

CZEBS - Centre for Zero Energy Building Studies

OVERVIEW - December 2020

Andreas Athienitis, FCAE, FIBPSA, FASHRAE

Director, Concordia Centre for Zero Energy Building Studies (CZEBS)
NSERC/Hydro-Québec Industrial Chair & Concordia Chair
Professor, BCEE Dept.



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

CZEB OVERVIEW



The mission of the CZEB is to reduce the environmental impact of buildings while enhancing their safety and comfort by advancing knowledge through research and the building engineering discipline in Canada, by enriching the learning and research experience of students, and by assisting industry in implementing research results and innovations.

Members distinctions include: 3 Fellows of CAE, 1 of ASHRAE, 2 of IBPSA, 1 of ASCE , 3 Concordia Chairs

FULL MEMBERS



Andreas Athienitis

*Director of CZEB
 Professor*



Radu Zmeureanu

Professor



Theodore
 Stathopoulos

Professor



Liangzhu (Leon)
 Wang

Associate Professor



Hua Ge

Associate Professor



Bruno Lee

Assistant Professor

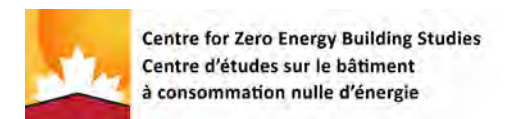


José Candanedo

Affiliate Professor

Concordia University Senate approved CZEB in January 2012

Above photos provided by David Ward, Concordia University



Concordia leadership in sustainable buildings

- Led **two NSERC strategic research networks** in solar and smart net-zero energy buildings - **\$15 M over the period 2005 – 2017** with about 30 researchers from 15 universities and 30 industry/govt sector partners. Canadian leadership of **IEA SHC Task 40 on NZEBs** through partnership with CanmetENERGY (renewed collaboration agreement for 10 years).
- **Leading edge demonstration projects:** EcoTerra EQUilibrium house (2007), JMSB solar system - Concordia (2009), Varennes Library (2016 -).
- **NSERC/Hydro Quebec Industrial Chair** (\$4m 2013 – 23). Solar Simulator – Environmental Chamber Lab (\$5 M). **Lafontaine tunnel project \$0.7 M.**
- **Contributed/led initiative for Canada Excellence Research Chair** in next-gen cities (Dr. Ursula Eicker) – \$10M for 2019-2026. Dr. Mohamed Ouf – cluster hire in BCEE.
- CAE Roadmap **Ultra-low Energy Built Environment with Deep Integration of Renewables until 2050;** 2019-22 - Technical Symposium 2020 Montreal.
- CFI grant (\$1.3M – the only one at Concordia in that year) was received by a CZEBS team led by Dr. Hua Ge in 2017 for “Concordia Field Research Facility for Buildings of the Future”.
- **Liangzhu Wang (PI), H. Ge and R. Zmeureanu** received a NSERC grant of \$540k: 2019/03 – 2022/02. “Assessment and mitigation of summertime overheating conditions in vulnerable buildings of urban agglomerations”.

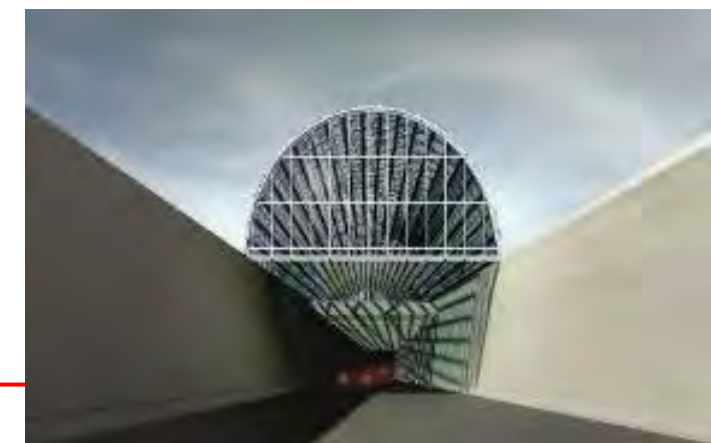


EcoTerra

JMSB BIPV/T

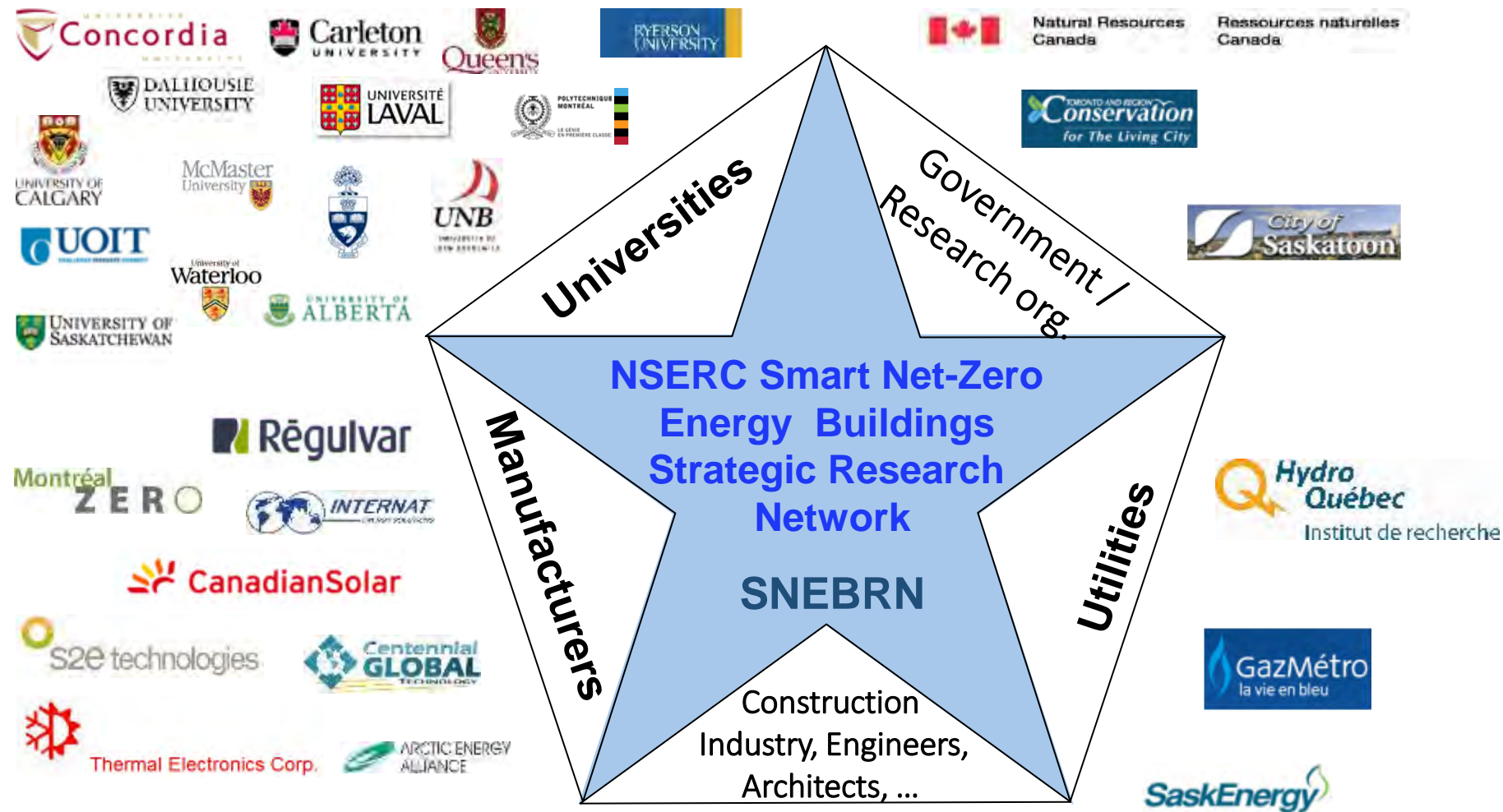


World class demos with a research component



PARTNERS OF CONCORDIA-LED NSERC STRATEGIC NETWORK

CZEBS - the leading and major research group in SNEBRN



Recent Research Chairs/Awards

- Dr. Stathopoulos – Tier 1 GCS Research Fellow for 2019-20
- Dr. Ge – Tier 2, Concordia University Research Chair (CURC) in *High Performance Building Envelope for Climate Resilient Buildings*
- Dr. Athienitis – CURC Tier 1, *Integration of Solar Energy Systems into Buildings and Communities* and NSERC/Hydro-Québec Industrial Research Chair in *Optimized Operation and Energy Efficiency: towards High Performance Buildings*
- Also associate member Dr. Carmela Cucuzella was awarded a CURC Tier 2 in *Integrated DDesign And Sustainability for the Built Environment (IDEAS-BE)*
- Several prestigious awards by HQP: e.g. H. Vallianos – FRQNT doctoral scholarship; Z. Ioannides – ASHRAE scholarship.



EXPERIMENTAL FACILITIES - BOUNDARY-LAYER WIND TUNNEL LAB



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

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

The effect of wind on building models is reproduced in a boundary layer wind tunnel. This enables 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 be performed.

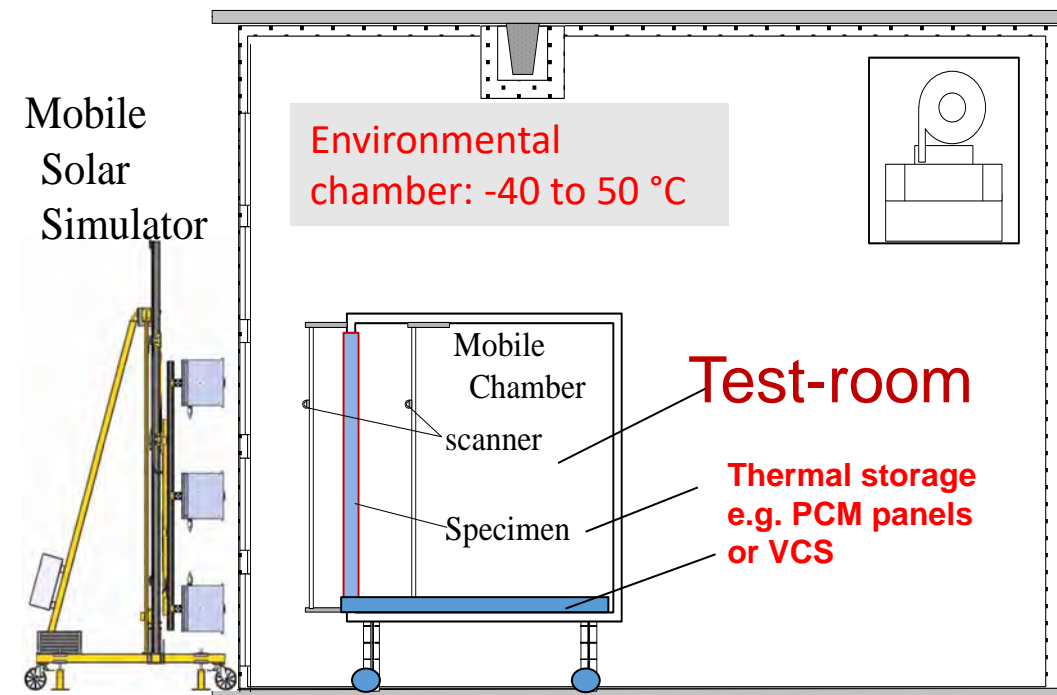


P. FAZIO ENVIRONMENTAL CHAMBER AND MOBILE SOLAR SIMULATOR



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.



EXPERIMENTAL FACILITIES - 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 $\pm 5\%$ variation under 0.85 to 1.15 sun

VARENNES LIBRARY NET-ZERO ENERGY BUILDING

ONGOING DEMO/ CASE STUDY



Photo of Varennes Library (taken during class visit). Library building also includes EV charging.

The roof is covered with photovoltaic (PV) panels, with 110 kW capacity. Part of the system is BIPV/T with fresh air preheating during the heating season.

Video made in collaboration with BBC, fall 2019



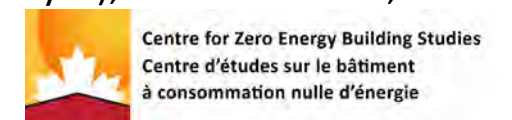
The Varennes library is the **first institutional solar net-zero energy building (NZEB) in Canada**. The building integrated energy concept was developed with guidance from a team led by Dr. Athienitis at the early design stage. The **SNEBRN-CZEBS team** provided guidance on the energy concept to achieve net-zero, sizing of solar system and the building shape, as well as other details such as roof slope. Currently, the building is used a case study for developing optimal control strategies, including grid interaction under a **NSERC/Hydro Quebec Industrial Chair**.



Photo showing PV systems and south facade

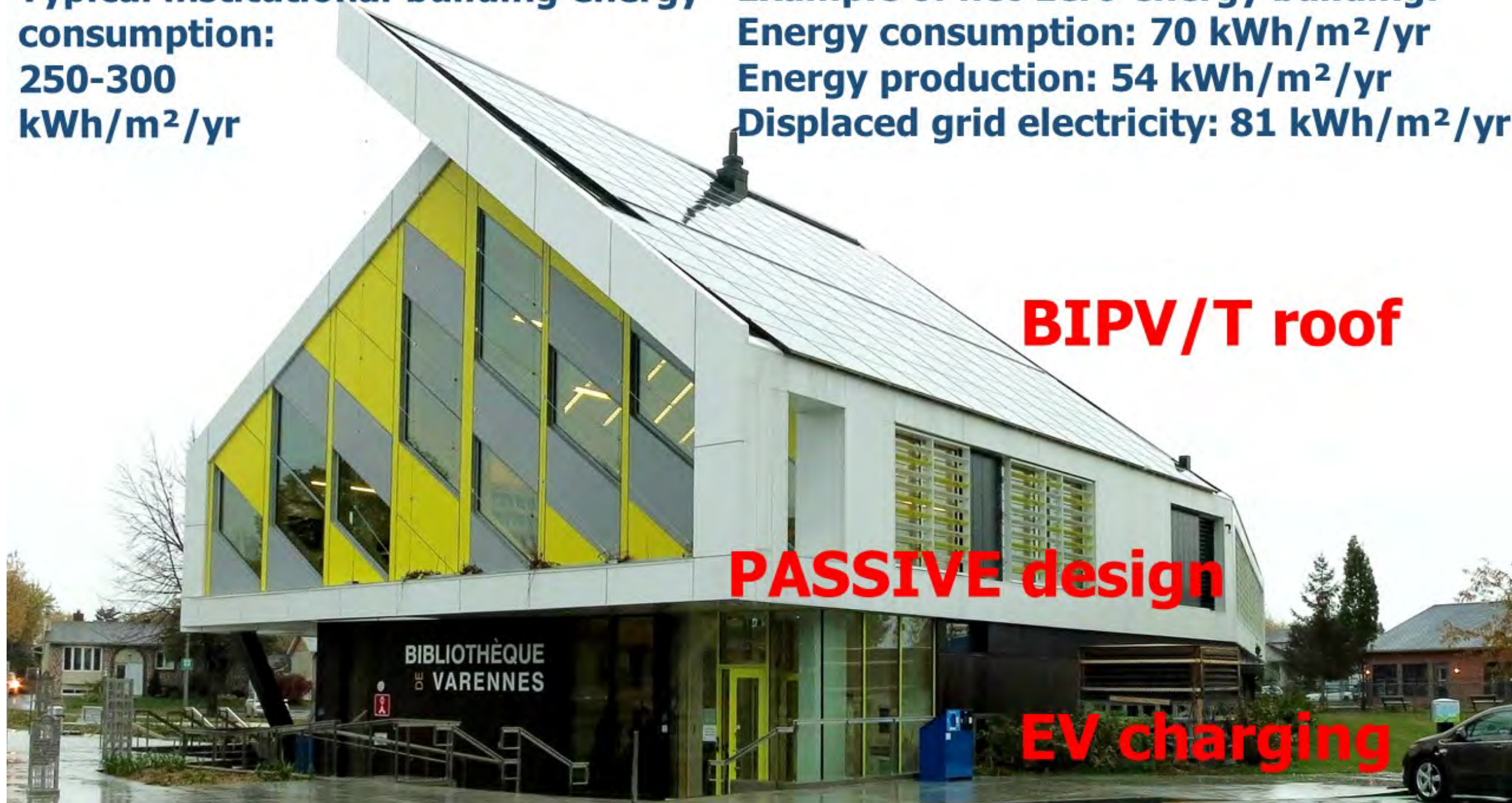


Varennes Library Inauguration (May 2016): C. Kapsis, A. Athienitis, M. Damphousse (mayor), V. Dermardiros, R. Dumoulin



**Typical institutional building energy consumption:
250-300
kWh/m²/yr**

**Example of net-zero energy building:
Energy consumption: 70 kWh/m²/yr
Energy production: 54 kWh/m²/yr
Displaced grid electricity: 81 kWh/m²/yr**

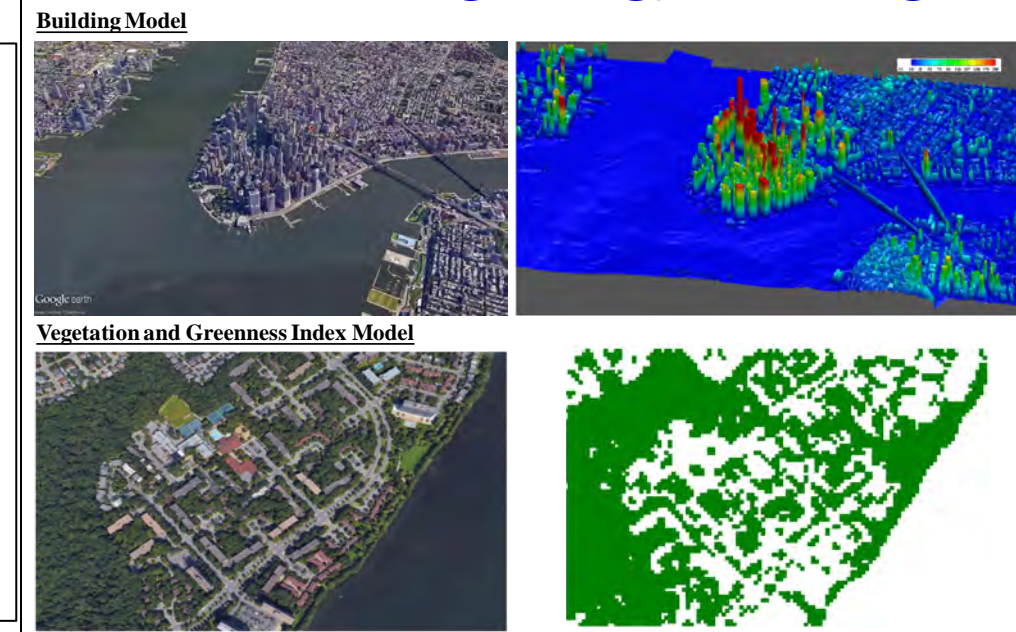
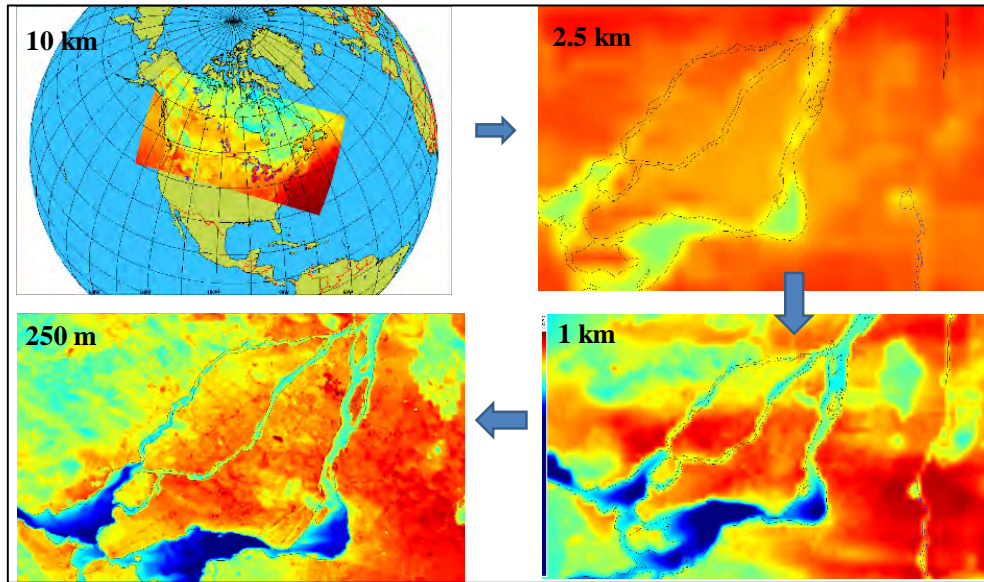
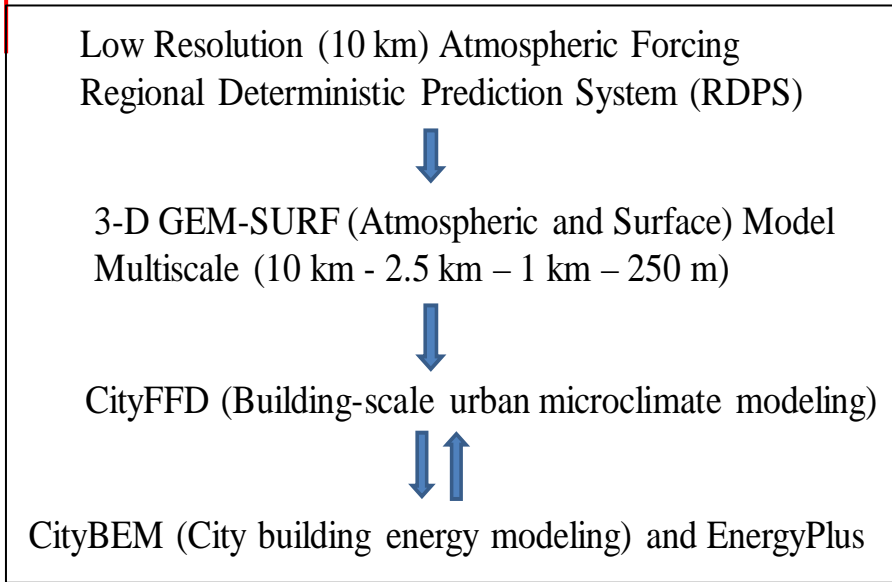


BIPV/T roof

PASSIVE design

EV charging

Multi-scale Modeling and Sensing for Climate Resilience: Urban Heat Island and Urban Building Energy Modeling

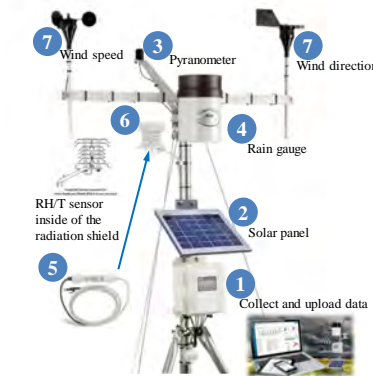


Multi-scale Downscaling (Global to Urban to Building to Rooms)

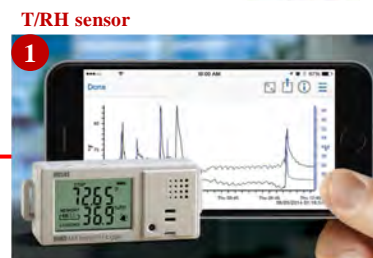
Weather forecasting and long-term climate change modeling (50 years)

Digital city creation with terrains and vegetation from Google Earth

Assessment and Mitigation of Summertime Overheating Conditions of Urban Agglomerations (\$1.084 million) led by Dr. Wang, Dr. Ge and Dr. Zmeureanu collaborating with NRC, ECCC and Health Canada



Minimum 11 weather stations installed and 11 buildings with indoor sensors



Task 1 – Field monitoring:

Indoor thermal conditions of selected buildings and exterior climatic conditions will be monitored to assess risks of summertime overheating.

Task 2 – Simulations:

Development of urban-scale microclimate model and building-scale overheating model.

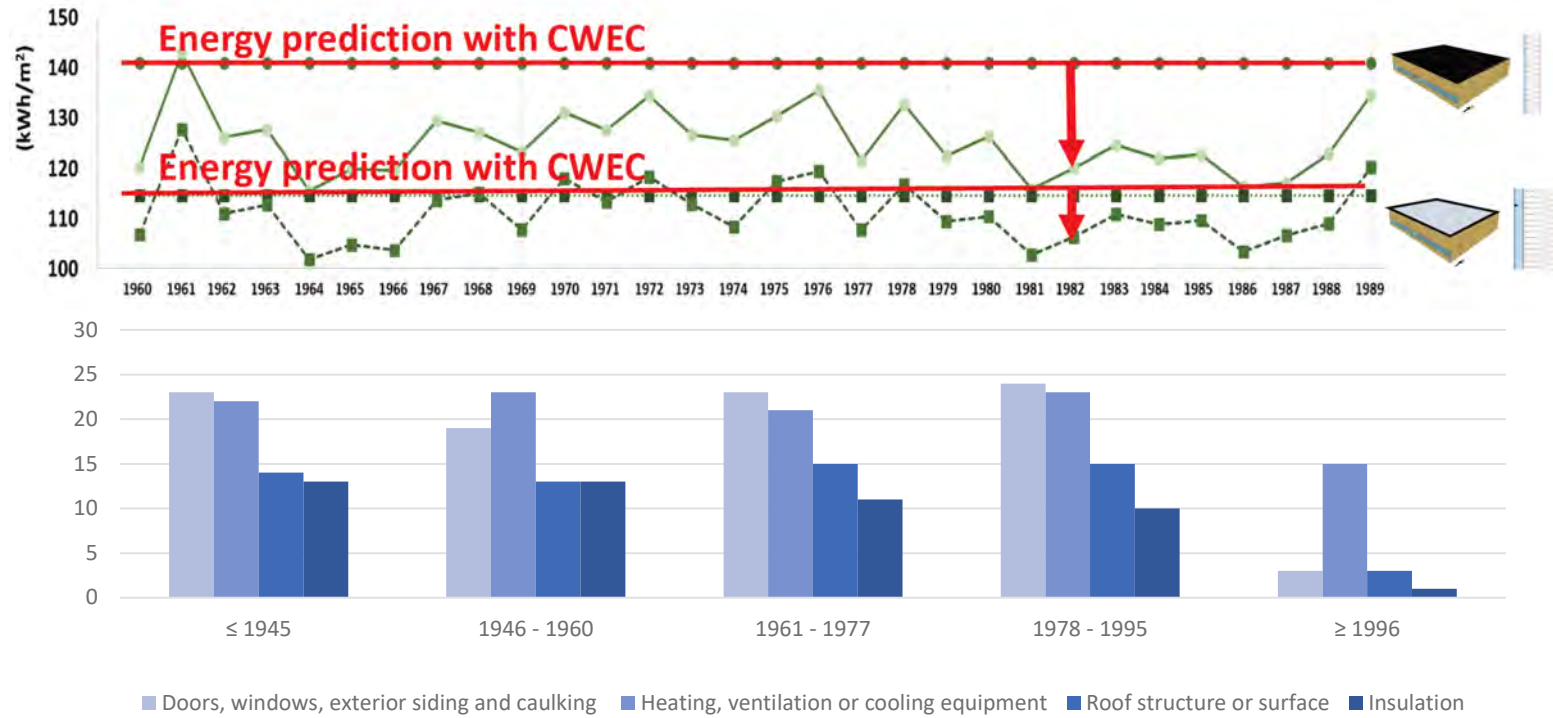
Task 3 - Mitigations:

Development of mitigation strategies at building levels by considering urban-scale microclimate and climate change for different Canadian climatic zones.

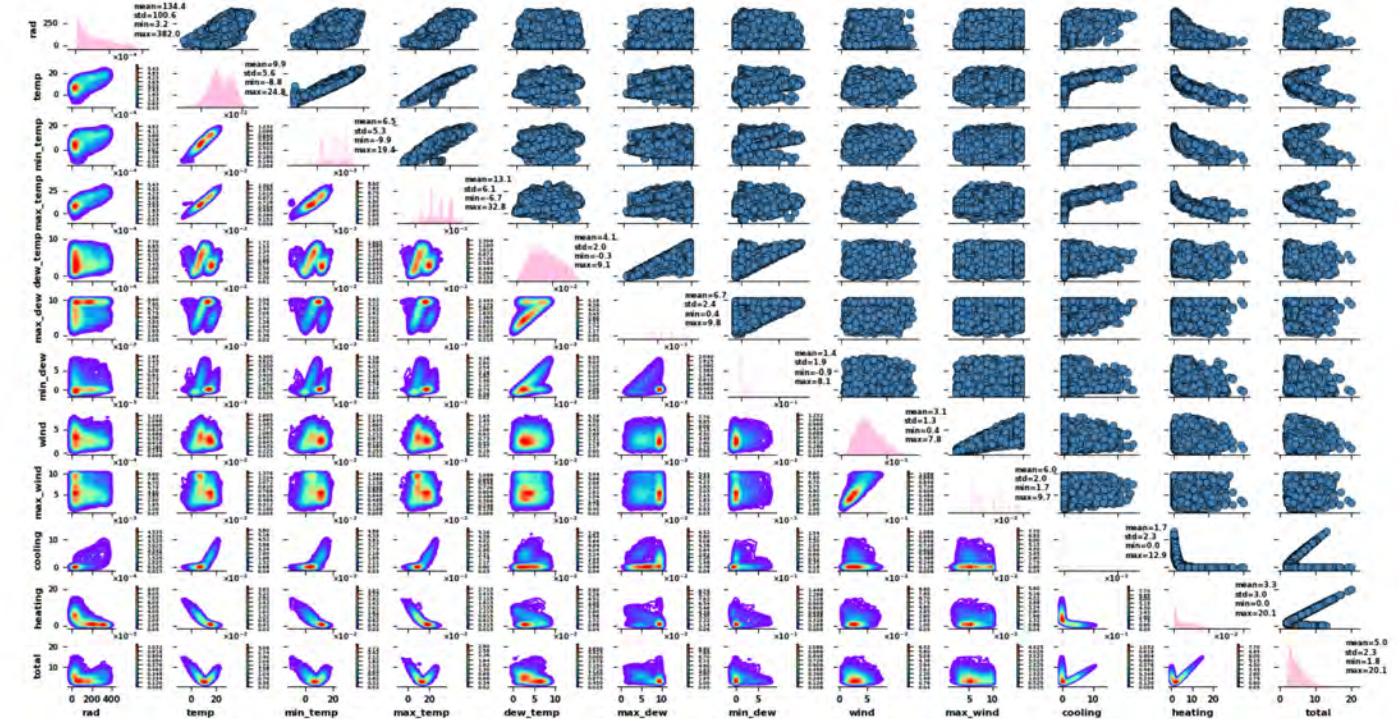
Task 4 – Guidelines:

Development of design guidelines to support the National Building Code of Canada and Canadian construction standards to address climate change.

Bruno Lee: Building Design for Climate Change



Weather Parameters on Energy Consumption



Performance-based Decision Making

each dot represents one design solution

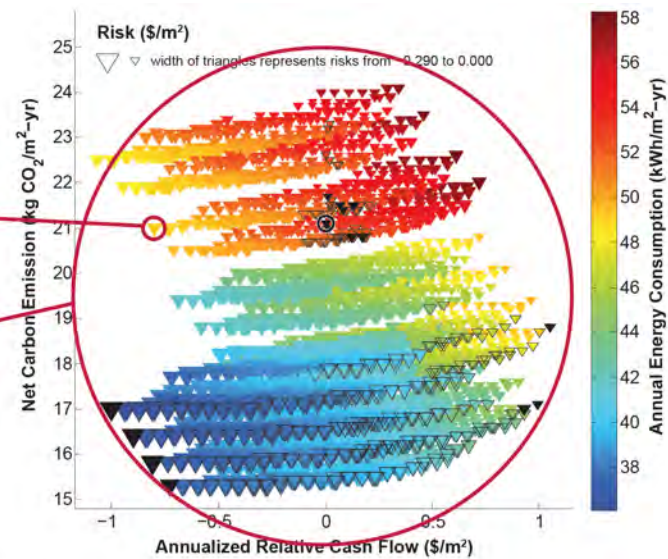
Ins_Roof	Ins_Wall	Mass_Roo	Mass_Wal	Daylightin	TSC
1.5	1.5	0.0	0.0	0	0.0

each design solution comes with an unique performance

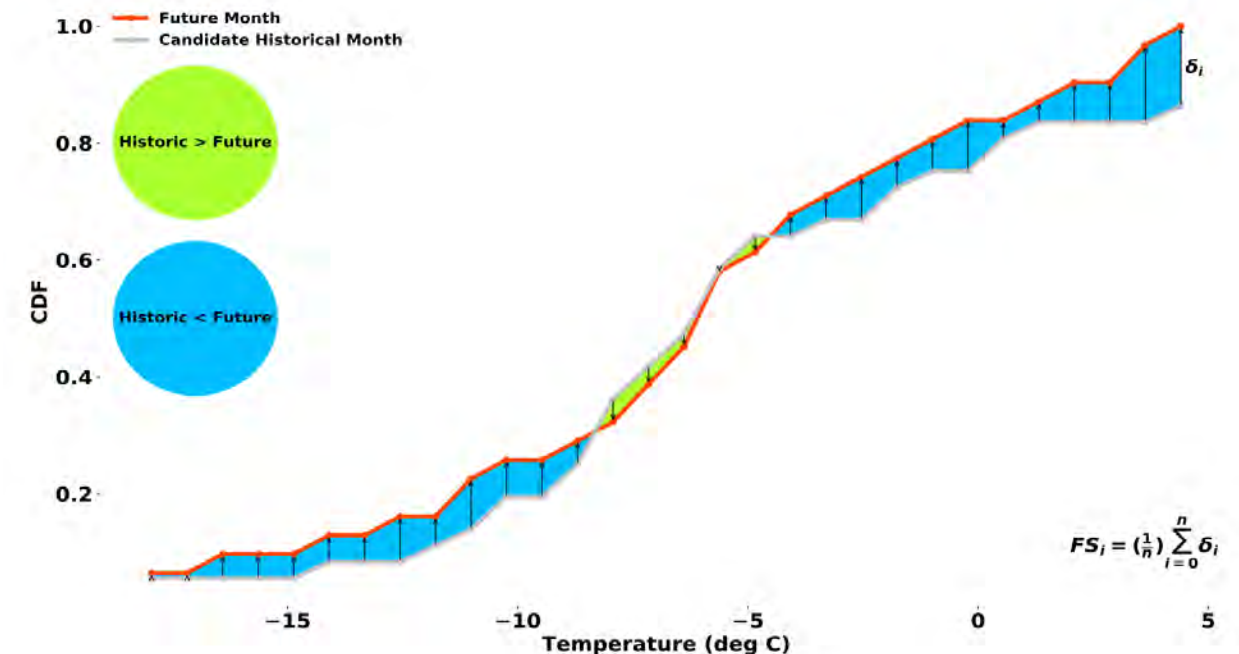
few thousand dots =
few thousand design solutions

► four design objectives :

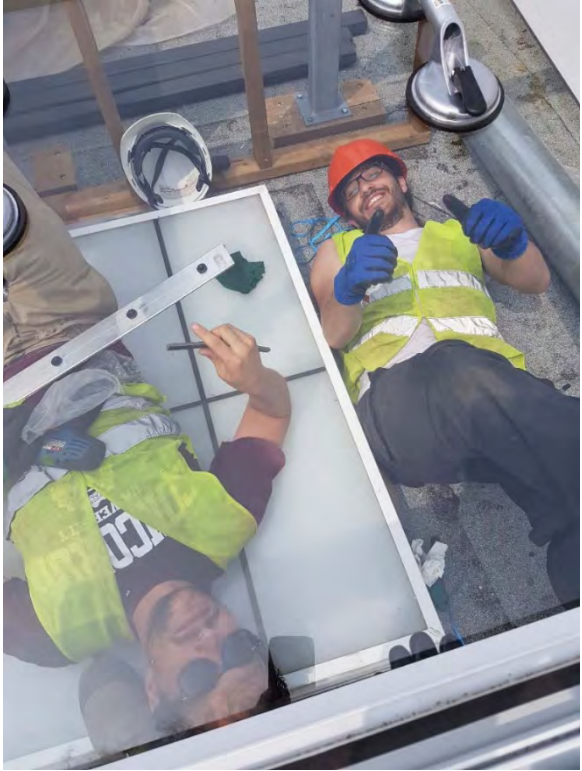
- minimize **Energy Consumption**
- minimize **Net CO₂ Emission**
- maximize **Annualized Relative Cash Flow**
- minimize **Risk**



Future Weather File Generation



Participation in Solar Decathlon China 2018 - Team Montreal



Participation in Solar Decathlon China 2018 – TeamMTL – Concordia + McGill Awards



Several design awards in engineering, innovation and architecture

3 CZEBS profs led by B. Lee

8 CZEBS HQPs (led by Remi Dumoulin, student in IRC)

Left: photo of TeamMTL Solar Decathlon house in Dezhou, China showing the integrated BIPV/T solar system specially designed and built by CZEBS and its partners at Canadian Solar and Uniel; **Right:** Photo for the **engineering and innovation prize**; right to left: Hua Ge - Assoc. Prof., Harry Vallianos PhD student, Anthony Rey PDF, Mary Li Ma MSc student, Remi Dumoulin MSc student, Stratos Rounis PhD student, Bruno Lee, Assist Prof.; Marie-Andree and Pierre Angers from Hydro Québec (Pierre trained students on the energy system).

Remi Dumoulin and Dr. Athienitis presented on the Solar Decathlon and also the Varennes Library at the ASHRAE Montreal Chapter on Sep. 10, 2018 to an audience of over 100 industry participants.

Concordia Field Research Facility for Buildings of the Future, led by H. Ge

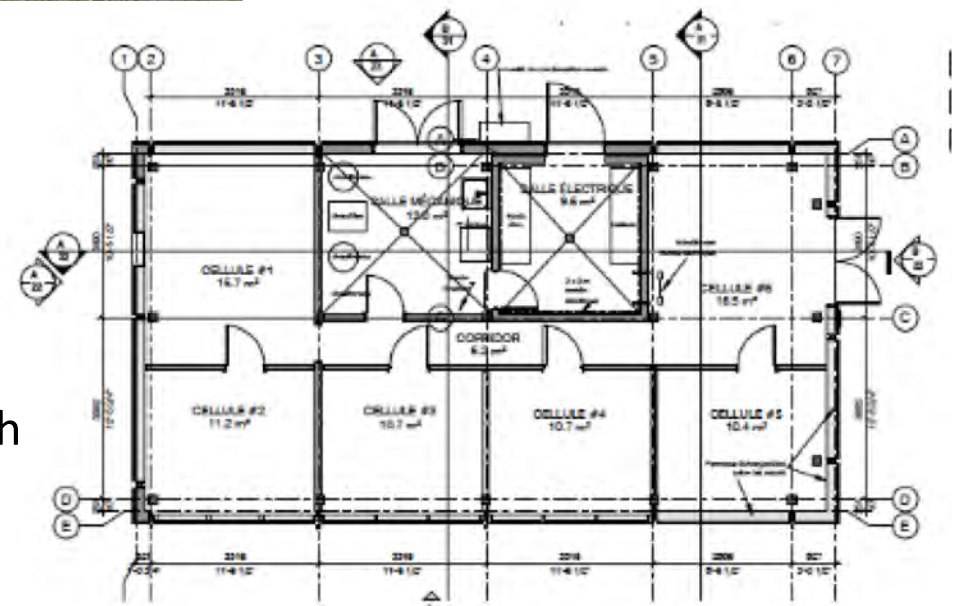
\$1.27M, six faculty members from CZEBS, 2 from ECE



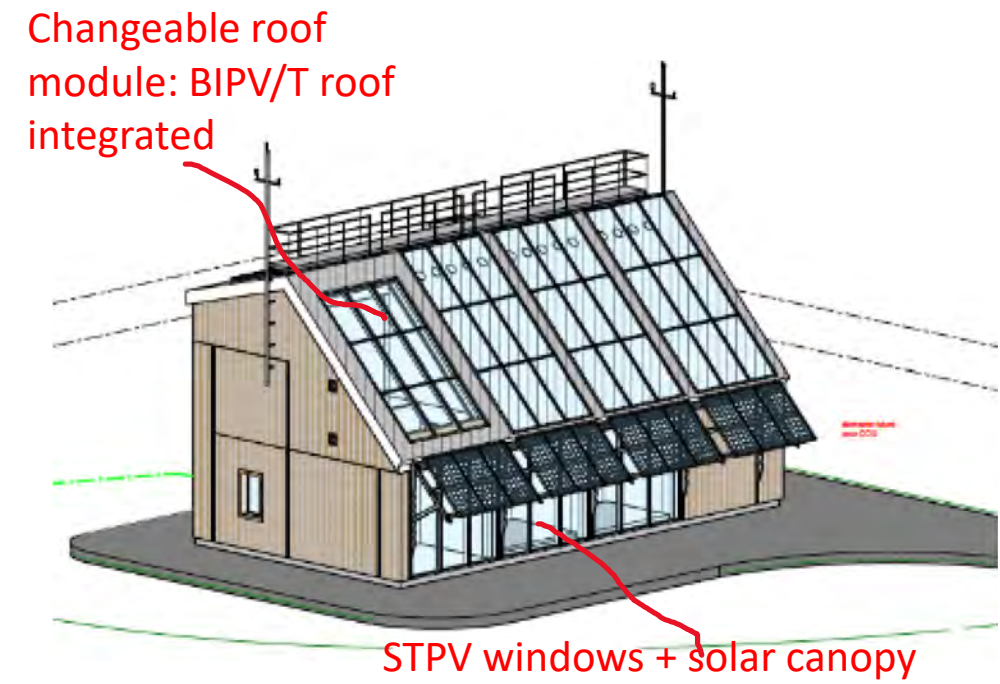
- **NOW UNDER CONSTRUCTION**
- Develop and test innovative building and energy technologies in a systematic setup.
- Test and optimize the integration, operation and energy management of multiple power sources and energy storage units
- Develop and advance net-zero energy building practices by optimizing integrated building and energy system performance under real weather operating conditions.
- Lead the building industry towards intelligent net-zero energy buildings of the future.

Research capabilities of CFRFBF

- Various envelope and mechanical systems
- Interaction between envelop, indoor environment and HVAC systems
- integration/interaction of renewables: solar, wind, fuel cells
- Capabilities to test interaction of buildings with grid, nano-grid
- Extensively instrumented: building intelligent information system



Floor plan: six test cells

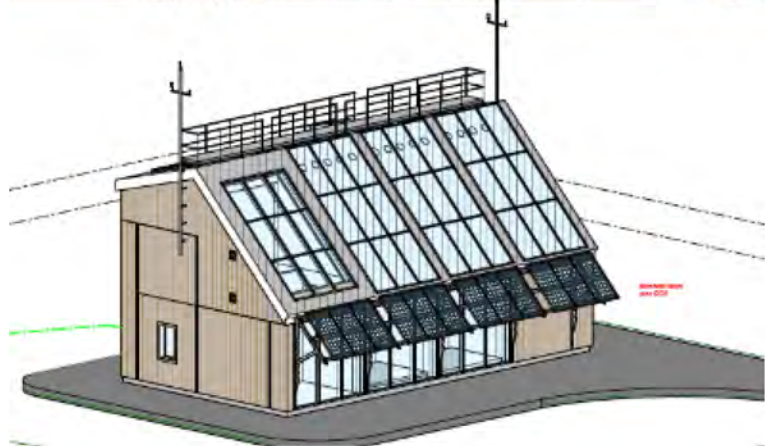
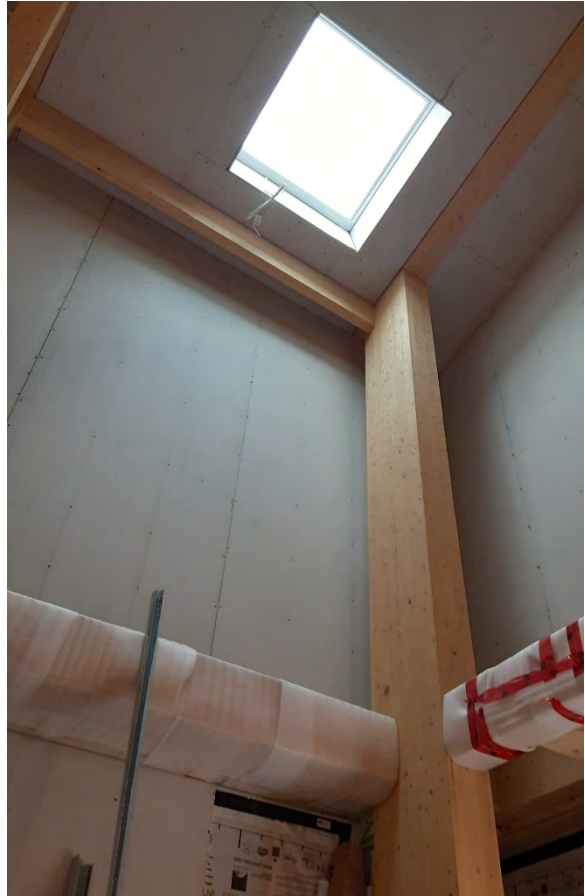


CFRFBF recent photos

- South facade



West facade



CZEBS GRADUATE STUDENTS - WORKSHOPS

CZEBS students participate in seminars and training events, enhancing their academic knowledge.

Photos from Jan. 2020 workshop shown:



CZEBS GRADUATE STUDENTS



CZEBS Workshop

Graduates of CZEBS are in high demand. For example, 7 doctoral graduates recently 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
- **Katherine D'Avignon**, École de technologie supérieure (ÉTS), Montreal, QC
- **Dahai Qi**, Building Engineering, University of Sherbrooke, Sherbrooke, QC
- **Costa Kapsis**, Civil Eng., U. of Waterloo



Recent Events Hosted by CZEBS, IEA Tasks related



Mission Innovation –
Co-organized by CZEBS and NRCan, Sep. 27-28, 2018; 24 researchers from 9 countries; 4 professors. & 10 HQPs of CZEBS



IEA-SHC Task 56: 6th Meeting
Building Integrated Solar Envelope Systems for HVAC and Lighting, Hosted by CZEBS, Sep. 20-21, 2018; 11 people from 7 participating countries.

Table 1. Related IEA Annexes, in which team members play a major role

Title	Participants	Notes
EBC Annex 83, Positive Energy Districts [42]	Ursula Eicker, Subtask B coleader	DLSC project will be considered as case study
SHC Task 63, Solar Neighborhood Planning [43]	Caroline Hachem-Vermette, Subtask A leader; Other participants: Eicker, Athienitis	S2e smart community project and DLSC as case studies
EBC Annex 82, Energy Flexible Buildings: Towards Resilient Low Carbon Energy Systems [11]	Michael Kummert, Subtask leader	Link to ongoing and new community projects
EBC Annex 81, Data-Driven Smart Buildings [44]	Jose Candanedo (Subtask Leader on MPC); A. Athienitis	MPC of archetype building such as Varennes Library
EBC Annex 79, Occupant-Centric Building Design and Operation [45]	Liam O'Brien (Operating Agent), Mohamed Ouf	Link to Living labs

CAE Roadmap to Resilient Ultra-low Energy Built Environment with Deep Integration of Renewables in 2050 – Webinar Oct. 16, 2016



Workshop on Roadmap to Resilient Ultra-low Energy Built Environment with Deep Integration of Renewables in 2050

Co-organized by CZEBS and CAE (Canadian Academy of Engineers), March 21st, 2019

Photo from planning workshop of 2019

Webinar of Oct. 16, 2020 included about 20 papers with presentations and two panel discussions. Over 200 participants. Published proceedings, interim report in preparation.

Roadmap (2019-22) will provide important input to national policies on the built environment

The 5th COBEE conference hosted by the CZEBS, Concordia University in Montreal

Chaired Dr. Liangzhu (Leon) Wang, with two **co-chairs**, Dr. Ge from CZEBS, and Dr. Zhai from University of Colorado Boulder, USA.

Dr. Athienitis, Dr. Stathopoulos, and Dr. Zmeureanu serve as **Program Chairs** for organizing and chairing different expertise programs.

Keynote speakers from Europe, North America, and East Asia.

Supported by Journals of Building and Environment, Energy and Buildings, Sustainable Cities and Society, Building Simulation, Wind Engineering & Industrial Aerodynamics, Indoor Air, and Journal of Building Performance Simulation.

Partnering with the National Research Council of Canada, International Association of Building Physics, Natural Resources Canada.

[CZEBS is expecting the conference will bring many researchers and experts from different continents in the world to Concordia in the summer of 2022.](#)