Centre for Zero Energy Building Studies

MISSION

To reduce the environmental impact of buildings while enhancing their safety and comfort.

Cutting-edge research on zero energy buildings

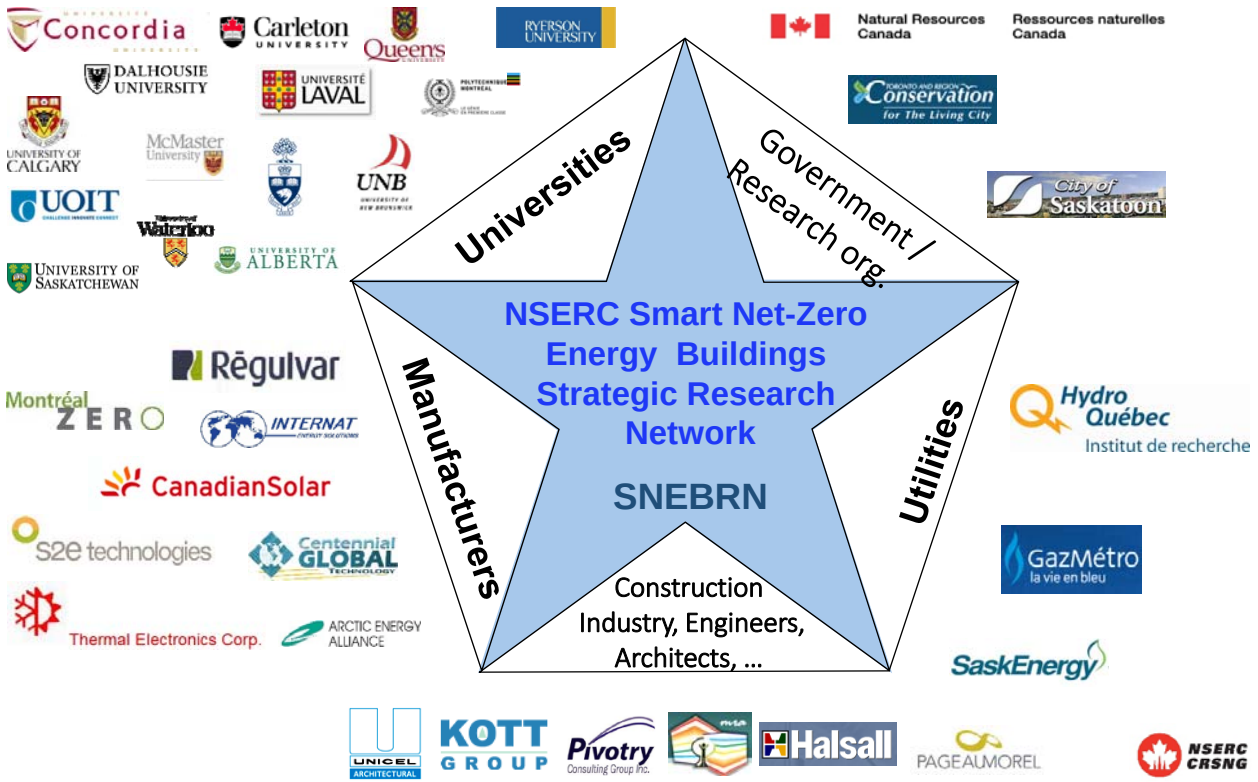
CZEBS website:

www.concordia.ca/research/zero-energy-building.html

Centre for Zero Energy Building Studies
Centre d'études sur le bâtiment
à consommation nulle d'énergie

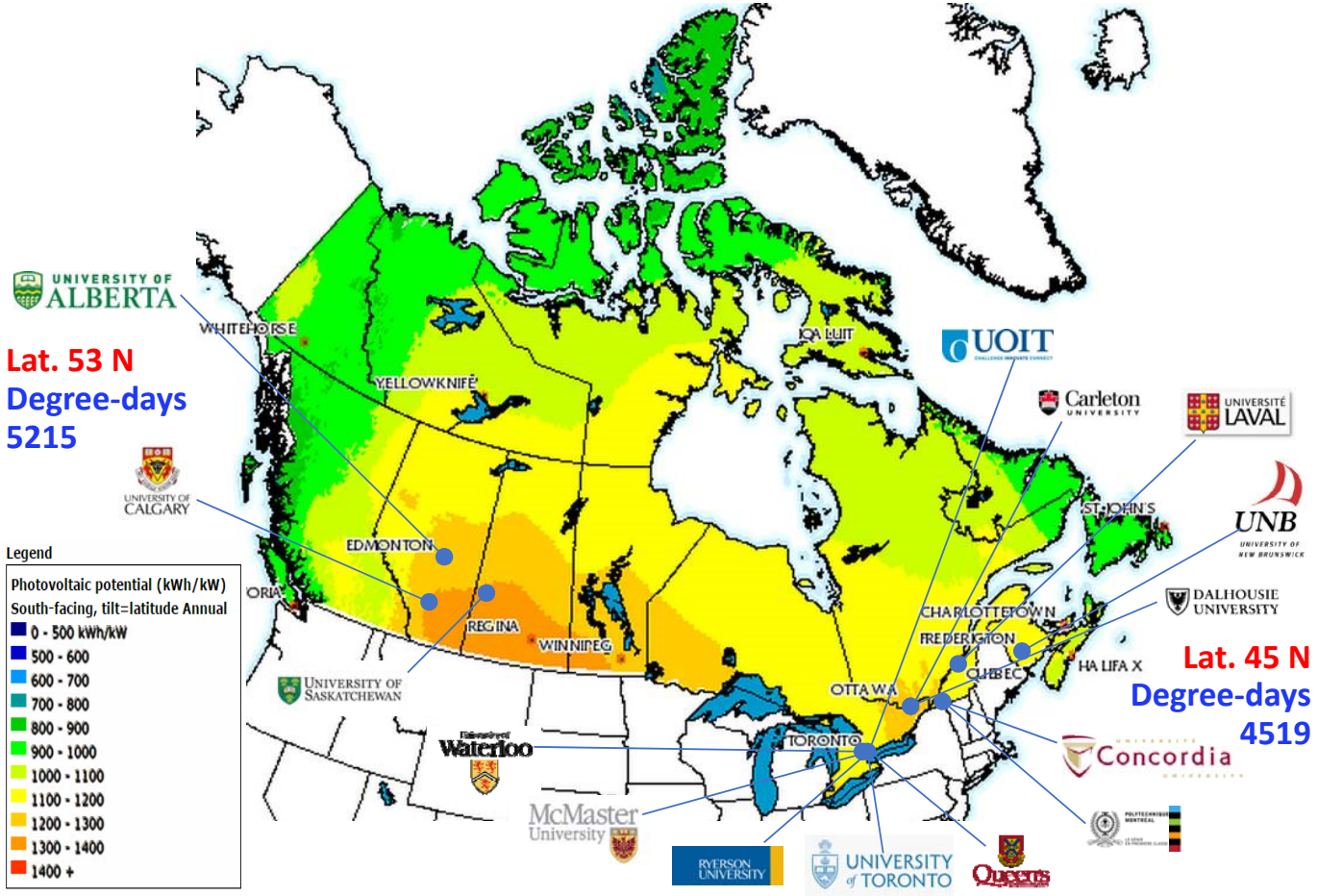
PARTNERS OF CONCORDIA-LED NSERC STRATEGIC NETWORK

CZEBS is the leading and major research group in SNEBRN.



CANADIAN PARTNERS OF CONCORDIA-LED SNEBRN

- Much of Canada is quite **sunny, with cold winters**
- Ground temperatures of 6-10°C in most populated areas (lat. 41-53 N)



Map of PV potential in Canada, with location of 15 SNEBRN Network Universities

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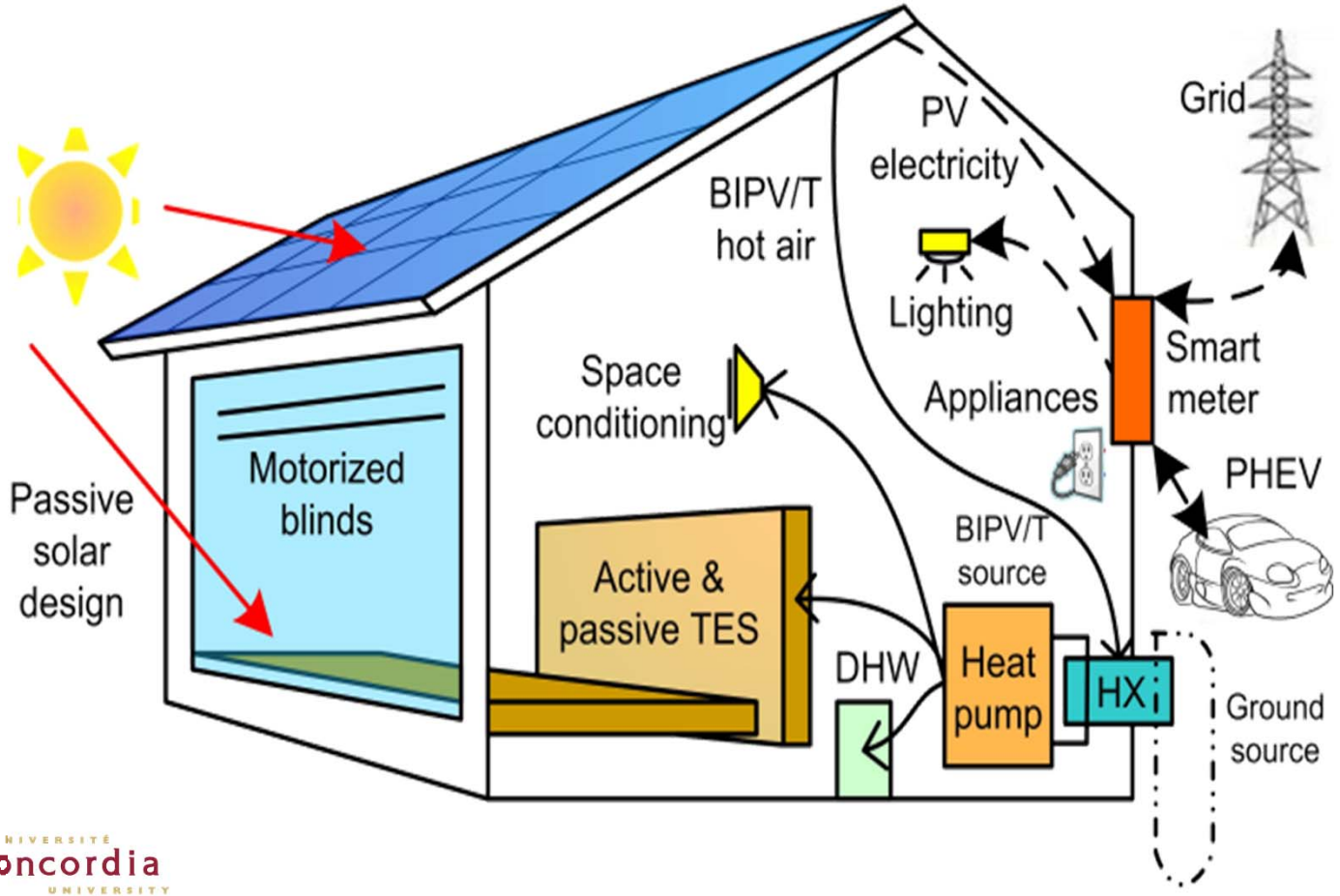
NET ZERO ENERGY BUILDING CONCEPT

Optimal combination of technologies towards net zero energy



Integrated approach to **energy efficiency and passive design**

Integrated design & operation

Solar optimization requires o**ptimal design of building form**

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ECOTERRA EQUILIBRIUM HOUSE

Roof BIPV/T system
- 2.84 kW PV, grid-tied
- Heat recovered is used to heat water (through air/water heat exchanger) and/or a hollow core concrete slab

Passive solar design
Optimized triple glazed windows and thermal mass floor

Ground-source heat pump

EcoTerra House
Demonstration project with design innovations including fully integrated BIPV/T system, an energy concept ***combining*** passive and active systems.

Major outputs
Novel technologies and personnel trained in high quality relevant engineering research.

EcoTerra EQuilibrium House (Alouette Homes), SBRN Network; IEA SHC Task 40 / ECBCS Annex 52 case study

Project Partners: Alouette Homes, NRCan, CMHC, Hydro Québec, Rēgulvar, Concordia

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JOHN MOLSON SCHOOL OF BUSINESS (JMSB) BUILDING – BUILDING INTEGRATED PHOTOVOLTAIC/THERMAL (BIPV/T) SYSTEM

The first BIPV/T system that is fully integrated with the façade, the architecture and the ventilation system.

Demonstrates a novel building envelope design of façades and roofs as active systems producing electricity and useful heat compared to traditional passive envelopes that lose heat in winter and gain heat in summer.

Close-up view of PV panels over UTC* cladding

BIPV/T system integrated into the façade of the JMSB building

BIPV/T system seen during JMSB building construction from downtown Montreal

* UTC: unglazed transpired collectors

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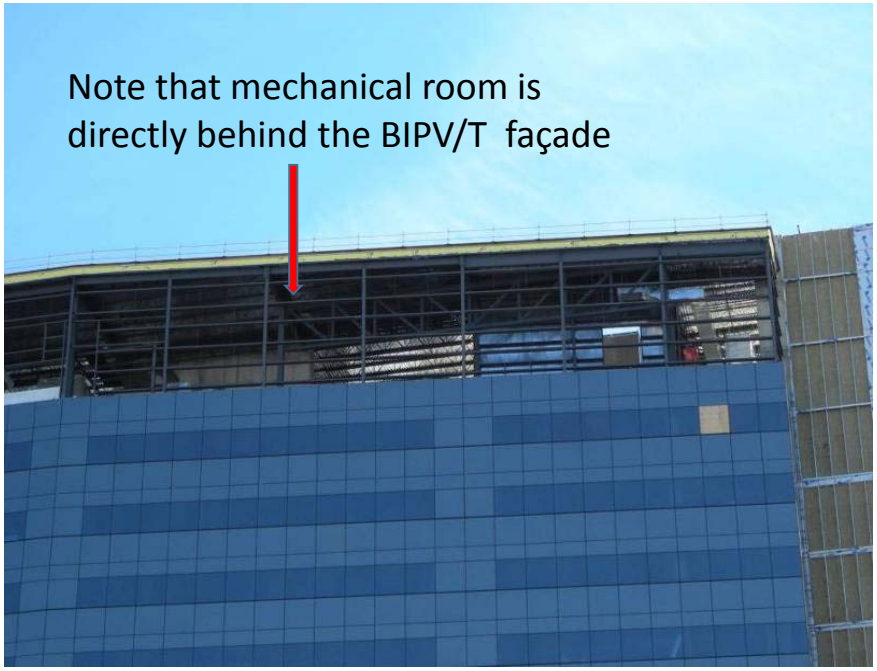
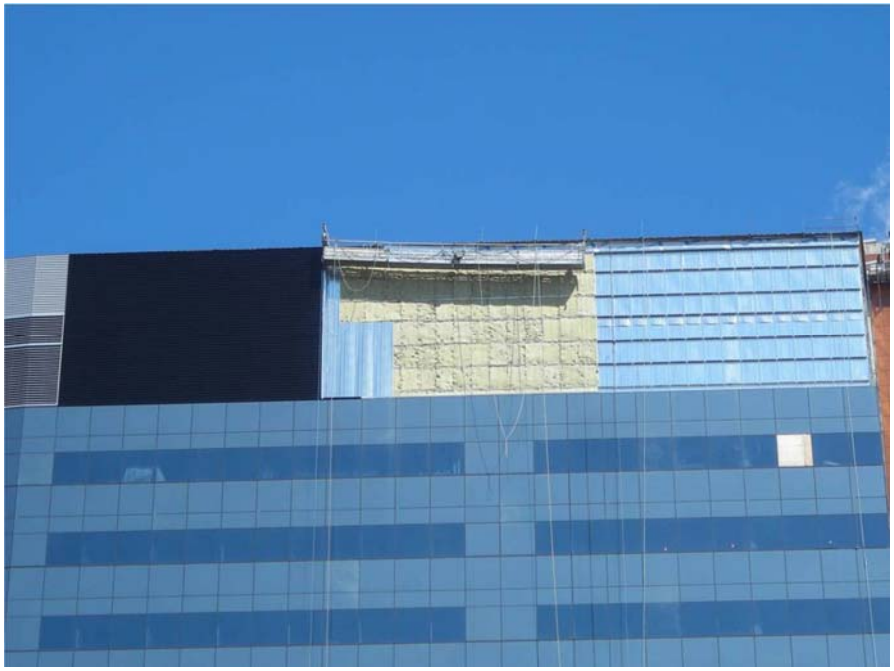
JMSB BIPV/T SYSTEM - CONSTRUCTION

300 m² BIPV/T collector area, 70% covered with PV panels.

The system was designed, fabricated, installed and commissioned in 2010.

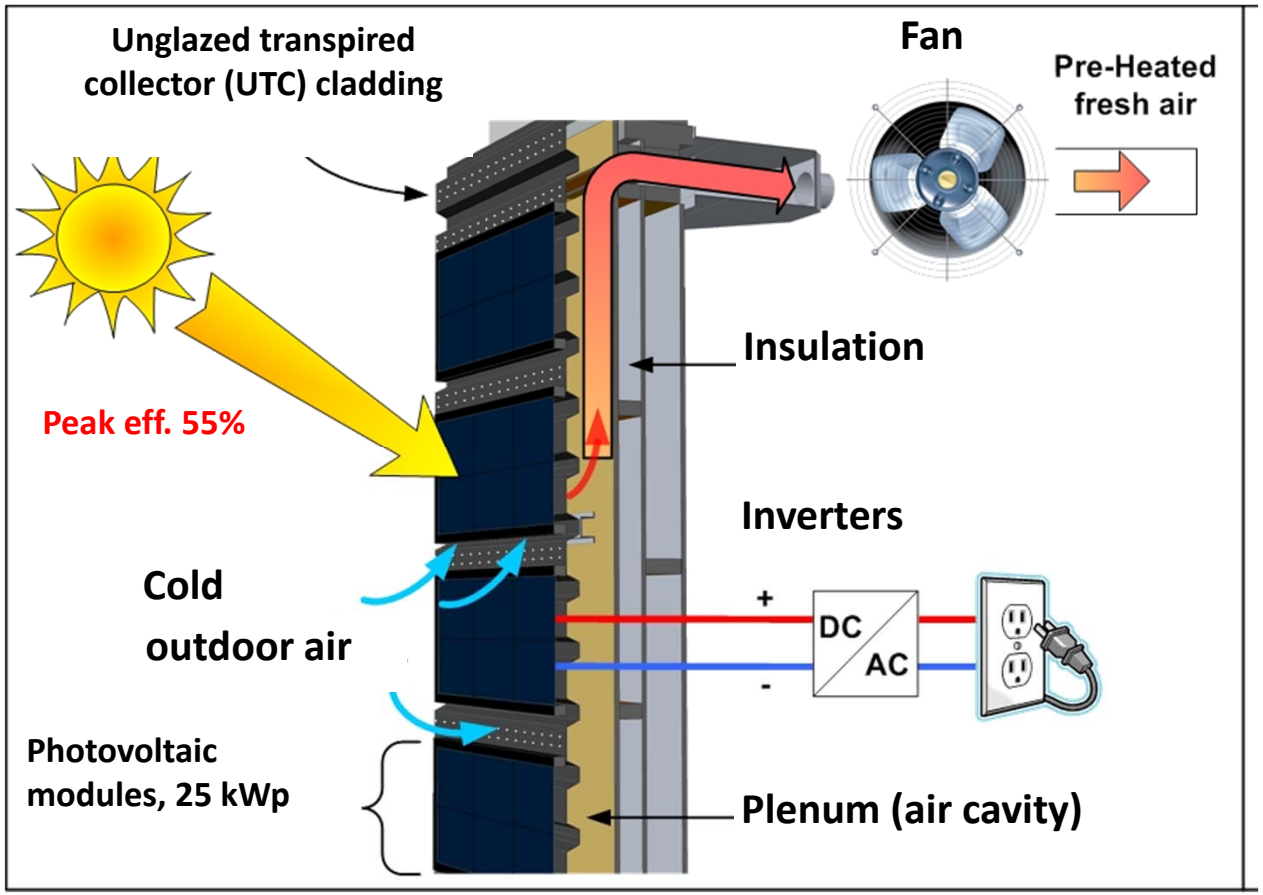


System with only the structural steel frame installed



System with a finished portion of UTC, thermal insulation and metal sheathing

JMSB BIPV/T SYSTEM



- Preheated fresh air: 4.7m³/s (10,000 CFM) with a temperature increase up to 25°C

- Co-generates solar electricity (25 kW peak) and solar heat (75 kW peak)

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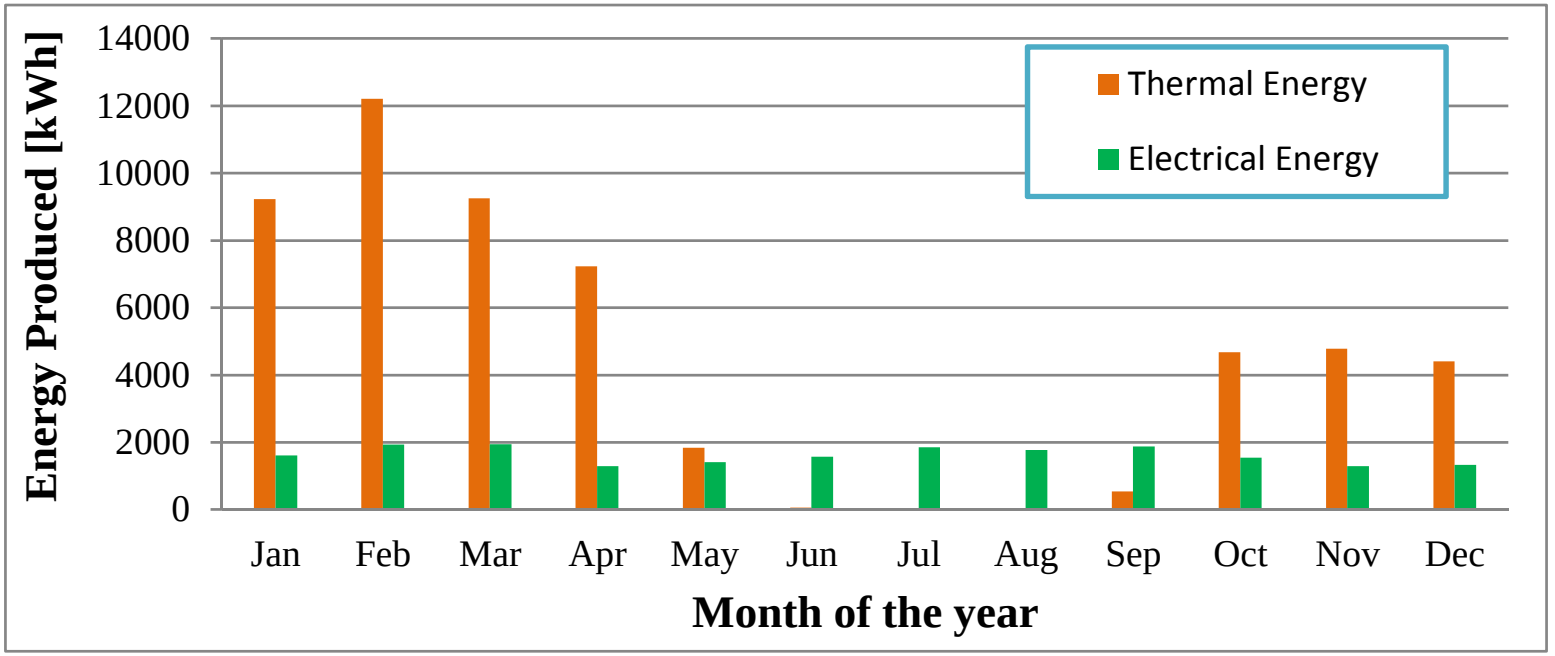
JMSB BIPV/T SYSTEM PERFORMANCE

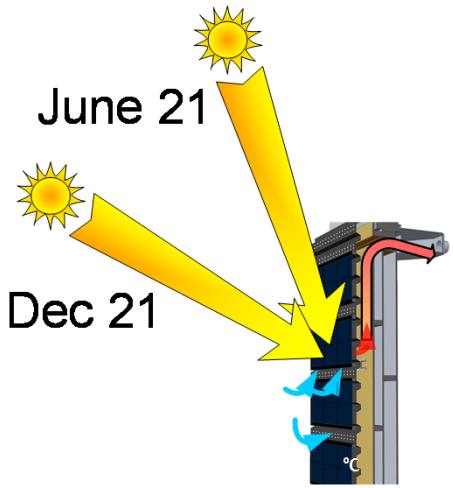
- Co-generates solar electricity (25 kW peak) and solar heat (75 kW peak).
- Combined electrical-thermal efficiency of 37-55%.
- **Annual energy: 20 MWh of electricity and 55 MWh of heat utilization**



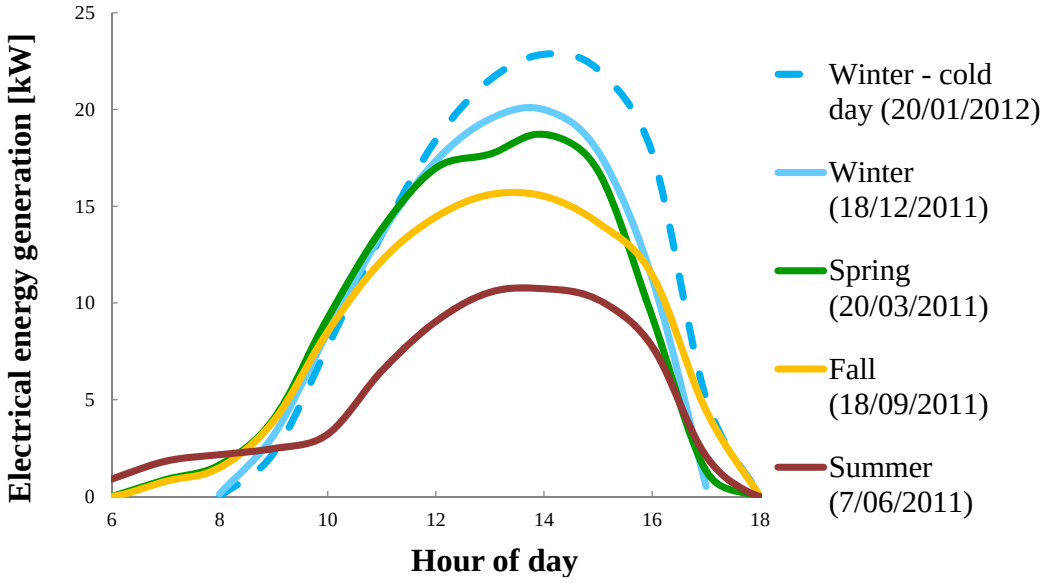
Monthly thermal and electrical energy generation during April 2011 – March 2012

JMSB BIPV/T SYSTEM PERFORMANCE

The 364 PV modules installed on the JMSB BIPV/T system generate solar electricity year-round with peak production occurring during winter when the sun is low.



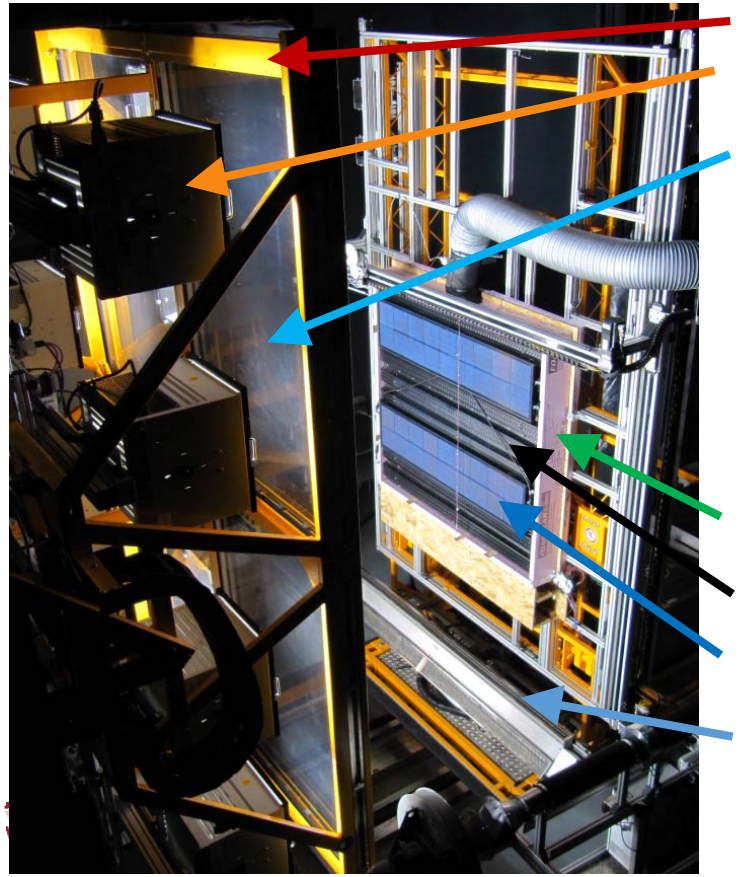
Solar heat is collected and preheats 4.7 m3/s (10,000 CFM) of fresh air with a temperature increase up to 25°C during winter and parts of spring and fall.



Daily electricity generation profiles of typical seasonal clear days. Peak production occurs in winter days when the sun is low.

EXPERIMENTAL TESTING OF JMSB BIPV/T SYSTEM

The JMSB BIPV/T system was tested with a full-scale mock-up in the Paul Fazio Solar Simulator - Environmental Chamber Lab to optimize the electrical and thermal efficiencies.



Solar Simulator

- 8 special metal halide global (MHG) lamps simulating solar spectrum
- **Artificial sky**

  Infrared radiation from the hot lamps is blocked from reaching the sample surface by two layers of glass which are kept cool by cold air passing between them

- Lamps individually dimmable to provide 0.85 to 1.15 sun on the sample surface, with less than ± 5% homogeneity variation.

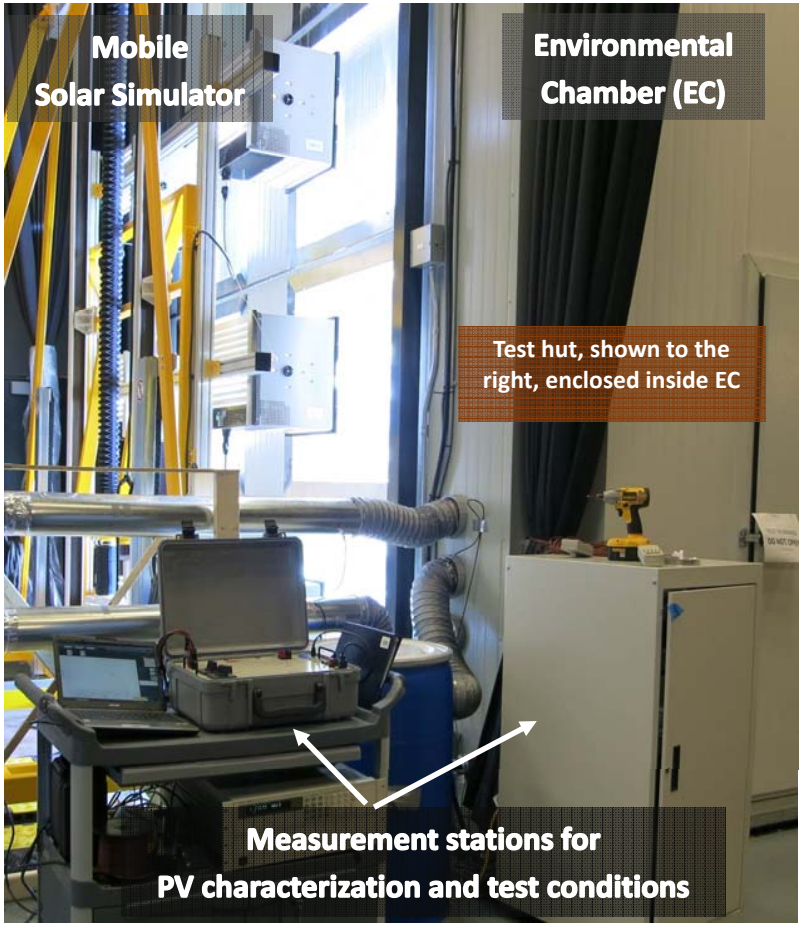
JMSB BIPV/T sample under testing

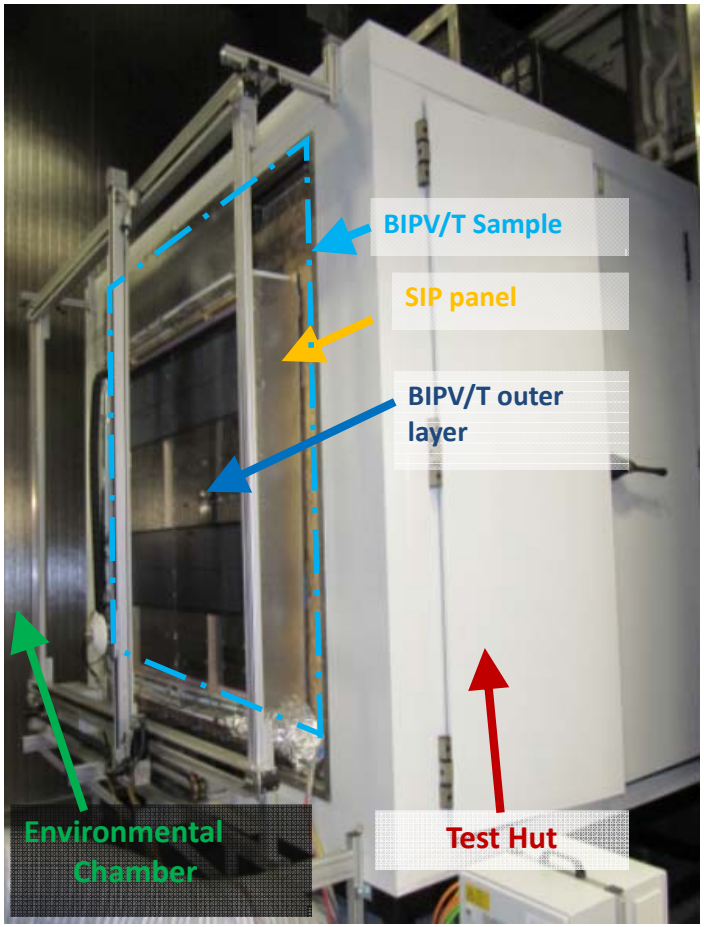
- **Unglazed Transpired Collector (UTC)**
- **Photovoltaic panels on top of UTC**
- **Artificial wind**

  Linear fans blow air uniformly over the sample surface

EXPERIMENTAL TESTING OF JMSB BIPV/T SYSTEM

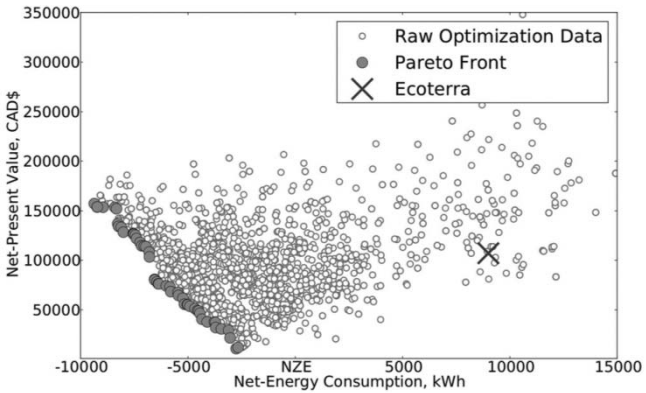
The JMSB BIPV/T system design was extended for an application suitable for extreme cold climates found in locations such as Iqaluit, Nunavut in the Canadian North. Several alternative BIPV/T configurations were evaluated in the SSEC lab.



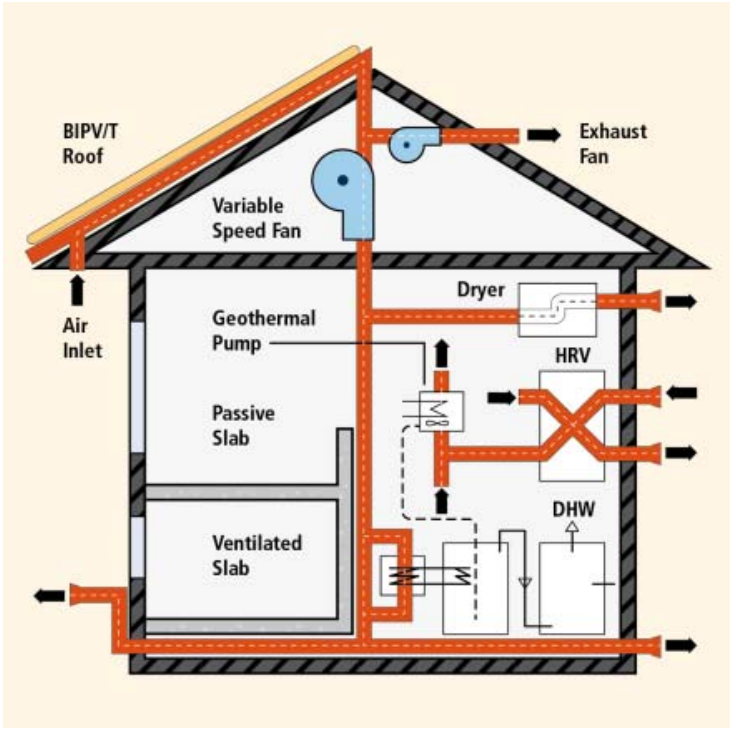


BEST PAPER AWARD BASED ON ECOTERRA HOUSE DESIGN

The awarded paper appeared in ASHRAE Trans. (2014) and included optimization approaches used to identify pathways to significantly reduce the net-present cost and net-energy consumption of homes. Two redesign case-studies were explored: (1) design changes that did not require major renovation to the archetype EcoTerra house; and (2) a complete redesign to achieve NZE. The recently reduced cost of high efficiency PV modules has made it possible to achieve NZE.



Multi-objective redesign of EcoTerra home



EcoTerra system schematic

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SOLAR SIMULATOR

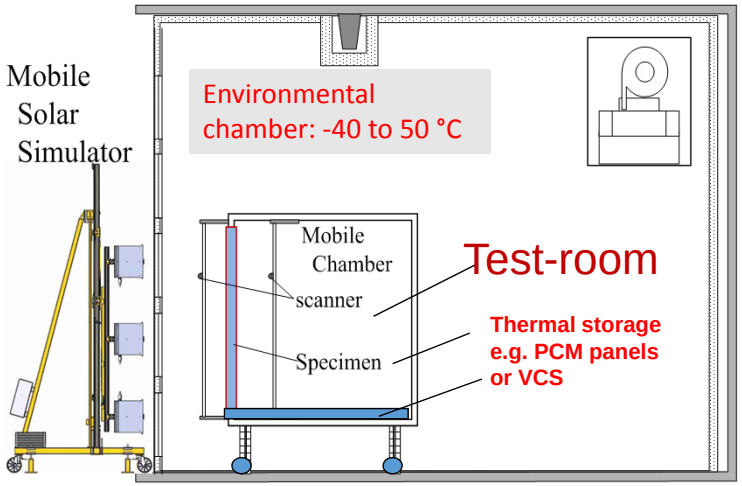
Designed for testing and evaluating solar technologies such as PV modules, PV/thermal, solar air/water collectors and a **range of building-integrated solar systems**.

- 8 special metal halide global (MHG) lamps simulating solar spectrum (lamps individually controlled & dimmable)
- Artificial sky to remove infrared radiation from lamps
- Homogeneity: less than ± 5% variation under 0.85 to 1.15 sun

ENVIRONMENTAL CHAMBER AND MOBILE SOLAR SIMULATOR

A two-story environmental chamber with a mobile solar simulator lamp field used to test building technologies under controlled environmental conditions (from arctic to desert).

- Temperature: -40 to +50°C
- Relative humidity: 20 to 95%
- Sunlight produced by a 6-lamp mobile solar simulator enters chamber via windows.



BOUNDARY-LAYER WIND TUNNEL LAB

Above: The boundary layer wind tunnel (BLWT) from the back end.

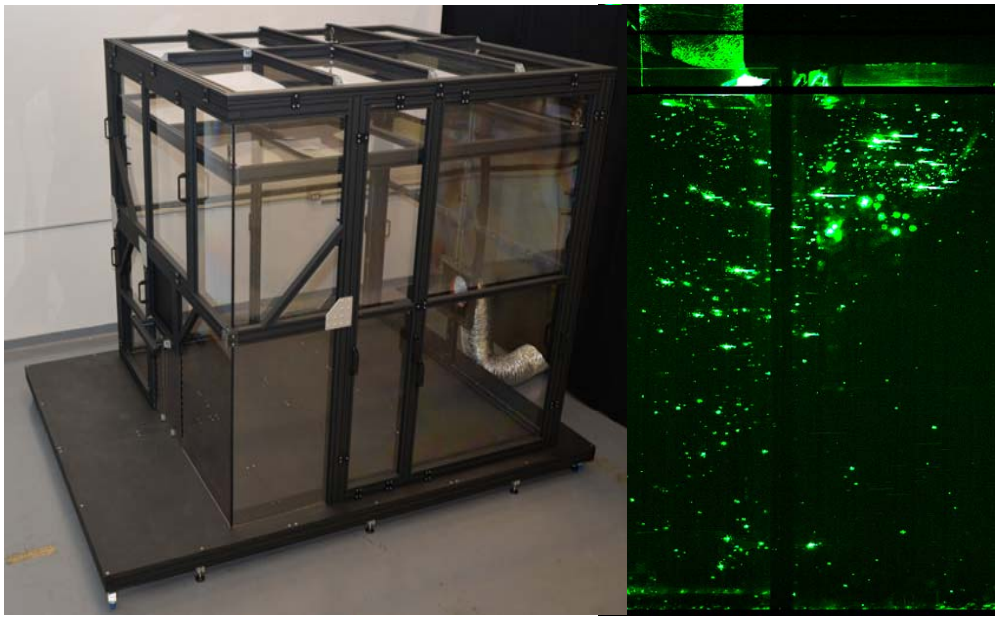
The effect of wind on building models is reproduced in a boundary layer wind tunnel. This allows for the measurement of: mean and fluctuating wind loads on buildings, air flow around individual and groups of tall buildings, environmental pedestrian level wind loads, and effluent dispersion (contamination of buildings by smoke and building exhaust from stacks). Computational evaluation of wind effects on buildings can also carried out.

Right: Smoke generated around scaled model buildings inside BLWT for studying contaminant dispersions within an urban environment.

THE “CUBE” - BUILDING ENVIRONMENT TEST CHAMBER

This chamber was designed for studying the infiltration characteristics of doors equipped with air curtains with the aim of evaluating their potential energy savings in commercial buildings. PIV (Particle Image Velocimetry) measurements are used to digitize the airflow under different conditions. The setup was designed with extendable partitions to form a scaled down model of a building with up to 8 zones.

The setup will be used in experimental and simulation projects for research in areas of building fire safety and smoke management, building airflow and thermal management, forecasting/hybrid building simulations using weather forecasting models, high-rise building fire protection, modeling and sub-scale experiments for building fire smoke management, real-time building simulations, and computational fluid dynamics (CFD) applied to building designs.

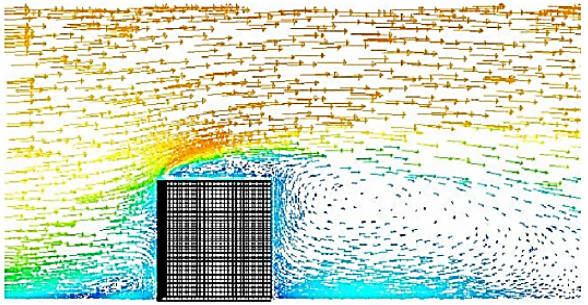


Newly constructed experimental chamber and a PIV field of view (Sponsored by AMCA)

BUILDING ENVELOPE PERFORMANCE

Buildings studied for wind-driven rain

Disdrometer



Simulation of air flow patterns over a building

Lab testing, field monitoring and computer simulations are used to study wind-driven rain and runoff, hygrothermal performance of innovative wood-frame constructions, dynamic effects of thermal bridges, durable building envelopes for future climates, advanced building façade, and high performance housing

for the Canadian North.

Arctic house with hot roof design changed to an unventilated cold roof, Iqaluit, Nunavut.

PAUL FAZIO: PHILANTHROPIST AND BUILDING ENGINEERING VISIONARY

Left to right: Ahmad Kayello (PhD student of Paul Fazio), Andreas Athienitis, Lucy Fazio (wife of the late Paul Fazio), Amir Asif (current Dean of ENCS) and Don Tadeo (former Dean of ENCS)

On September 28, 2014, Building Engineering in Canada lost its key founder and CZEBS lost one of its most respected researchers, Paul Fazio.

Paul's friends, colleagues and family gathered on May 7, 2015 for a ceremony in the EV building to celebrate his achievements, including the endowment he created for student support in partnership with ENCS, and to announce the naming of the Paul Fazio Solar Simulator – Environmental Chamber Lab.

Paul Fazio receiving the Order of Canada from Governor General Michaëlle Jean in 2007.

INTERNATIONAL SYMPOSIUM AND EXPERT FORUM ORGANIZED BY CZEBS

Photo by Marc Bourcier, Concordia

CZEBS-iiSBE-APEC Net Zero Built Environment 2015 Symposium: ***Smart Net Zero Resilient Buildings and Communities***, Concordia University, August 20-21.

Over 70 researchers, government and industry representatives from 16 countries gathered over 2 days at Concordia University to discuss a broad scope of topics related to Smart Net Zero Resilient Buildings and Communities. The symposium consisted of panel discussions of eight themes relating to net zero energy buildings, including: building design, building case studies, communities, standards and incentive measures, architecture and engineering education, enabling technologies and renewable energy integration.

Experts Research Forum on Intelligent Building, Concordia University, April 21, 2015

Organized in collaboration with CanmetENERGY-NRCan and Concordia University, the meeting aimed to discuss the state-of-the-art in intelligent building technology and to identify the short, medium and long-term research needs and key partnerships required to deliver buildings that can self-diagnose and self-optimize, in presentations and brain-storming sessions focused on automated building performance assessment, advanced dynamic control and responsive buildings to future smart grid. Close to 50 people, including members and students of CZEBS, participated in the event.

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PUBLICATIONS

Since the senate approval in 2012, CZEBS has published:

- 75 referred journal papers,
- 101 referred conference papers,
- 5 patents submitted, and,
- many invited keynotes and speakers, research reports, etc.

Recent best publication awards:

- A best paper award was given by ASHRAE for a paper authored by Scott Bucking (former PhD student) and his supervisors Dr. Athienitis and Dr. Zmeureanu.

- An Excellent Poster Award was awarded by AOSFST in 2015 (Asia-Oceania Symposium on Fire Science and Technology) for a poster authored by Cheng-Chun Lin and his supervisor Dr. Wang.

CZEBS GRADUATE STUDENTS

CZEBS students participate in seminars and training events, enhancing their academic knowledge. Each year, students present their work at two workshops.

CZEBS director, Andreas Athienitis, started the Spring 2015 CZEBS Workshop on May 4th.

Graduates of CZEBS are in high demand.

For example, four doctoral graduates obtained faculty positions (tenure-track).

- Liam (William) O'Brien, Carleton U, Architectural Conservation and Sustainability Engineering
- Scott Bucking, Carleton U, Civil Engineering and Architecture
- Caroline Hachem-Vermette, U of Calgary, Architecture / Planning
- Yuxiang Chen, U of Alberta, Civil Engineering / Building Science

Carleton UNIVERSITY

UNIVERSITY OF CALGARY

UNIVERSITY OF ALBERTA

Concordia UNIVERSITY

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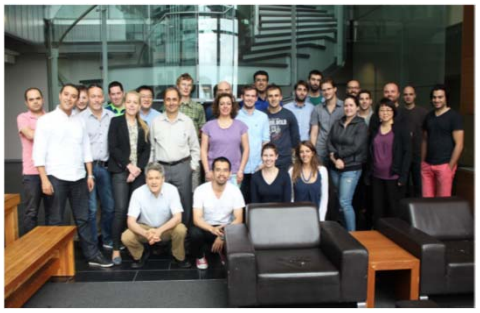
STUDENT TRAINING



SNEBRN/IABP PhD Summer School

From August 20-28, 2014, 21 students from Brazil, Canada, Denmark, Estonia, Italy, Romania, and Sweden attended the PhD Summer School *Net-Zero Energy Building Modelling and Design for High Performance,* held at Concordia University. The course focused on the science of net zero energy design and its place in the future of building engineering.

NSERC/Hydro-Quebec IRC (Industry Research Chair) Workshop June 1, 2015

The workshop was hosted at CanmetEnergy in Varennes, Québec to review the status of the IRC projects and plan for upcoming tasks. Seven CZEBS graduate students (Jennifer Date, Vasken Dermardiros, Edvinas Bigaila, Stratos Rounis, Sophie Yuan, Tassos Papachristou, and Zissis Ioannidis) presented progresses and results in subprojects. A tour of the CanmetEnergy research facilities followed.

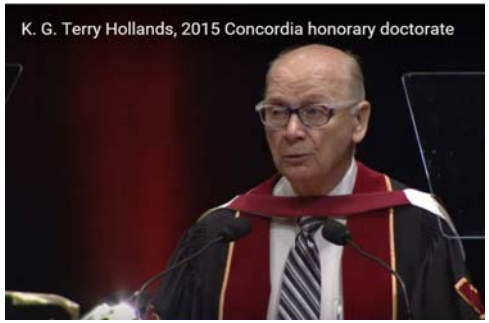
SIMEB (Simulation énergétique des bâtiments) Training, June 2, 2015

A full day training was given at Concordia by Dr. Ahmed Daoud and Ms. Karine Lavigne of Institut de recherche d'Hydro-Québec (IREQ). Fifteen CZEBS graduate students and several undergraduate internship students attended the training. The aim was to include exercises, case studies and a short section on EnergyPlus for students to have hands-on experience with the specialized building energy simulation software developed by IREQ and with building simulation programs in general.

RECOGNITIONS

Dr. Theodore Stathopoulos was awarded an honorary doctorate from Eindhoven University of Technology (TU/e) in The Netherlands, for his lifelong contribution as a top researcher in the field of wind engineering and building aerodynamics on April 29, 2015. A symposium was also held in his honour. He has been appointed as Distinguished Professor by TUE for 2015 to 2019. Beijing Jiaotong University, China also appointed Dr. Stathopoulos as a Visiting Professor in the "111 Talents" Project for 2014-2019.

Dr. Terry Hollands received an honorary doctorate from Concordia University for his outstanding contributions to the field of solar energy, on June 10, 2015. In more than a quarter-century at the University of Waterloo, Hollands excelled in his training of graduate students, many of whom went on to make a mark in the field of solar energy. Currently, Hollands chairs the board of the NSERC Smart Net-zero Energy Buildings Strategic Research Network (SNEBRN).



Dr. Radu Zmeureanu received the 2015 Academic Leadership Award

Dr. Zmeureanu received an Academic Leadership Award in June 2015 for his exceptional leadership abilities through the realization of significant administrative accomplishments at Concordia.

RECENT MEDIA REPORTS

Radu Zmeureanu talks to Le Devoir about what makes a "smart building"

Dr. Zmeureanu discussed the importance of air distribution in a room using displacement ventilation and explained what makes a "smart building", in an interview with Le Devoir, in April 2014. He and his colleagues were testing a new system at the Concordia Centre for Structural and Functional Genomics that evaluated the performance of building components as ventilation, heating and electricity in order to enable measures that can improve efficiency.

Theodore Stathopoulos and PhD student, Mauricio Chavez were featured by Télé-Quebec, March 18, 2014.

They explained the research they carried out on the effects of wind on buildings. Dr. Stathopoulos explained some commonly occurring mischiefs and difficulties caused by wind, such as a gust blowing an umbrella inside-out on the street corner and how research can improve the situations.

“Montreal’s bright future” – a media interview of Andreas Athienitis

In the interview published in the Montreal Gazette, March 6, 2015, Dr. Athienitis discussed the solar power utilization for the cold climate of Montreal, elaborated on the innovative research on integrated technologies that enable buildings to generate, manage, and store energy on-site, or export it to the grid optimally to reduce peak electricity demands. Costa Kapsis, a PhD student of Athienitis, demonstrated the testing of a semi-transparent photovoltaic (STPV) panel on the solar simulator and talked about integrating STPV into building façades to capture electricity, heating energy and natural lighting.

“Un froid de -40 °C recréé en laboratoire pour tester des maisons nordiques.”

Télé-Québec produced a television segment that was aired on March 25, 2014, about research conducted in the SSEC lab. Master students Ahmad Kayello and Daniel Baril, supervised by the late Paul Fazio, investigated structures that were designed to withstand the frigid cold of Canada's North.

INTERNATIONAL COLLABORATION

Collaboration discussions with Dr. Christophe Ménézo, of the Thermal Centre of Lyon, France, Head of INSA/EDF (Institut National des Sciences Appliquées de Lyon Lyon, France)

Dr. Menezo visited CZEBS on Jan. 26, Apr. 30 and Aug. 20, 2015. Discussions took place focusing on topics for collaboration including the application of BIPV, thermal, and lighting to double façade applications.

Photo to the left: Dr. Ménézo (right) and his graduate student (left), and Dr. Athienitis (middle) in front of the JMSB BIPV/T installation.

Collaboration with Dr. Soteris Kalogirou of Cyprus University of Technology (CUT) on solar energy integration in buildings and higher education

Dr. Kalogirou is also the current Editor in Chief of *Renewable Energy*, Deputy Editor-in-Chief of *Energy*, and Editorial Board Member of 12 other international scientific journals.

In August 2015, Dr. Kalogirou presented overviews and main results of many current research projects on the optimal utilization of solar and other renewable resources for buildings and built environments. This was followed by discussions about international collaborative funding and actions to initiate collaborations between CUT and CZEBS in the area of building integrated solar energy utilization and of joint education programs for HQPs.

NATIONAL AND INTERNATIONAL COLLABORATION

Collaboration with SQI-Directions immobilières Centre-Ville de Montréal

BIPV/T façade renovation project for the Montreal municipal courthouse (Palais de Justice de Montreal).

Air Movement and Control Association (AMCA)

A research project sponsored by AMCA investigates the infiltration reductions benefiting from the application of air curtains and their energy saving impact on commercial buildings in comparison to single doors and vestibules.

Collaboration Asia-Pacific Economic Cooperation (APEC) researchers

Develop mutually interested research areas and projects for future collaborations with Dr. Wei Pan of University of Hong Kong, Dr. Chun Ping Gao of Building and Construction Authority Singapore, and Drs. Dongwoo Cho and Suwon Song of Korea Institute of Civil Engineering & Building Technology.

Collaboration with Environment Canada

A weather station has been installed on the rooftop of the Concordia EV building measuring temperatures, relative humidity, wind speed and direction, rain fall and raindrop size distribution, and horizontal global solar radiation and providing data for building automation system and research needs.

CZEBS Website

www.concordia.ca/research/zero-energy-building.html