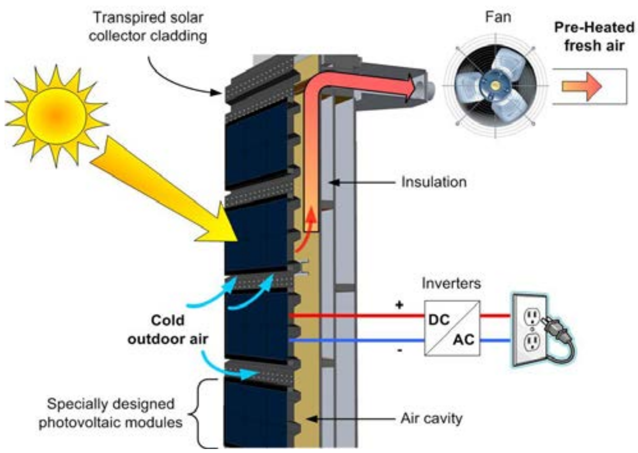

Fig. 2. Concept schematic for BIPV/T system

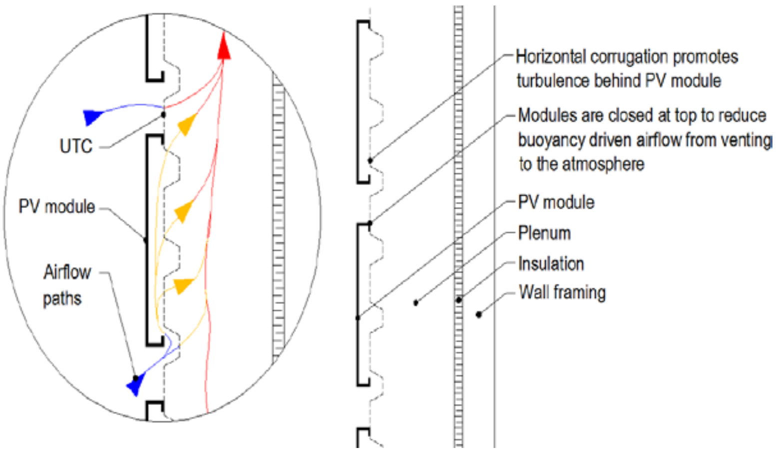

Fig. 3. Attachment of PV modules, and airflow paths around the bottom frame of a PV module and into the transpired collector

Partners: **Concordia (Director: Andreas Athienitis), Conserval, Day4 Energy, Schneider Electric (Xantrex), NRCan (Josef Ayoub)**

SNEBRN Researchers

Researchers	**University and department/program**	**Relevant Expertise**
Athienitis, Andreas *Scientific Director and Theme 4 co-leader*	Concordia, *Building Eng.*	Building operation dynamics and control, building-integrated photovoltaic/thermal systems, daylighting, passive solar design, design of NZEBs
Beausoleil-Morrison, Ian, *Theme 1 co-leader*	Carleton, *Mechanical Eng.*	Building performance simulation, building energy systems, micro-cogeneration, combined heat and power
Bernier, Michel, *Theme 3 co-leader*	Polytechnique Montréal *Mechanical Eng.*	HVAC systems, geothermal systems, solar thermal systems, heat pumps, building simulation, NZEB design
Chang, Liuchen	UNB *Electrical Eng.*	Load management in buildings, power electronics, electrical machines, motors, power system control
Collins, Michael	Waterloo *Mechanical Eng.*	Fenestration systems, photovoltaic/thermal systems, solar thermal systems, radiation heat transfer
Cotton, James	McMaster, *Mech. Eng.*	Thermal storage, CHP, heat transfer
Cruickshank, Cynthia	Carleton, *Mech. Eng.*	Solar thermal systems, thermal storage
Fazio, Paul *Theme 2 co-leader*	Concordia *Building Eng.*	Building envelope technologies, building physics, moisture transfer, curtain wall technology, policy
Flynn, Morris	Alberta, *Mech. Eng.*	Convection, hybrid ventilation
Fung, Alan	Ryerson *Mechanical Eng.*	Energy modeling, HVAC system and control, energy efficiency, cogeneration systems, design of NZEBs
Harrison, Steve, *Theme 1 co-leader*	Queen's *Mech. & Mat'l Eng.*	Solar thermal systems, heat pumps, thermal storage, solar cooling, technology transfer
Kennedy, Chris	Toronto, *Civil Eng.*	Sustainable communities, GHG emissions, quantitative urban planning
Kherani, Nazir	Toronto *Electrical Eng.*	Photovoltaic/thermal systems, thin films, amorphous silicon, crystalline silicon
Kummert, Michael	Ecole Polytech. *Mech. Eng.*	Building simulation and operation dynamics, HVAC
Lightstone, Marilyn	McMaster *Mechanical Eng.*	Computational fluid dynamics, turbulence, thermal storage modeling
Love, Jim	Calgary, *Architecture*	Daylighting, architecture, building simulation, building design
Naylor, David *Theme 2 co-leader*	Ryerson *Mechanical Eng.*	Fenestration systems, laser interferometry, convection, CFD, experimental methods in heat transfer & fluids
O'Brien, Liam	Carleton, *Civil and Environmental Eng*	Building performance simulation-supported design occupant behavior & building performance
Oosthuizen, Pat	Queen's, *Mechanical*	Convection, fuel cell systems, CFD applications
Pearce, Joshua	Queen's *Mech.& Mat'l Eng.*	Applied sustainability, energy efficiency, photovoltaics
Rosen, Marc *Theme 3 co-leader*	OIT, *Mech. Eng.*	Thermal storage, thermodynamics, cogeneration, HVAC systems
Rowlands, Ian	Waterloo, *Environment and Resource Studies*	Sustainability, environment and business, international political economy, electricity policy, climate change
Simonson, Carey	Saskatchewan *Mech. Eng.*	Building physics, HVAC systems, air-to-air energy recovery devices
Stathopoulos, Ted	Concordia, *Building Eng.*	Building envelope, wind effects on buildings, hybrid ventilation
Swan, Lucas	Dalhousie *Mech. Eng.*	Renewable energy storage, electric vehicles storage
Ugursal, Ismet	Dalhousie, *Mech. Eng.*	GHG emissions, community scale simulations
White, Mary Anne	Dalhousie, *Chemistry*	Materials science, thermodynamics, thermal conductivity, phase-change materials
Williamson, Sheldon	Concordia, *Elec. Eng.*	Electric vehicles (control), charging strategies
Wright, John	Waterloo, *Mech. Eng.*	Solar Optics, fenestration, shading, convection, building simulation
Zmeureanu, Radu *Theme 4 co-leader*	Concordia, *Building Eng.*	Building simulation, energy efficiency, HVAC systems, building operation, continuous commissioning, comfort