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

Integrated design and control of decarbonized and resilient buildings

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CZEBS - CENTRE FOR ZERO ENERGY BUILDING STUDIES

UNIVERSITÉ Concordia UNIVERSITY

The mission of the CZEBS 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: 3 Fellows of CAE, 2 of ASHRAE, 4 of IBPSA, 1 of ASCE; 2 Concordia Chairs, 1 NSERC IRC

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Above photos provided by David Ward, Concordia University

Concordia University Senate approved CZEBS in January 2012

About 100 HQP, a total of over 20 full and associate members

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CAE Roadmap to Resilient Ultra-Low-Energy Buildings with Deep Integration of Renewables

- Canada's goal of rapidly **reducing GHG by 2050 and reaching carbon neutrality** needs a multifaceted and comprehensive approach adapted to different regional contexts and energy mixes.
- Addition of **resilience** can help develop **practical integrated solution pathways** while bringing many national benefits.
- Many pathways to achieve this goal are being debated in different contexts and from different perspectives in different provinces.
- CAE Roadmap to Resilient Ultra-Low Energy Built Environment with Deep Integration of Renewables released in May 2024.

Extreme Weather events such as Ice-storm of '98 in Canada & Energy Resilience

- The ice-storm of 1998, costliest natural disaster to occur to date in Canada's history
- **Over 70 mm of freezing rain fell**, transmission lines collapsed, and power was cut, sometimes for up to 5 weeks!!!
- Many residents left their homes which sustained high damages due to bursting water pipes.
- **Ice storm was followed by cold sunny weather**

Production of **solar electricity and heat may provide emergency power and heat** for a home and charge EV

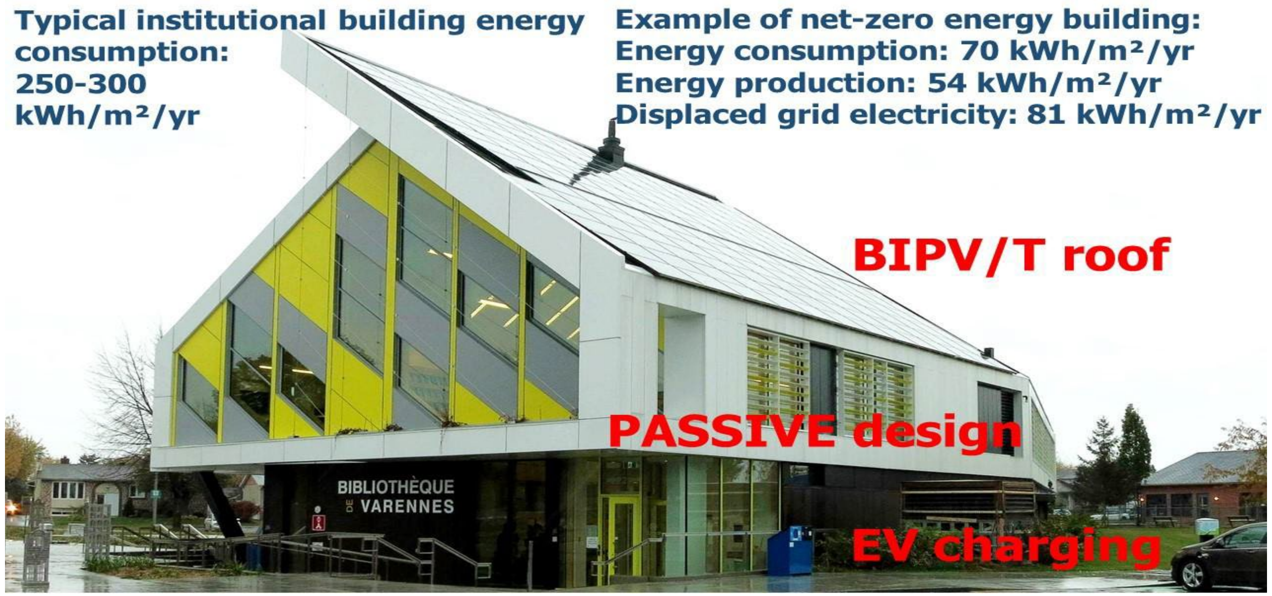
Costliest natural disaster; **economic loss $6.4 billion**
4.7 million people left their homes for up to five weeks
HOW CAN CANADA BE PREPARED IN THE FUTURE?

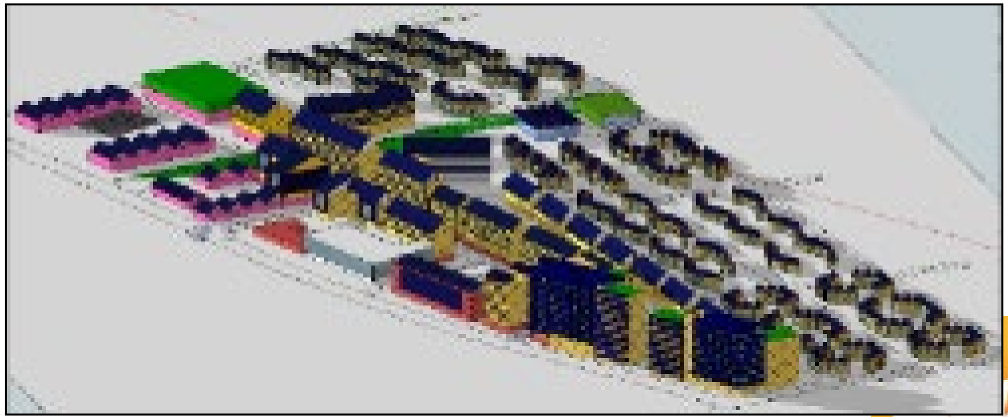
Scope of CAE Roadmap

- The **tangible outcomes** include a building stock that will be resilient through disasters and climate change, utilize new efficient ways of powering infrastructure, achieve net zero emissions, minimize costs, maximize public safety, optimize occupant health and comfort, incorporate circularity of materials use and integrate with electrified transportation.
- The **role of engineers** is to bring technical insight into policy development processes, collaboratively, from multiple fields of expertise, and engaging with experts from multiple non-engineering fields (such as urban planning) who may be trained to work from significantly different paradigms.

Two key case studies – living labs

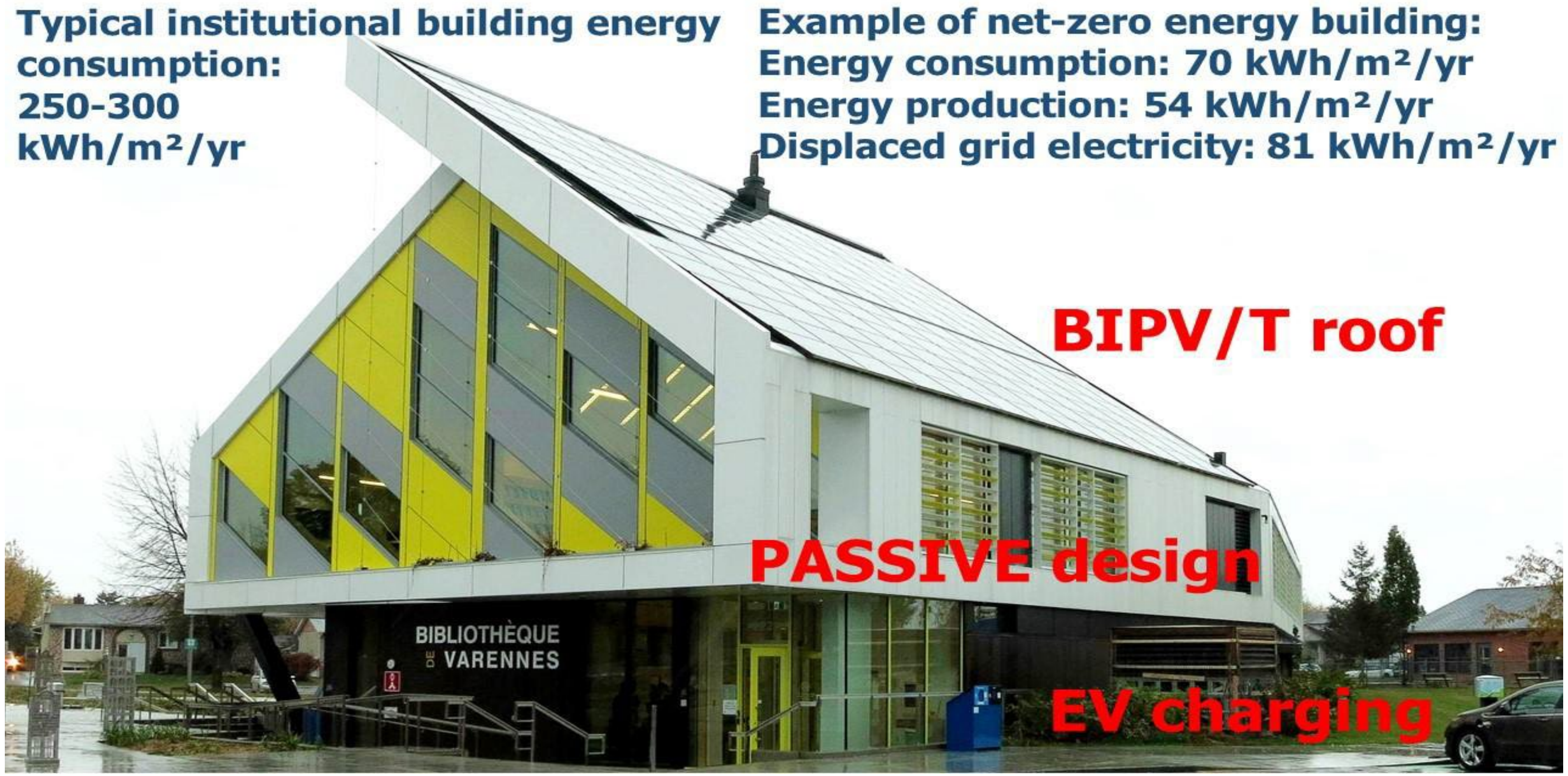
- Importance of systematic modelling and early-stage design decisions of advanced solar buildings and communities
- Optimized to capture solar energy through building-integrated solar systems for the simultaneous production of electricity & heat, optimally designed windows for passive solar heat gains and daylight, and efficient energy storage systems – thermal and batteries.
- Aim for net-zero energy (and carbon neutral) for buildings plus local transportation with electric vehicles





The Varennes library NZEB in Quebec

It was shown that by **exporting solar electricity from a building-integrated photovoltaic system to the grid**, displaced more primary energy through photovoltaic generation than electricity imported from the grid in an average year, thereby achieving net zero energy performance.

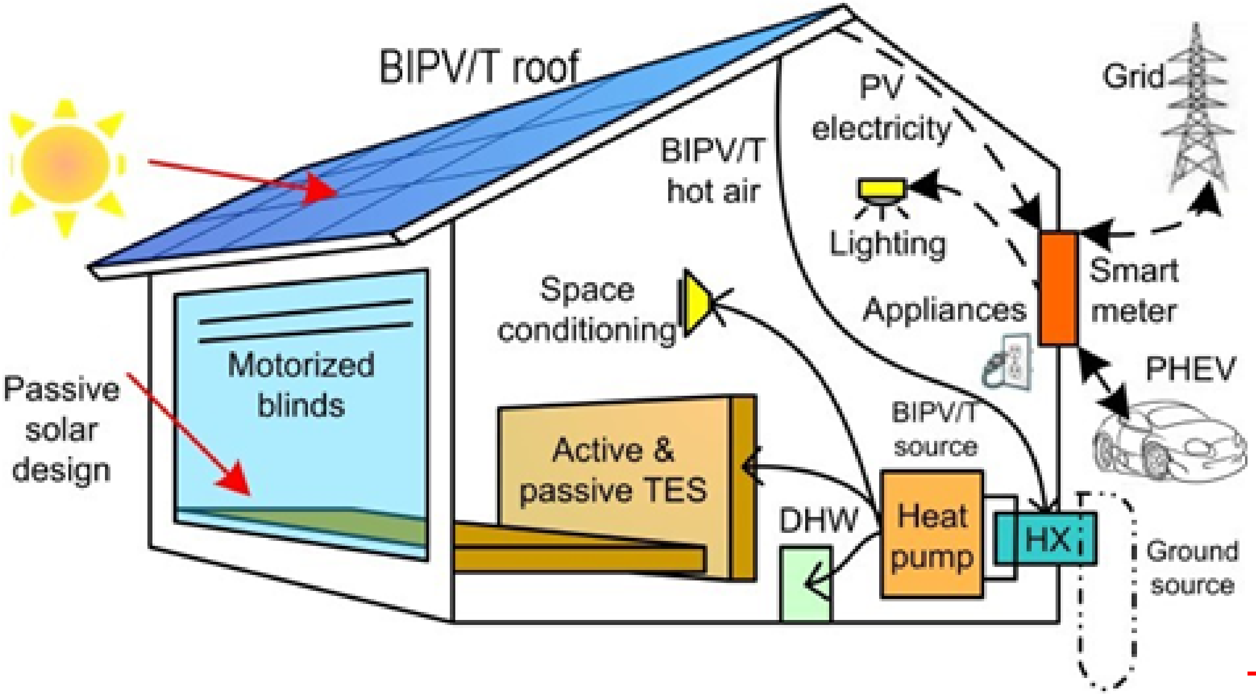


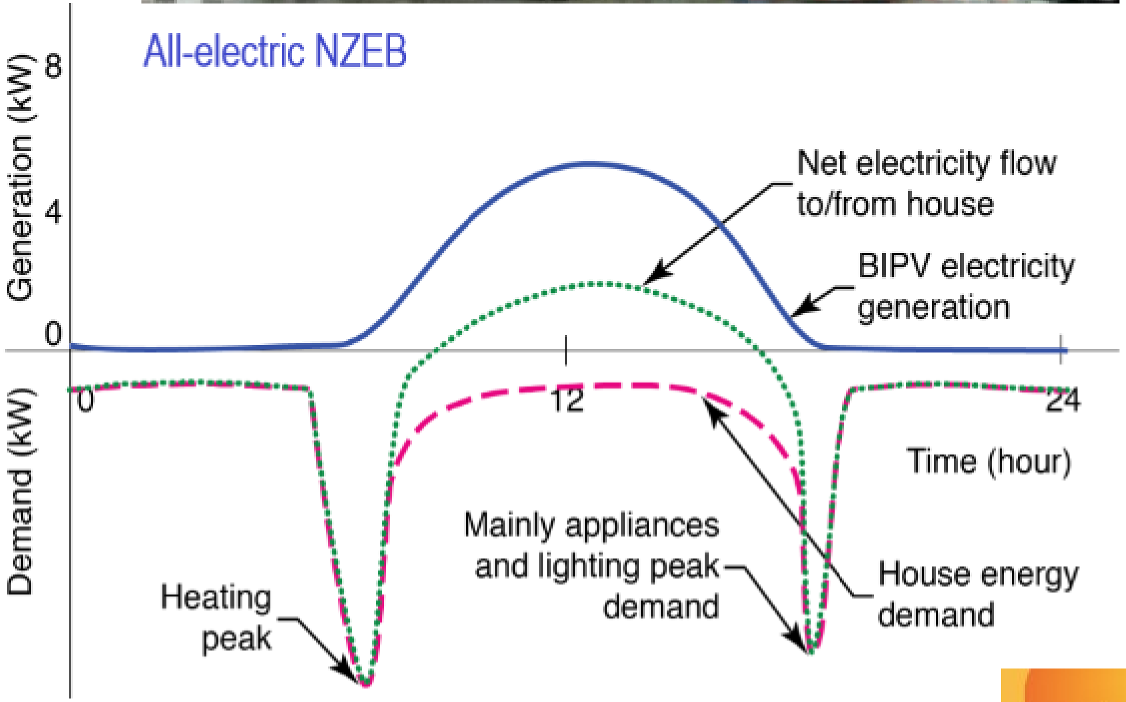
We advised the design of Canada's first net-zero energy institutional building.

Now its operation (model predictive control and energy flexibility) is studied under a NSERC Hydro-Québec Industrial Chair

V. Dermardiros, A. K. Athienitis and S. Bucking, "Energy performance, comfort, and lessons learned from an institutional building designed for net zero energy," ASHRAE Transactions, Vol. 125, 2019.

Integrated smart solar building concept and grid integration – need for energy flexibility





Overview of energy flows in a NZEB like Varennes Library

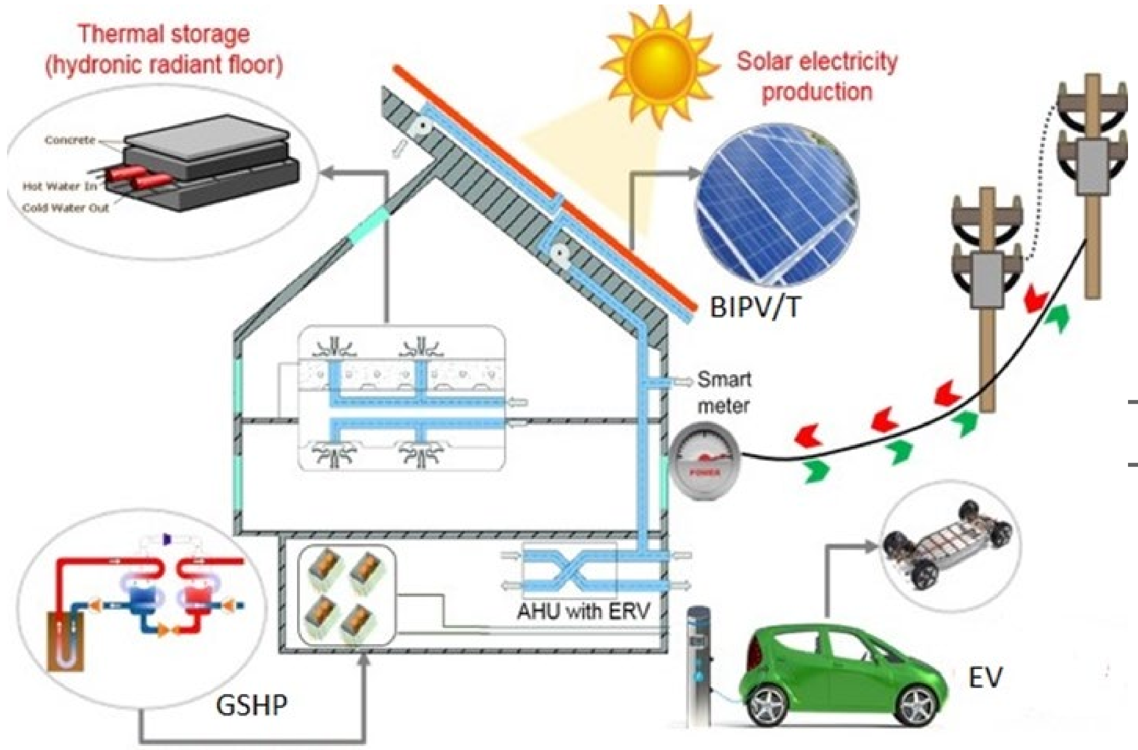
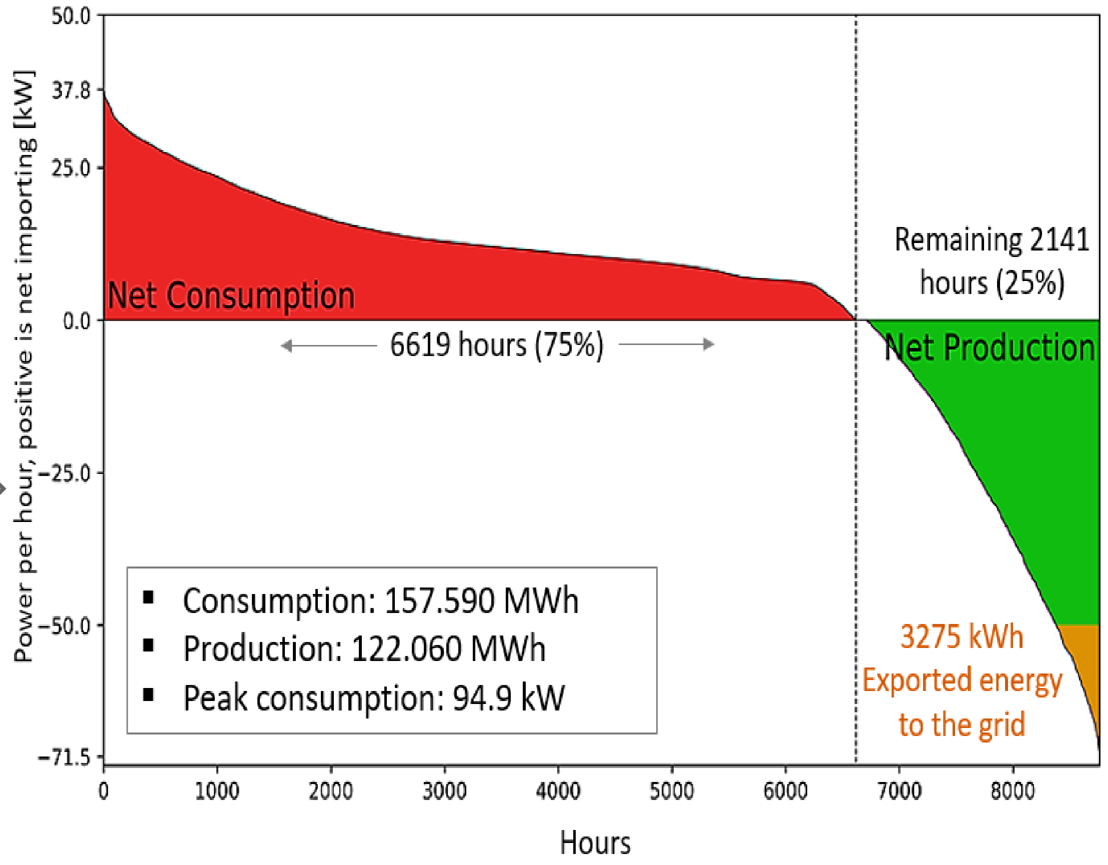


Illustration of different energy technologies that can be used to enhance flexibility in the operation of the Varennes library



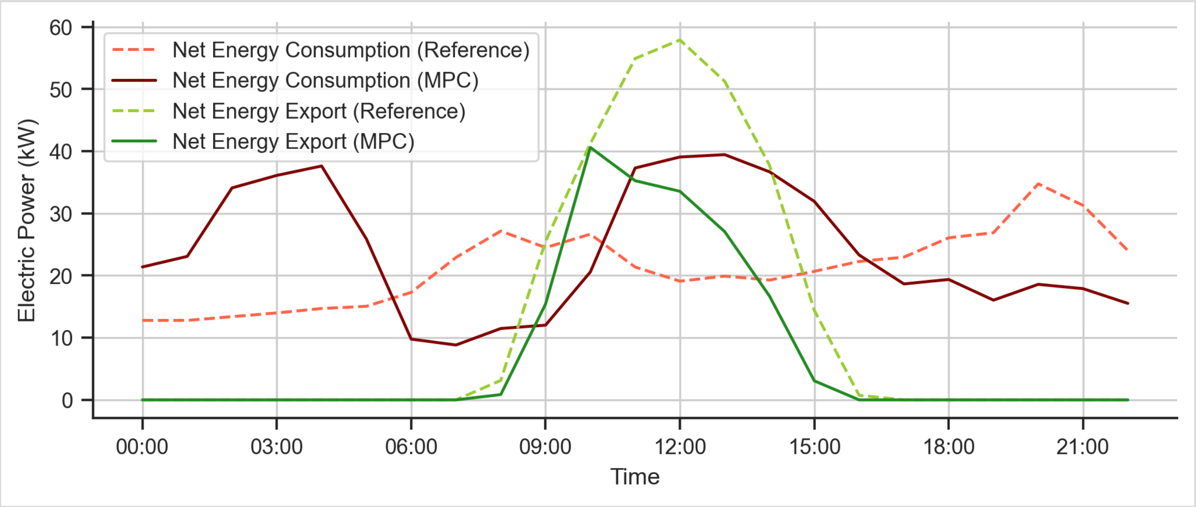
Load duration curve: electricity flow from and to the grid

Note: grid will buy up to a max. of 50 kW from building

A NZEB like the Varennes Library can provide flexibility to the grid in response to grid signals through predictive control

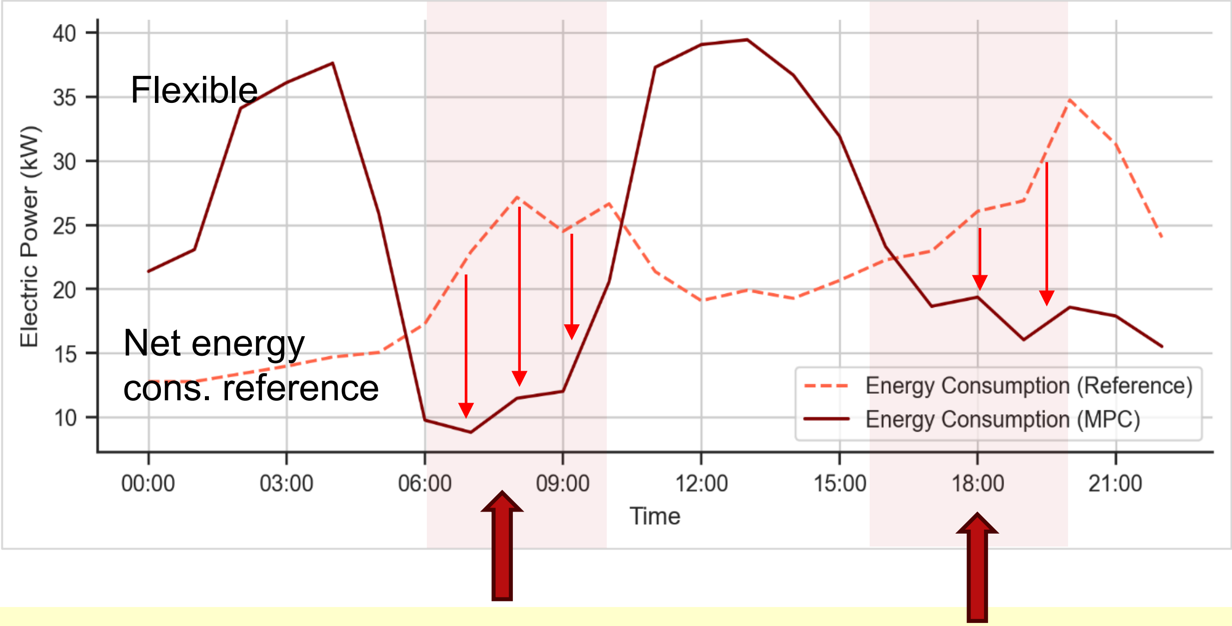
HEURISTIC MODEL PREDICTIVE CONTROL TEST VARENNES LIBRARY (23/12/21 to 03/01/22)

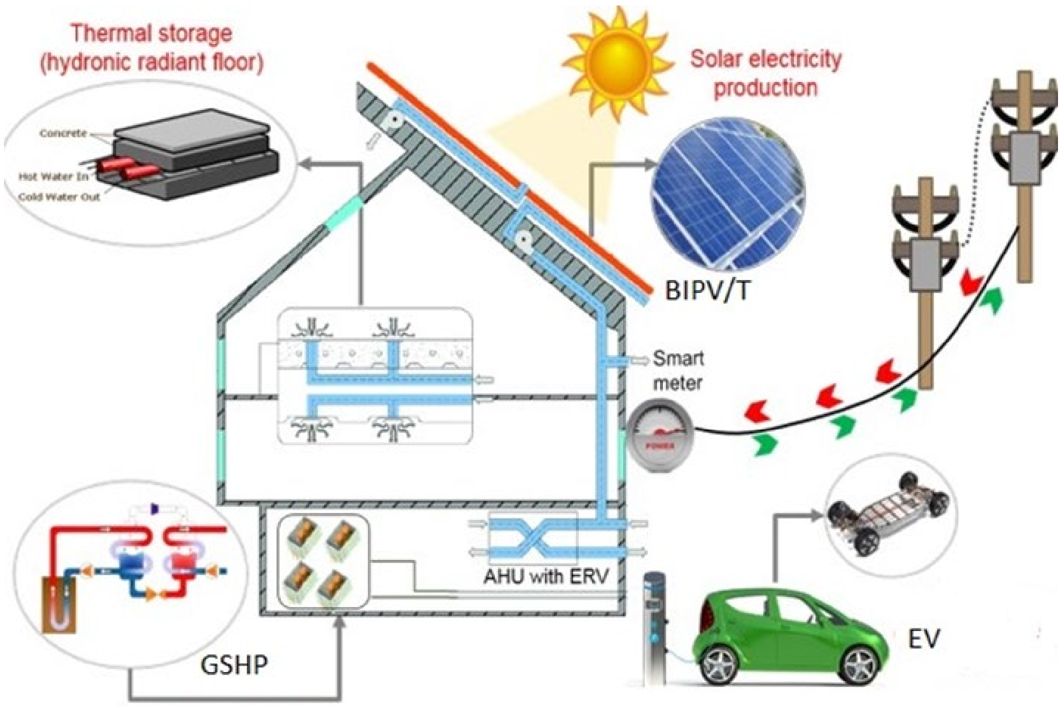
DURING SUNNY COLD DAYS



- Morning Peak Reduction: **- 50 kWh**
- Evening Peak Reduction: **-20 kWh**

Self-consumption of PV electricity was increased by about 40%

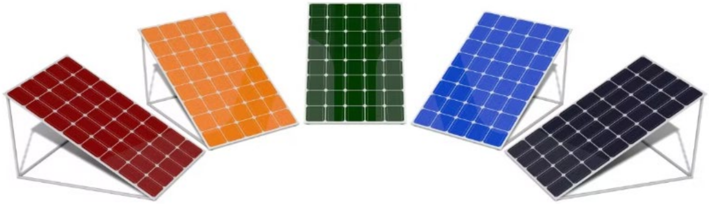


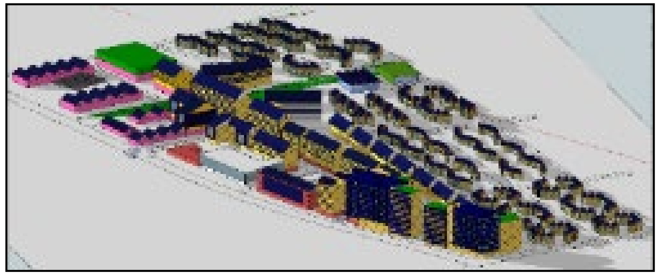


Predictive control used to shift demand from the two peak periods for the grid

Major challenges

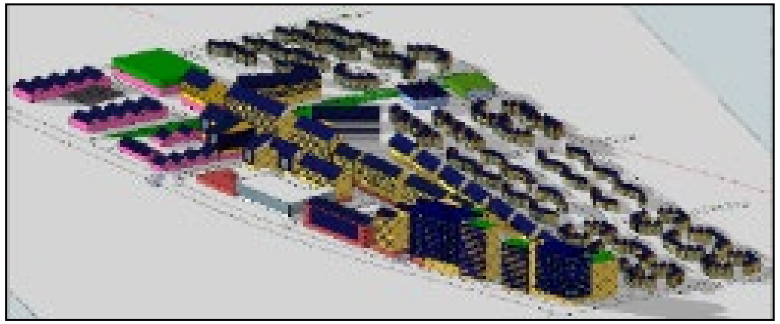
- How do we accomplish most efficiently smart energy-generating building and community design at the different design stages and finally optimize predictive operation and grid interaction?
- How do we integrate design of form (architectural) with energy design?
- How do we optimize land use, density, building shapes, EV integration of distributed energy resources energy storage





The West 5 sustainable community in London Ontario

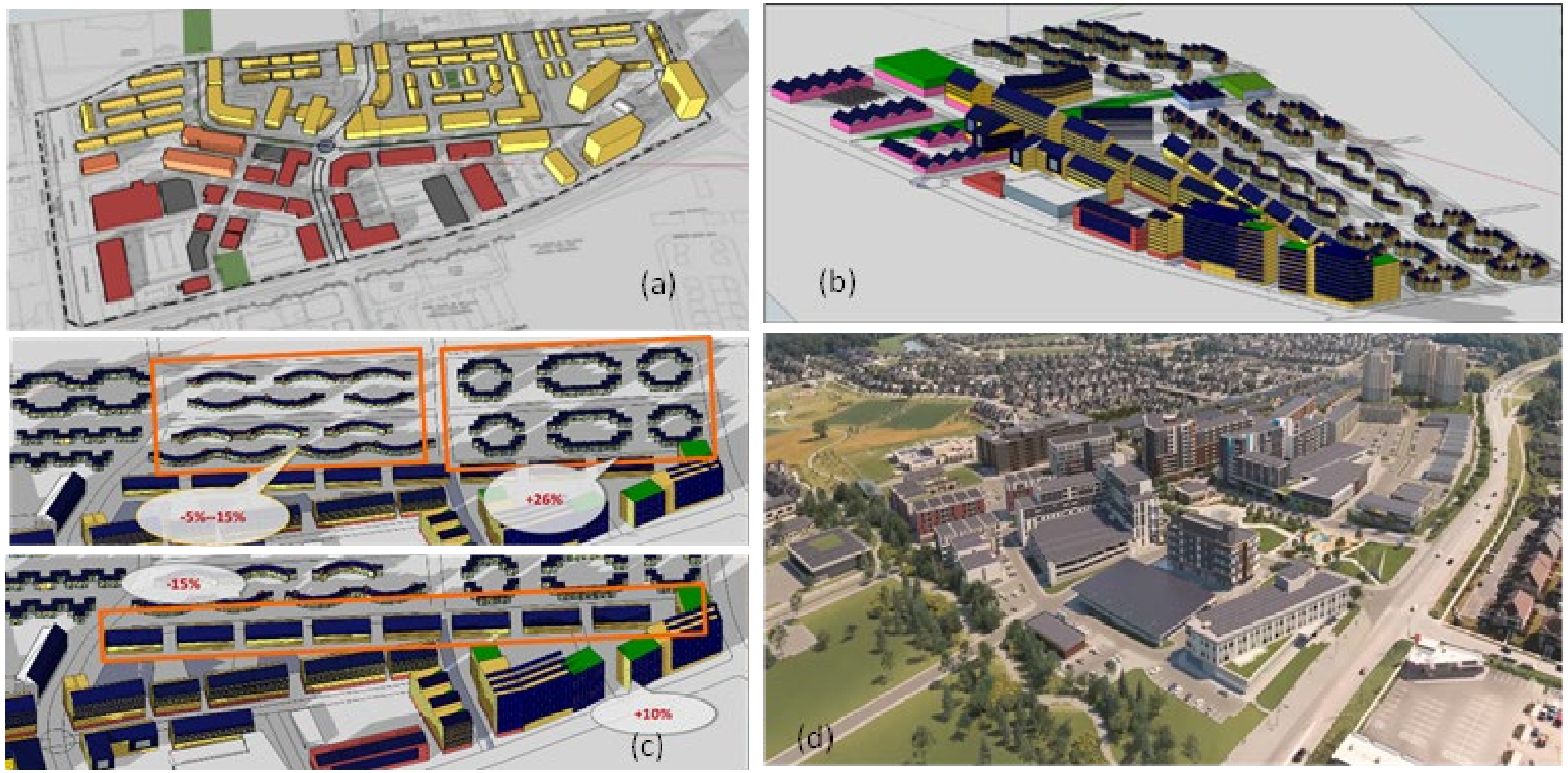
Showed that with energy efficient buildings and extensive use of solar panels heat pumps and integrated electric vehicles, demonstrated that innovations in microgrid business models and adaptations to code limitations are necessary to efficiently integrate renewable energy into communities.



Early design stage concept for community

Pictures from West 5 (about 30% completed)

Various stages of the design process of the West 5 Community, in London Ontario

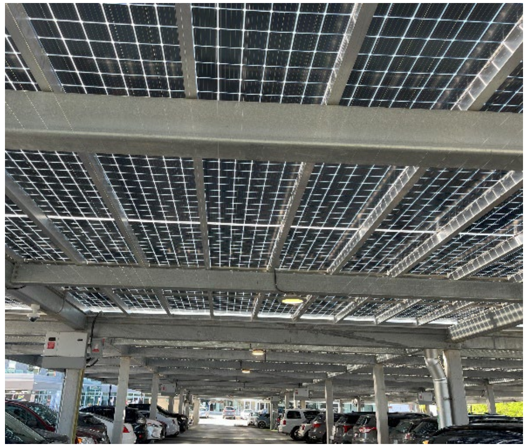


Credit: Dr. Caroline Hachem-Vermette

Recent photos from workshop at West 5 (May 30, 2024)

Elevator for parking Electric vehicles

Row houses



Some lessons learned from West 5 community

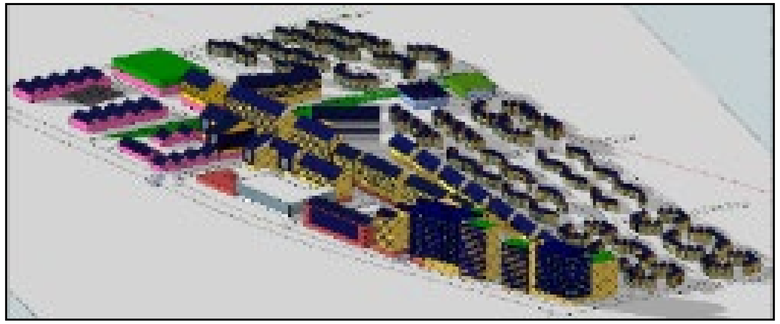
- Key decisions made at the early design stages such as form and density of buildings have a major impact on energy performance.
- Land use – public spaces and infrastructure - integrated planning is essential. Common parking structures?
- Electrification is an important means to reach net-zero – e.g. heat pumps, BIPV, electric vehicles.
- Energy storage together with predictive control is needed to provide energy flexibility to the grid: thermal mass, water thermal storage, batteries, EVs etc.

CONCLUSION

- **Building- and community-scale renewable electricity generation and storage** will be essential for making existing and new communities resilient to climatic shocks and extreme weather events.
- **Ambitious design goals** do not necessarily cost more if both **resilience and decarbonization are considered together**, particularly at the early design stages.
- More **sophisticated and integrated policies, codes and incentives** are needed – resilience needs long-term solutions.

Prefab solar roof

Semitransparent solar panels
Skylight in train station



Design and operation and grid integration
At early design stage