Bacon and Eggheads

This flagship series brings together Parliamentarians with experts across science and engineering, showcasing outstanding Canadian research accomplishments. Its purpose is to provide unbiased insight into topical scientific issues, within a non-partisan forum in which lobbying is not permitted. This prestigious forum represents a unique opportunity for scientists to communicate important findings to a distinguished and influential audience, which includes key decision-makers.

The series is organized by PAGSE, an umbrella group of 25 + science and engineering organizations operating under the auspices of the Royal Society, and is cosponsored by NSERC.

Cities in the Sun: The Path Towards Smart Net-zero Energy Solar Buildings and Communities

with

Andreas Athienitis, Concordia University

Imagine a building that acts as a small power plant, able to produce as much energy on-site as it consumes over a year. Net-zero energy buildings (NZEBs) are today becoming technically possible by combining energy efficiency measures with building-integrated solar systems and other renewable energy systems in an optimal manner. The rapid drop in prices of photovoltaic panels over the last few years and recent advances in NZEB research and technologies facilitate the adoption of the NZEB concept both at the single building level and the community level. This talk will explain how, based on this concept and vision, we can transform the way we design and operate our buildings and communities, opening the way for innovative new products such as multifunctional building walls, roof systems and windows that generate electricity while controlling and storing sunlight.

Andreas Athienitis is a Professor of Building Engineering at Concordia University and the Scientific Director of the NSERC Smart Net-zero Energy Buildings Strategic Research Network (2011-2016). He led the recently completed NSERC Solar Buildings Research Network program, receiving the ADRIQ-NSERC Celebrate Partnerships Award for the broad national and international impact of its work and successful partnerships. He holds a Concordia University Research Chair, Tier I in Integration of Solar Energy Systems into Buildings. He is the author of more than 200 papers in solar energy and buildings, including several best paper awards. He played a key role in the energy design of several award winning net-zero and low energy buildings with building-integrated solar systems.

Organized by: The Partnership Group for Science and Engineering (PAGSE)

Sponsored by:

--the Speaker of the Senate
--the Speaker of the House of Commons
--Natural Sciences and Engineering Research Council (NSERC)

Date: Thursday September 27, 2012, 7:30 am - 8:45 am
Location: Government Conference Centre, Colonel By entrance

Cost: No charge to Members of the House of Commons, Senators and Media. All others $25
Registration: Please register by contacting Donna Boag, PAGSE Manager: **613**-991-6369, pagse@rsc.ca
Registration Deadline: Monday September 24, 2012

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Bacon & Eggheads Breakfast
Petit-déjeuner avec des têtes à Papineau

Andreas Athienitis

Concordia University

Cities in the Sun: The Path Towards Smart Net-zero Energy Solar Buildings and Communities

Des villes ensoleillées : vers des collectivités et des bâtiments solaires et intelligents à consommation énergétique nette nulle

Co-Sponsor
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NSERC
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Energy and Buildings

Solar Technology

Building Energy Systems

Smart net-zero energy solar buildings and communities

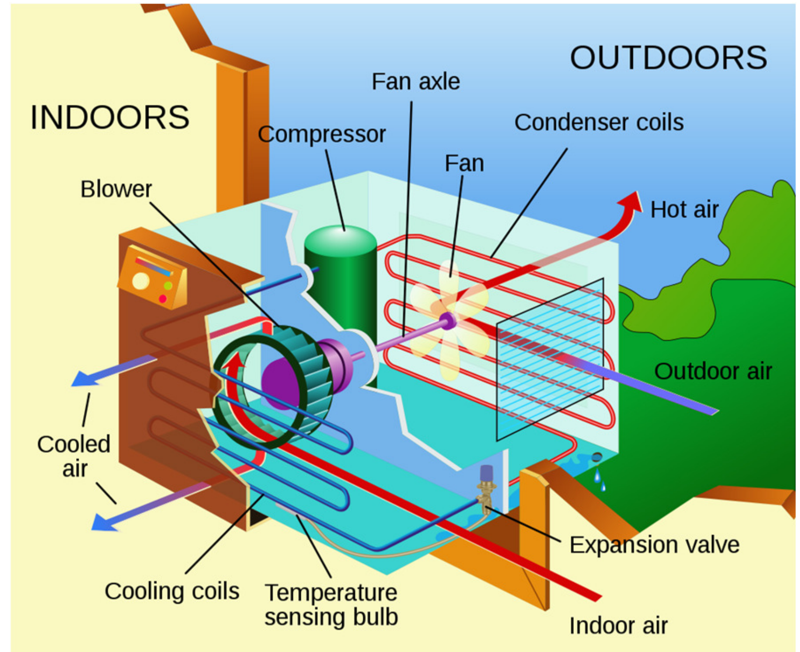
Canadian Energy & Buildings Picture

- Energy use in buildings in Canada
  - 31% of total secondary energy use
  - 28% of GHG emissions *(Energy Use Data Handbook, 1990 to 2005, NRCan)*
  - Buildings consume about 53% of electricity production
- Electrical Energy picture changes between provinces
- Quebec and BC - mainly hydro
- Ontario - fossil fuels/nuclear and recently introduced incentives for renewables

- Building industry is fragmented, with pockets of excellence

Introduction to Energy and Buildings: early technological developments

- Building evolution as protected indoor environments with increasingly higher levels of indoor environment control
- Increased levels of health, wellbeing, and productivity, contributing to our modern way of life
- One early invention was electrical air-conditioning unit (Carrier 1902) and the Heat Pump
- Coal-, oil-, and gas-fired furnaces



Example: A/C unit *Wikipedia*

Basic **heat pump** unit: **1 watt** of electricity produces about 4 watts of **heat** or **coolness**

Introduction: The building itself - housing

- Passive solar design – near-south facing windows (known since Roman times - but challenges remain)

- Buildings used a lot of stone and bricks (until ~50 years ago) but have recently evolved to use more insulation and better windows – aided by incentive programs & standards (R2000)

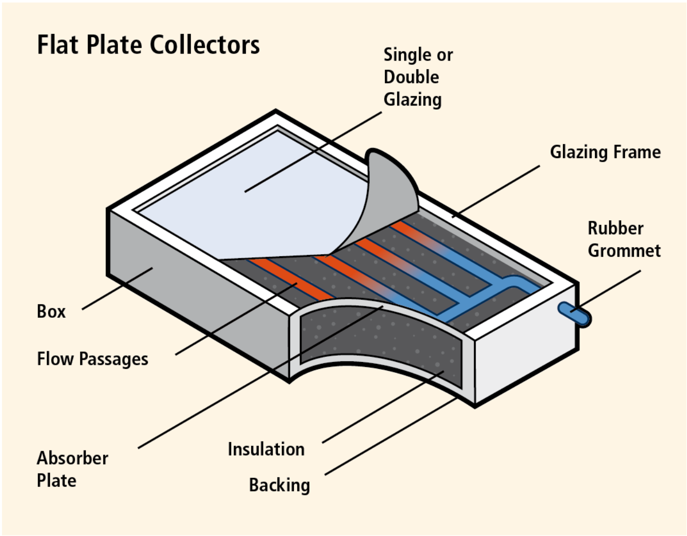
- Canada has been a leader in energy efficient housing such as the Saskatchewan Conservation House (1977) and more recently the EQuilibrium Houses

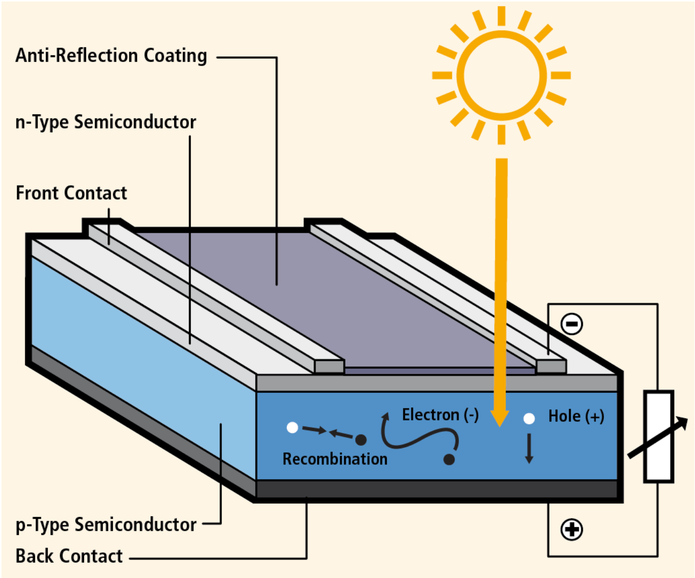
Saskatchewan Conservation House (1977)

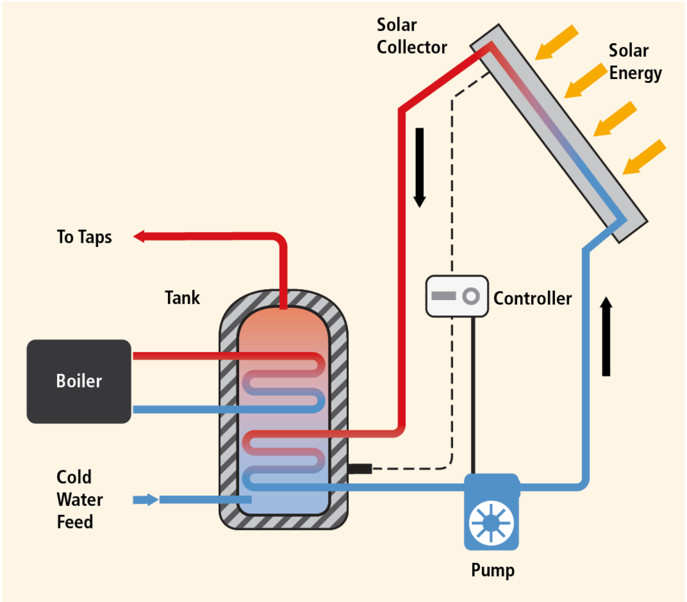
EcoTerra™: first EQuilibrium™ Demonstration House (2007)

Solar technology in 20th Century

- Active Solar Heating: solar collectors for water and space heating, solar air collectors
- Solar Photovoltaic Modules – space applications, then off-grid and now grid-connected systems and building-integrated







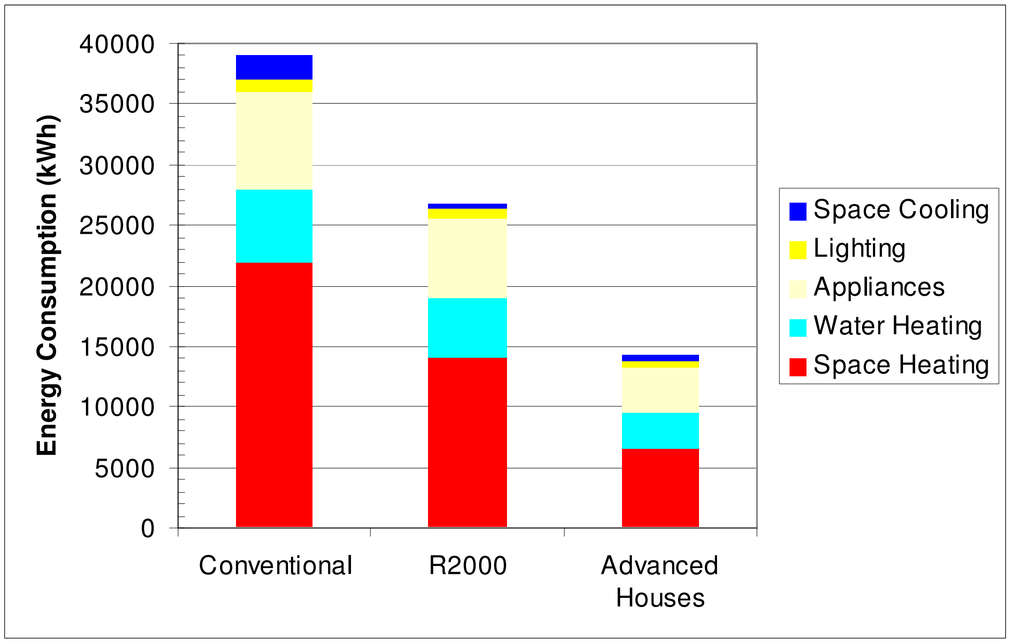
Source: IPCC

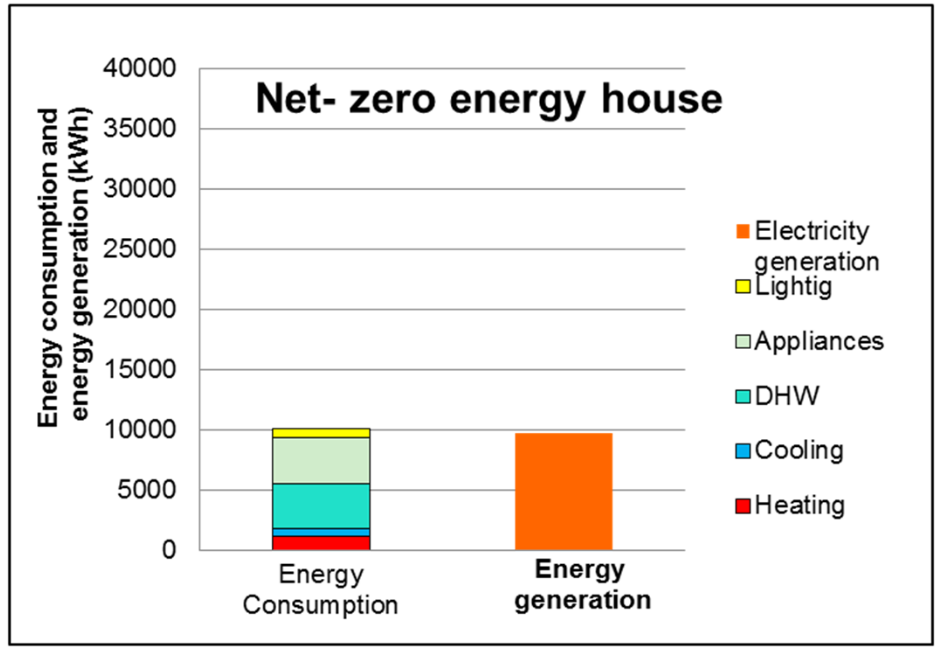
Building Energy Systems & Heating Ventilation and Air-Conditioning (HVAC)

- HVAC developed incrementally with building automation systems made possible since 1980s
- Energy producing systems and cogeneration systems introduced in large buildings
- Solar thermal systems slowly adopted for domestic hot water heating and in limited cases for space heating/cooling
- Integration of 1) ventilation functions with space heating and solar, 2) thermal storage in building design and operation

Residential energy use in Canada

Fact: The annual solar energy incident on a roof of a typical house far exceeds its total energy consumption





Source: NRCan

A net-zero energy house produces from on-site renewables as much energy as it consumes in a year

Commercial and Institutional Buildings

- Electric lighting: transformation in building design that moved towards smaller window areas until the 1950s

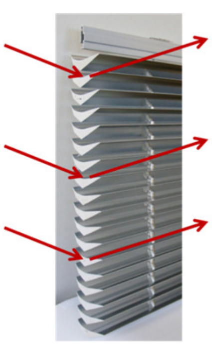
- Followed by evolution to air-conditioned and heated "glass towers" with large window areas: more daylight – but higher cooling and heating requirements
- Currently: renewed interest in daylighting and natural/hybrid ventilation

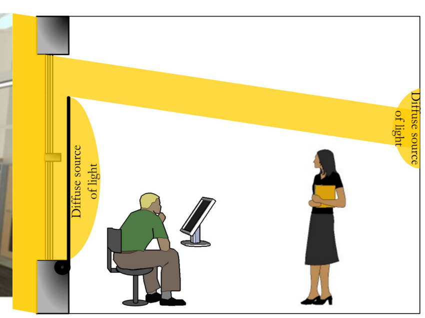
Major international trends in high performance buildings

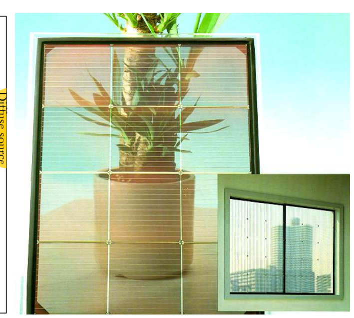
- Adoption by engineering societies and developed countries of **net-zero energy** as a long term goal (*ASHRAE Vision 2020*)

- Measures to reduce and shift **peak electricity demand** from buildings, thus reducing the need to build new power plants; integrate with smart grids

- Steps to efficiently **integrate new energy technologies** such as controlled shading devices and solar systems







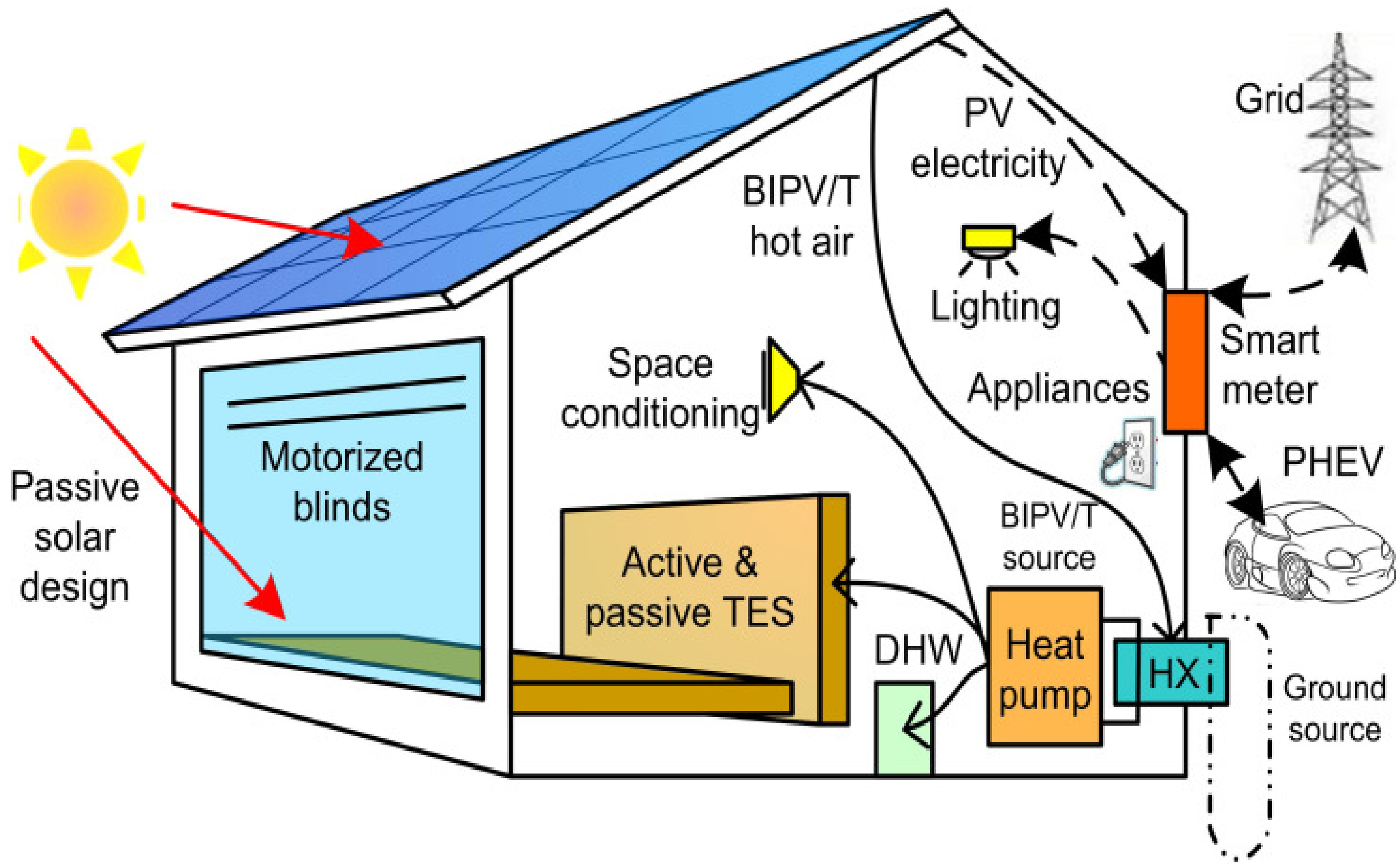

Smart Net-Zero Energy Solar Buildings (NZEBs)

- Net-zero annual energy balance: many possible definitions depending on boundary: House? Community? Net-zero energy cost?
- Net-zero is an objective target that promotes an integrated approach to energy efficiency and renewables; <u>path to net-zero is important</u>
- Why smart? NZEBs must be comfortable and optimally interact with a smart grid
- NSERC **S**mart **N**et-zero **E**nergy **B**uildings Strategic **R**esearch **N**etwork (SNEBRN) builds on the previous NSERC Solar Buildings Research Network (SBRN)

Smart NZEB concept

Optimal combination of solar and energy efficiency technologies and techniques provides **different pathways to reach net-zero**

Solar energy: electricity + daylight + heat

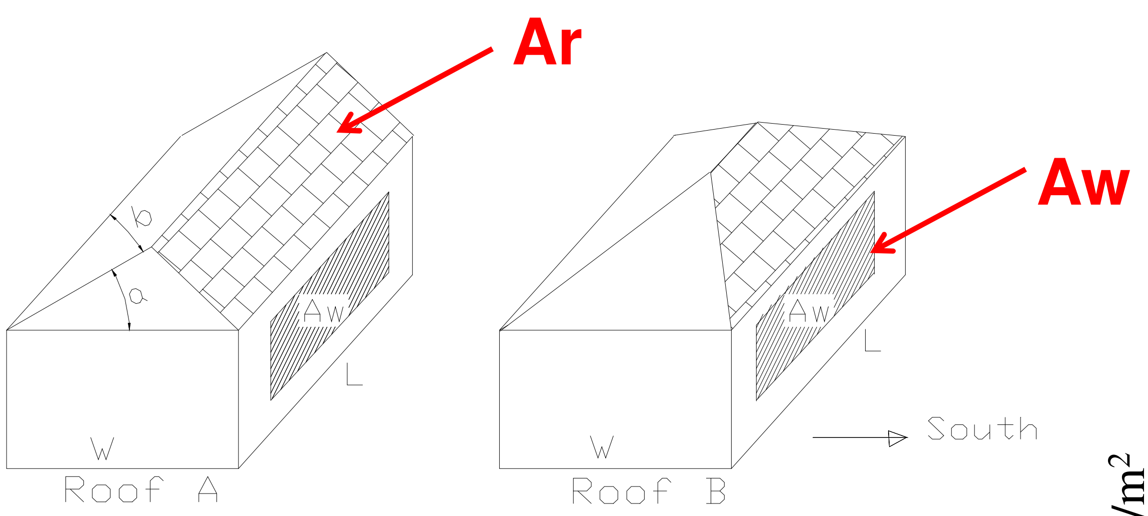


Integrated approach to **energy efficiency and passive design**

Integrated design & operation

Solar optimization: requires **optimal design of building form**

Optimization of buildings for solar collection

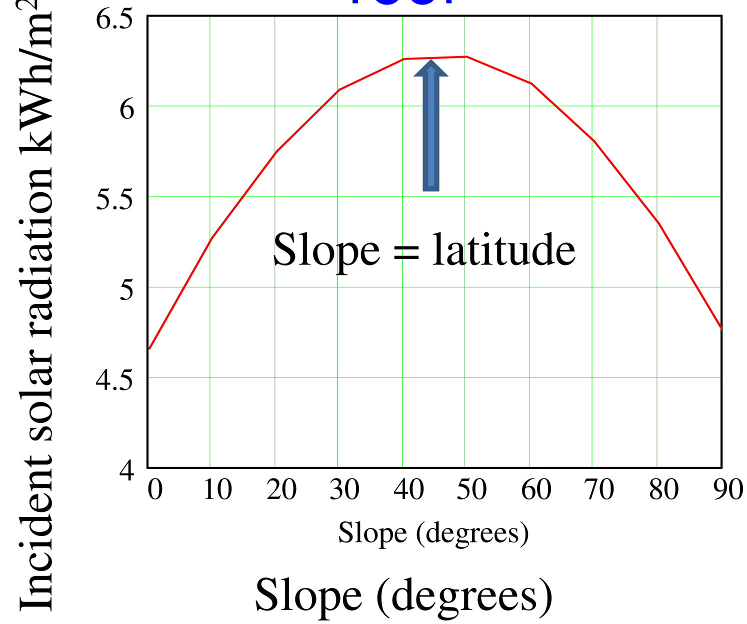


Two roof forms for the same floor plan

Important design variables:
Roof slope and aspect ratio L/W
Also window area

Slopes 40-50 degrees desirable
Aspect ratio higher than 1; around 1.3

Solar energy on roof

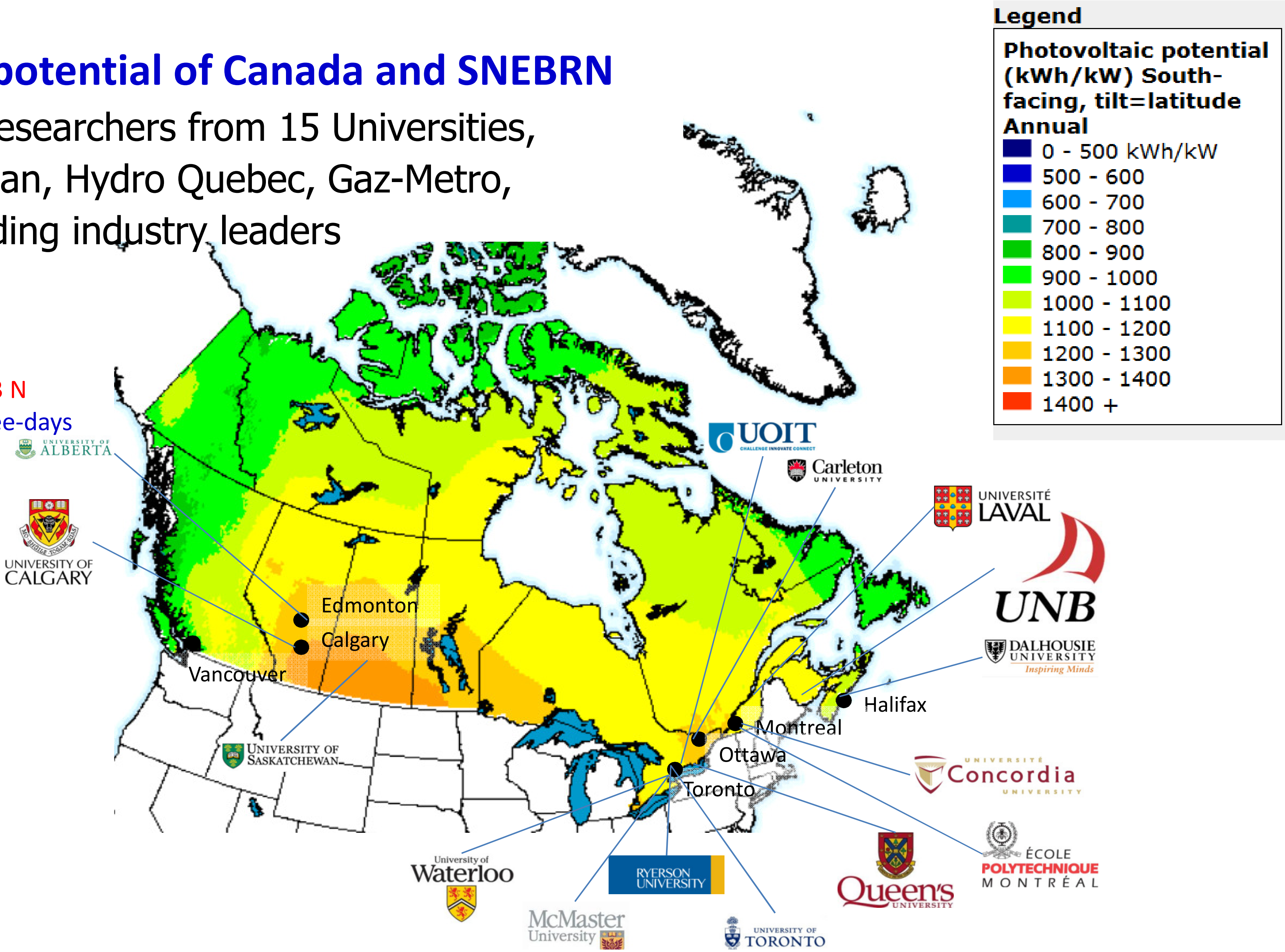


Optimize surfaces Ar and façade Aw simultaneously

PV potential of Canada and SNEBRN

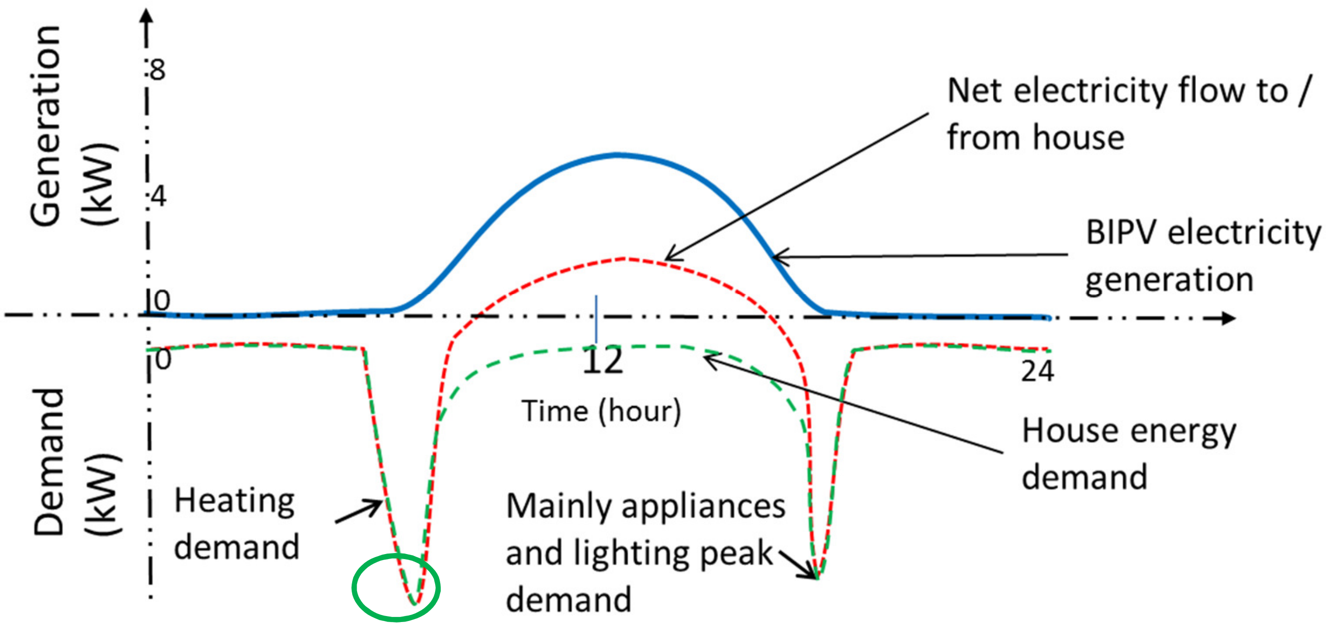
29 researchers from 15 Universities, NRCan, Hydro Quebec, Gaz-Metro, building industry leaders

Lat 53 N
Degree-days
5212



NSERC Smart Net-zero Energy Buildings strategic Research Network (SNEBRN)

Electricity demand and generation: typical profile for NZEB on cold clear day



Ontario has a summer (due to cooling) peak demand

27 GWe

Quebec has a winter peak demand

38 GWe on Jan. 24, 2011 7:30 am with

To = -33 C in Montreal

Peak heating demand can be reduced through predictive control

NZEBs need to be designed to ensure a predictable impact on the grid and to reduce and shift peak demand

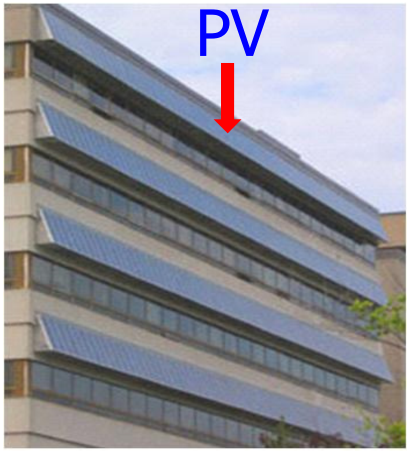
Towards net-zero energy

BUILDING SYSTEMS	CURRENT BUILDINGS	FUTURE SMART NET-ZERO ENERGY BUILDINGS
Building fabric	Passive, not designed as an energy system	Optimized for passive design and integration of active solar systems
Heating & Cooling	Large oversized systems	Small systems optimally controlled; integrated with solar, CHP; Communities: seasonal storage and district energy
Solar systems /renewables	No systematic integration – an after thought	Fully integrated: daylighting, solar thermal, PV, hybrid solar, geothermal systems, biofuels
Building operation	Building automation systems not used effectively	Predictive control to optimize comfort and energy performance; online demand prediction

Building-Integrated Photovoltaics (BIPV): Integration

- into roofs or facades – opaque or semitransparent PV in windows;
- PV panels could perform dual function as roof shingles;
- standard glazing and curtain wall technology employed with wires through framing;
- integration with HVAC;

→ functional integration, architectural and aesthetic.



Queen's U. (retrofit)

Univ. of Calgary

Not just adding solar technologies on buildings

EcoTerra™ EQuilibrium House

NSERC Solar Buildings Research Network Demonstration Project

2.8-kW Building-integrated PV-thermal system

Passive solar design: Optimized triple glazed windows and thermal mass

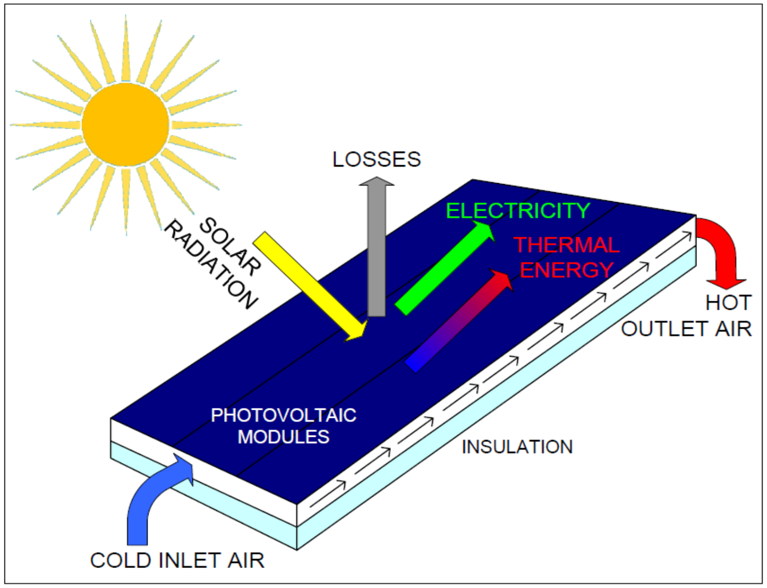
Ground-source heat pump

Partners: Alouette Homes, Concordia U., NRCan, CMHC, Hydro Quebec, Regulvar
Prefabricated home designed to have close to net-zero annual energy consumption

BIPV – integration in EcoTerra

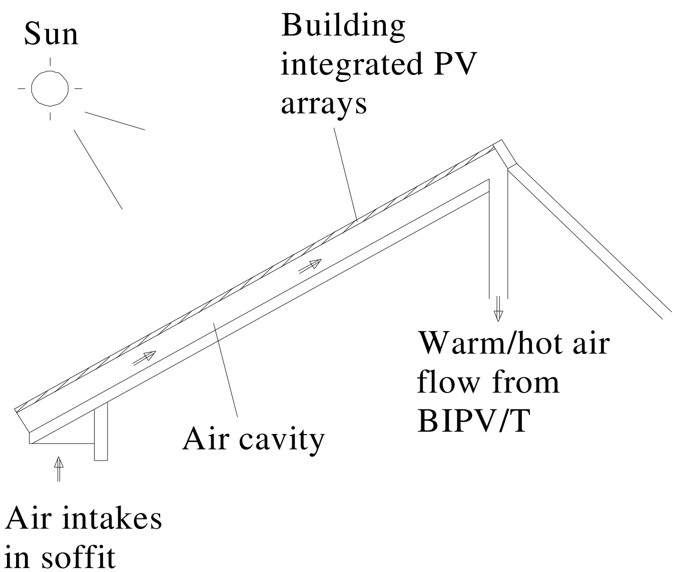
EcoTerra™

- Building integration: integration with the roof (envelope) and with HVAC
- BIPV/T – (photovoltaic/thermal systems): heat also recovered from the PV panels, raising overall solar energy utilization efficiency
- Heat recovery may be open loop with outdoor air or closed loop with a circulating liquid; possibly use a heat pump



Open loop air BIPV/T

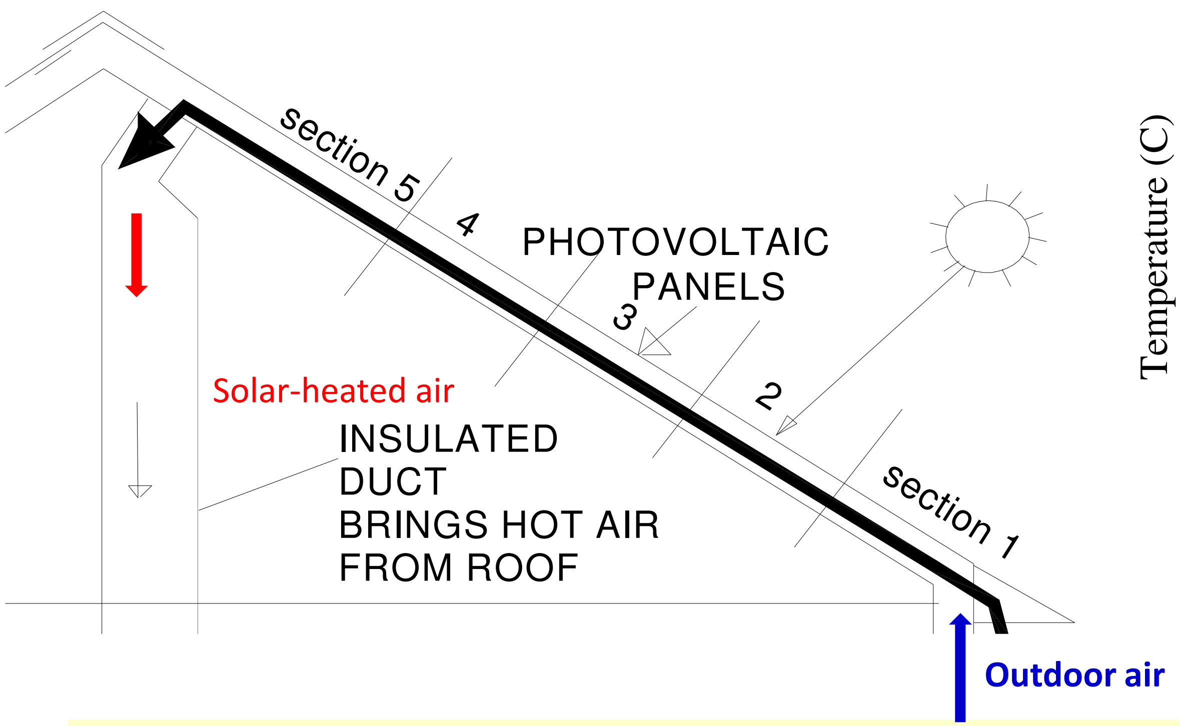
BIPV/T roof construction in Maisons Alouettes factory as one system – a major Canadian innovation

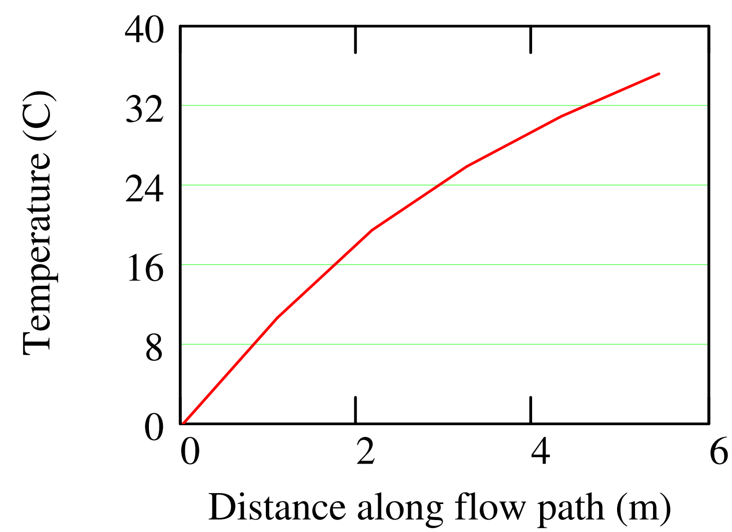


Based on research and simulation models developed at Concordia

BIPV/T roof in 5 sections for analysis: Energy model

Modelling work in SNEBRN to support industrial innovation





Building simulation: Similar modelling is done at Polytechnique on geothermal systems, Queen's U. on solar cooling, Carleton on seasonal storage and Waterloo/Ryerson on fenestration

Assembly of EcoTerra Modules (in ~ 5 h)




Prefabrication/pre-engineering can reduce cost of BIPV through integration

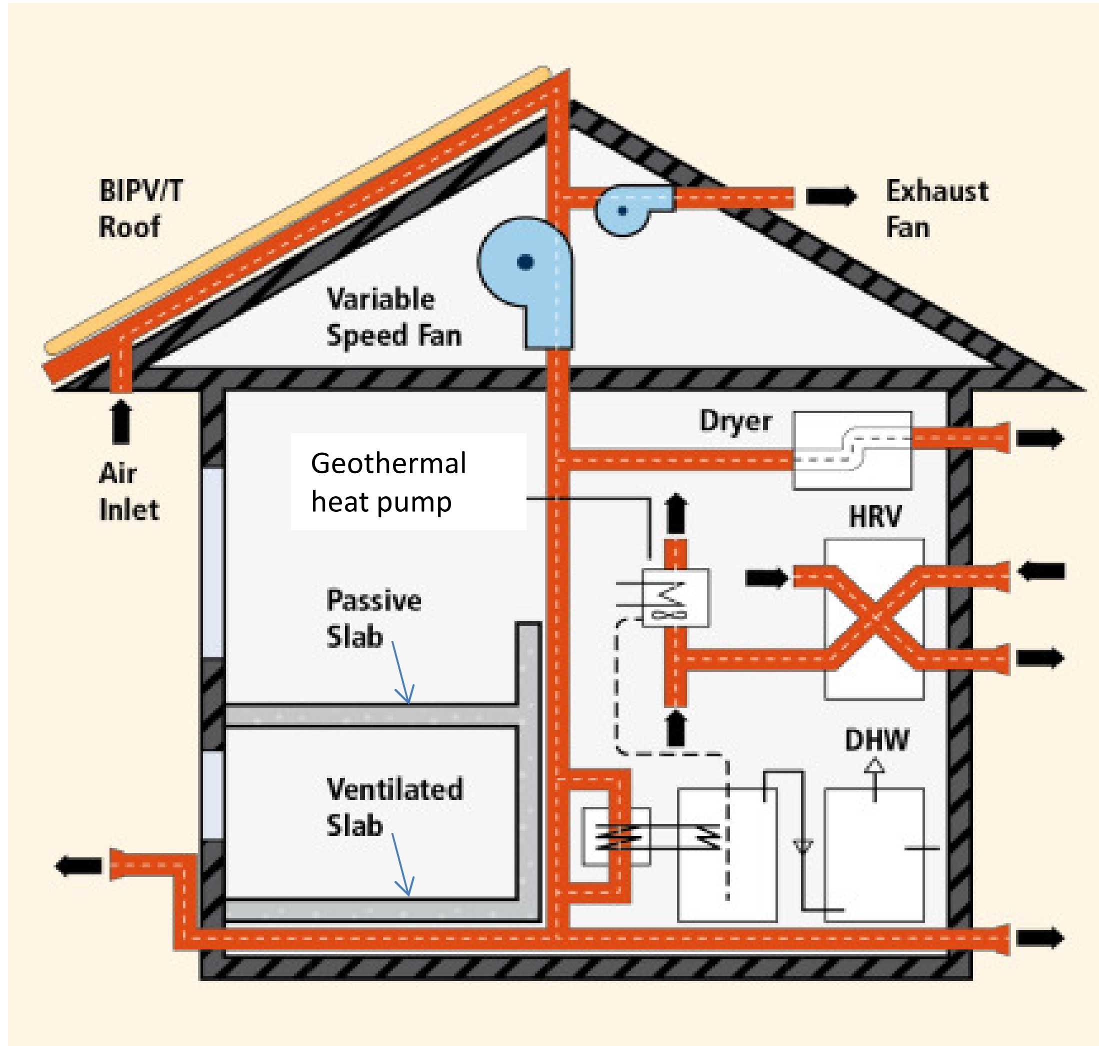
Built quality is enhanced

Passive design and integration with active systems

Near net-zero house; a higher efficiency PV system covering same area would result in net-zero.

Study of occupancy factors indicated importance of controls.

IEA Task 40 case study (SNEBRN/NRCan).



EcoTerra energy system

John Molson School of Business Building (JMSB) BIPV/T
A NSERC Solar Buildings Research Network Demo Project

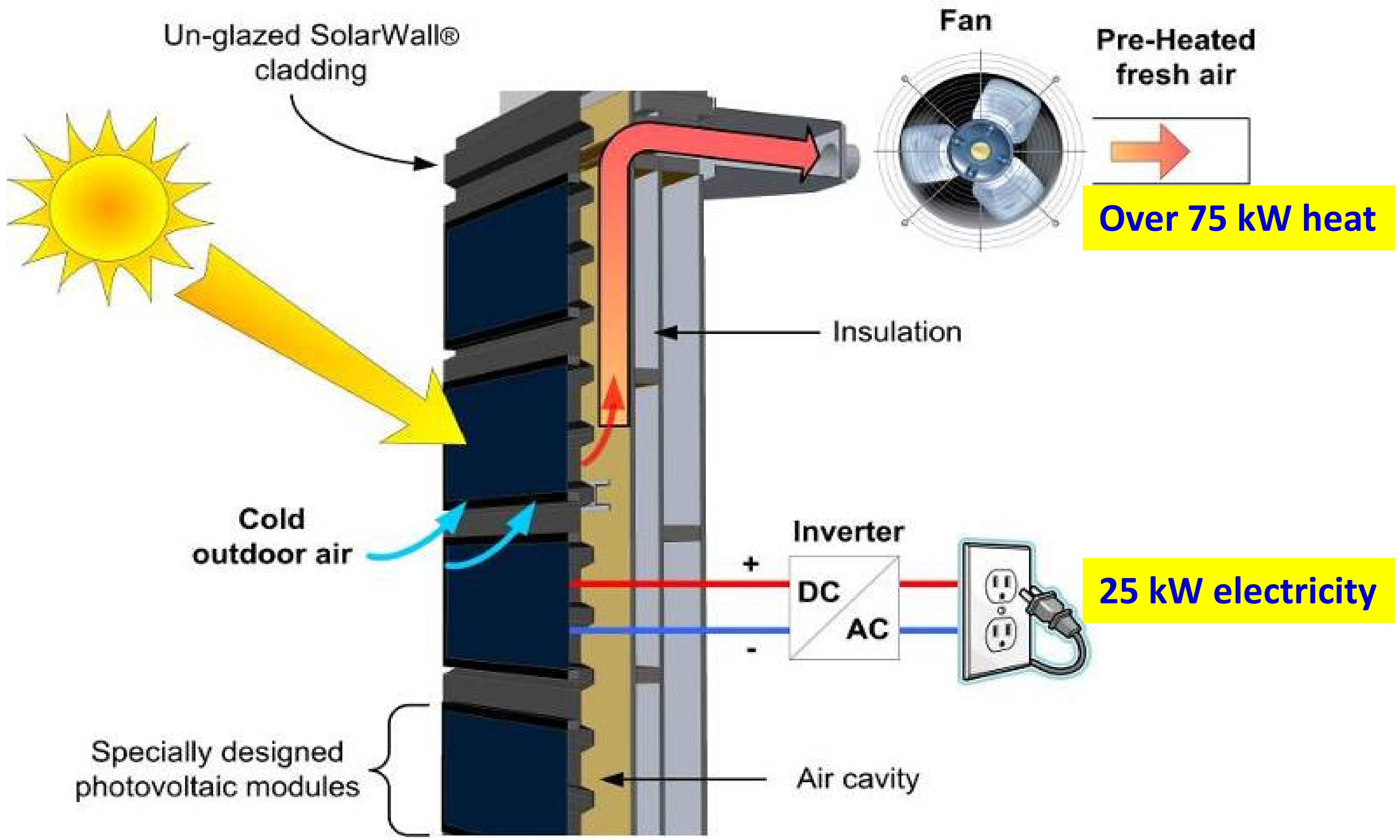
Back façade
of new building
(JMSB-Concordia)

Partners: Concordia University, Conserval, Day4 Energy, Schneider -Xantrex

Funded by NRCan TEAM Program
through CanmetENERGY Varennes

Brendan O'Neill – research engineer,
Josef Ayoub - NRCan

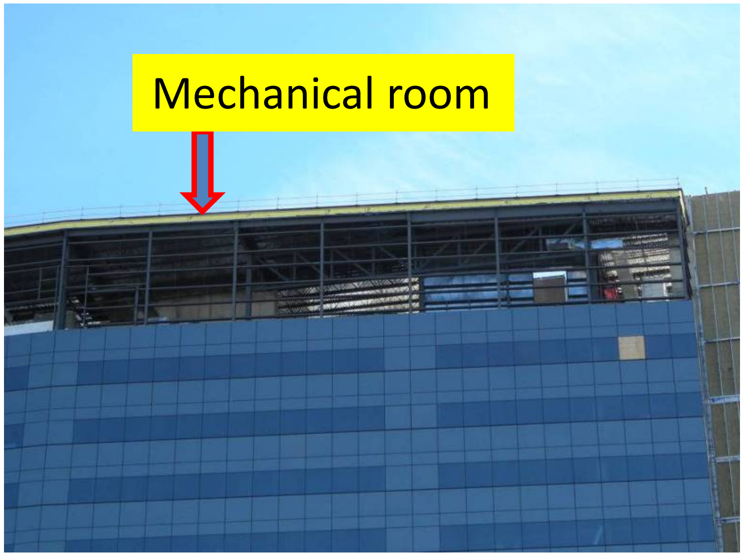
JMSB BIPV/T system schematic

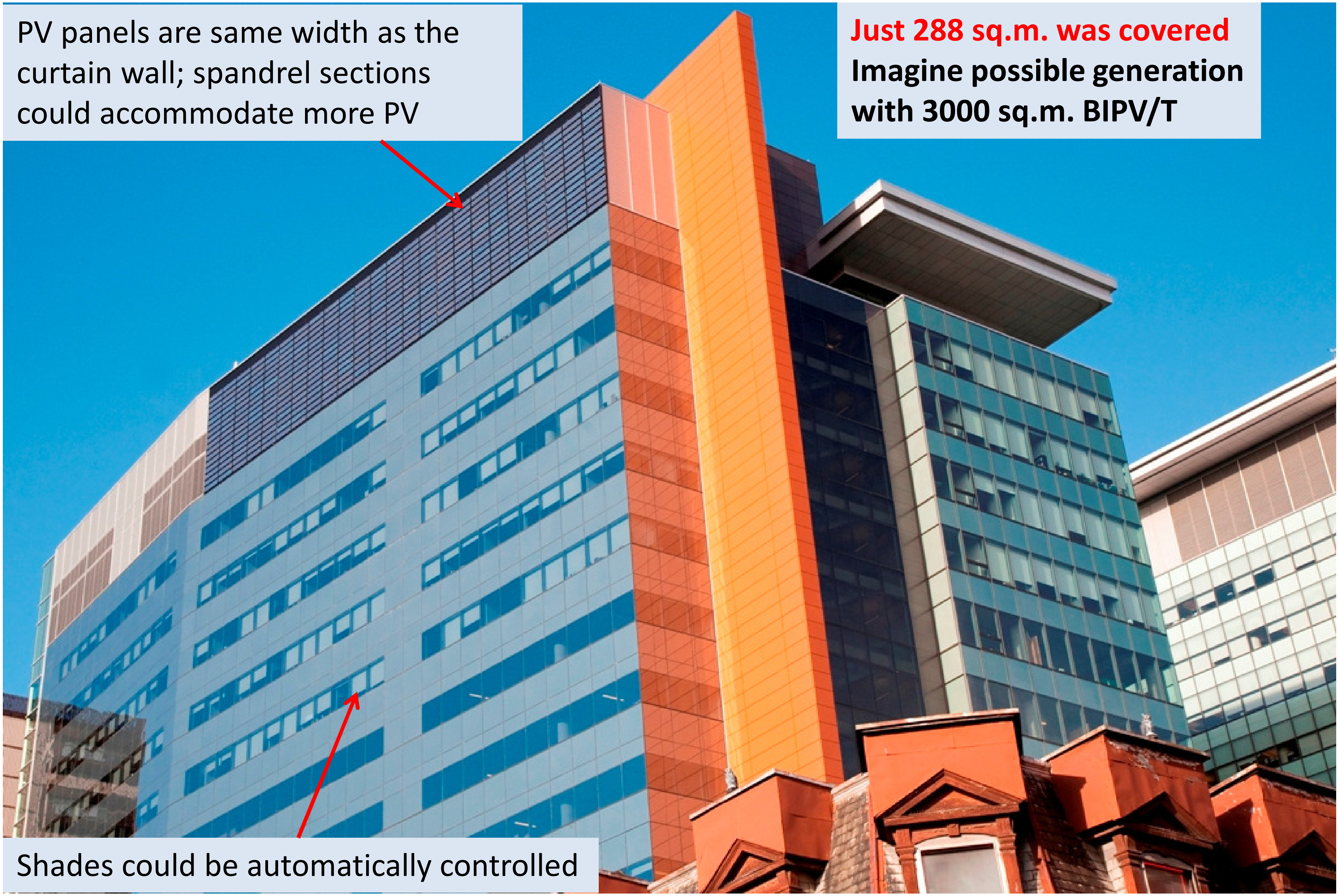


Optimal integration of unglazed transpired collector with specially designed PV to optimize heat recovery

JMSB BIPV/T SYSTEM – First of its kind

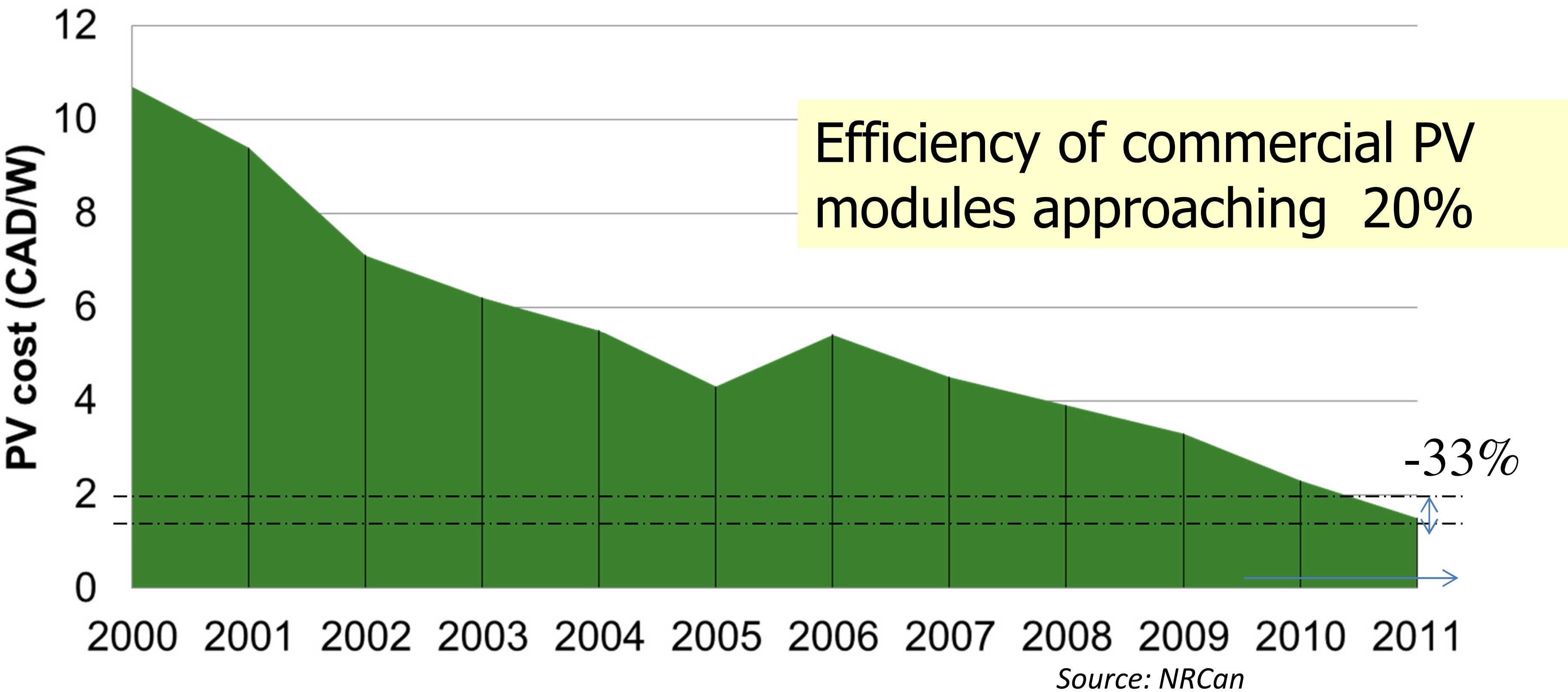
- Building surface ~ area 288 m^2 generates both solar electricity (up to 25 kilowatts) and solar heat (>75 kW of ventilation air heating)
- System forms the exterior wall layer of the building; it is <u>not</u> an add-on (building-integrated)
- Mechanical room is directly behind the BIPV/T façade – easy to connect with HVAC
- Total peak efficiency over 55%





More R&D needed to make design of such systems routine

Photovoltaics (PV) declining in price

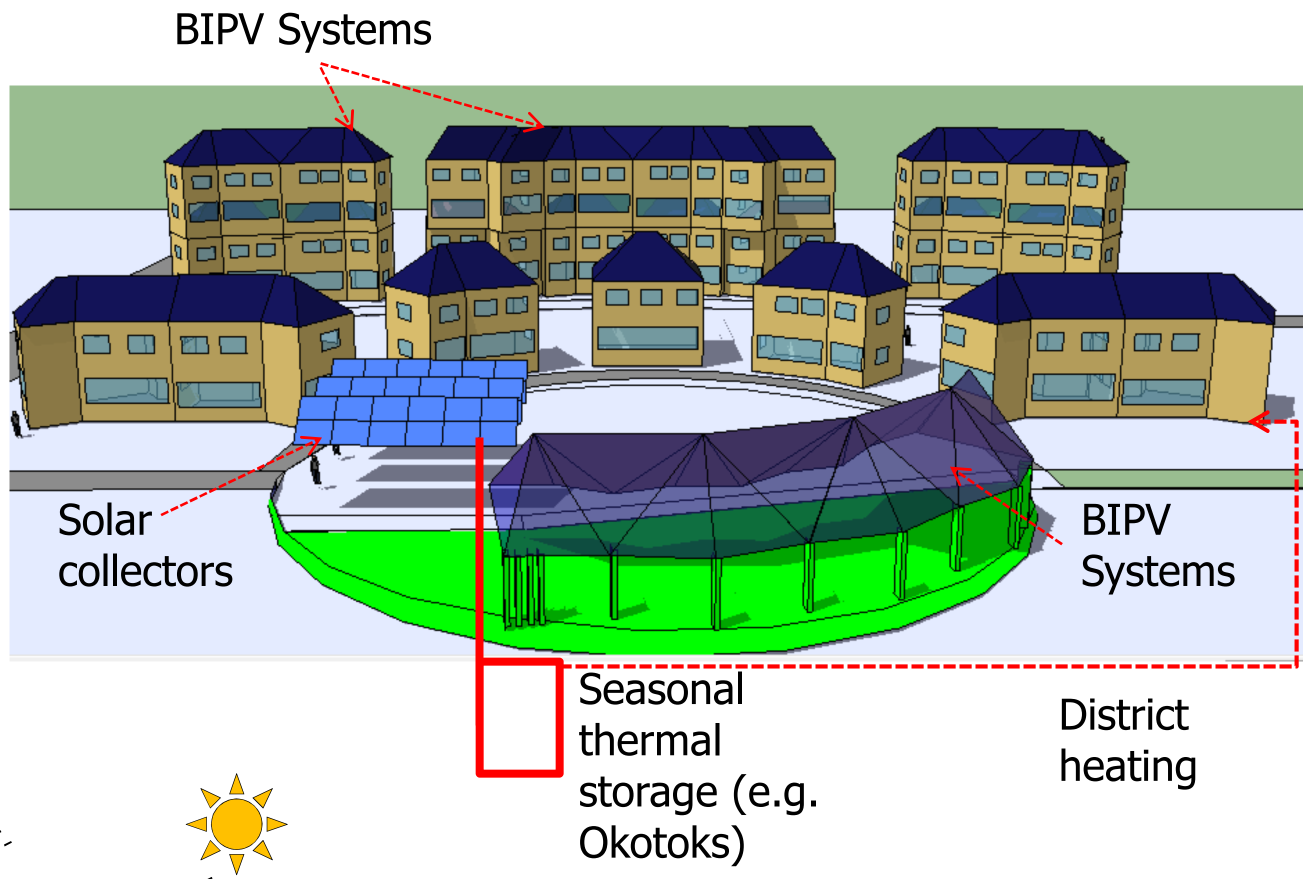


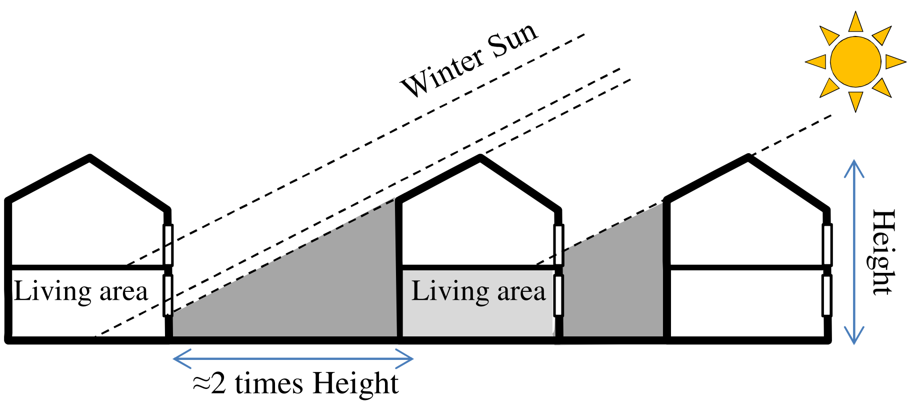
PV price has dropped by ~ **90% from 2000 to 2011!**

Now feasible to use PV as building façade and roof element on surfaces facing East-South-West (depends on location)

Solar Community Design

- Heating load is not significantly affected by the layout of streets, provided solar access is respected
- Some house shapes (e.g L-shape) are more beneficial in a specific site layout





Electricity generation 85%-110% of the total energy use of the neighborhood

Design: C. Hachem

Athienitis house, Domus award finalist

No snow on BIPV/T roof

Note large south facing window area

The path towards Smart NZEBs – an opportunity for innovation

- Buildings undergoing a transformation to reach net-zero
- Canada needs to be a leader – construction is the engine of economic growth, built environment is key to high quality of life
- NZEBs will lead to many novel products: exports, jobs
- Challenges:
  - fragmentation of building industry: need systems approach
  - transformative changes to building design and operation
  - training of engineers and architects
  - ambitious R&D programs: from basic research to full scale demos with a research component
  - incentive measures with multiple benefits such as production of renewable energy at times of peak demand