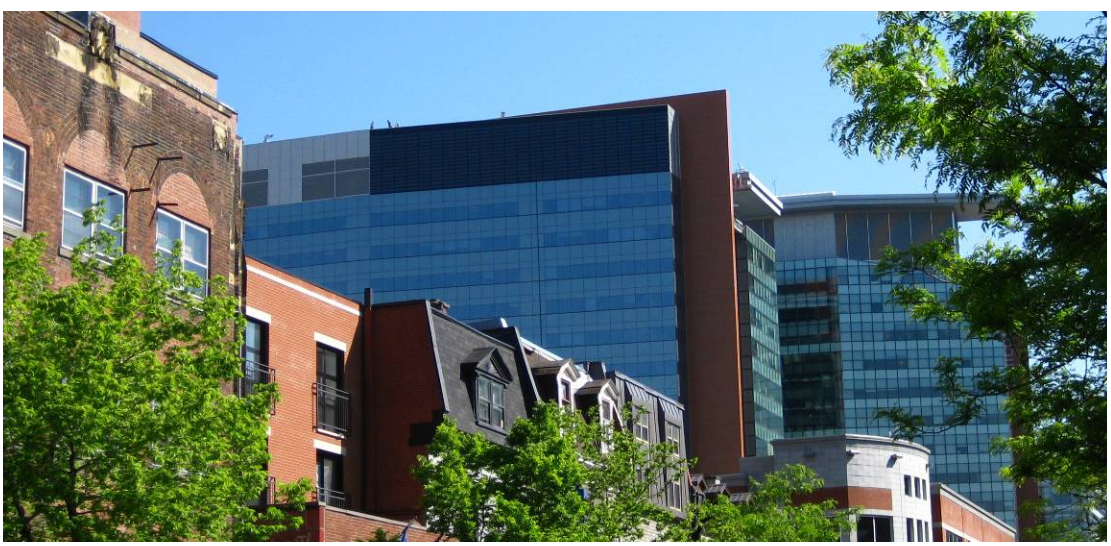
Building Integrated Combined Solar Thermal and Electric Generation Demonstration Project at Concordia University

Summary

An innovative solar energy installation has been installed at Concordia University's campus in downtown Montreal. With the design and implementation led by Dr. Andreas Athienitis of the *Building, Civil and Environmental Engineering* department, and also Principal Investigator of the *NSERC Solar Buildings Research Network (SBRN),* this project demonstrates state of the art solar technology optimized and integrated by Concordia University researchers for the cold Canadian climate. BCEE MASc graduate Brendan O'Neill worked as the project engineer for this installation, with the support of Meli Stylianou, SBRN Manager, and Gilles Desrochers, construction project manager.

The LEED® registered John Molson School of Business building will use a single façade surface to generate both heat and electricity from the sun. This type of solar installation is referred to as a Building Integrated Photovoltaic/Thermal (BIPV/T) application, and it is the first installation of its particular configuration. The combined generation is expected to have an overall efficiency of about 60% (the rate of utilization of incident solar energy).



JMSB Building Solar Façade, Concordia University

Project Highlights

- Building-integrated photovoltaic/thermal installation (BIPV/T) combining electric generation and high efficiency solar air heating from the same surface. World's first fully functional architecturally integrated BIPV/T façade that uses high-efficiency distributed air inlet technology.
- 24.5 kWp photovoltaic (PV) installation (Day4 Energy modules).
    - Largest PV Installation to date in Québec.
- Up to 75 kWp of heat by fresh-air solar heating with a 288 m^2 SolarWall® system (Conserval Engineering); will preheat up to about 15,000 cfm of fresh air.
- "Parallel-interconnect" inverters (Sustainable Energy Technologies) to increase PV yield.
- Construction completion date: December 18, 2008.

This project was funded by Natural Resources Canada's Technology Early Action Measures (TEAM) program, championed by Josef Ayoub of CanmetENERGY at the Varennes research centre, with significant contributions from the Agence de l'efficacité énergétique and from network partners Conserval Engineering, Day4 Energy and Sustainable Energy Technologies.

Background

Renewable energy generation using radiation from the sun is most often carried out in two forms: thermal generation, for heating air or water; and electric generation using the photovoltaic effect. The former is usually the most efficient process, although the delivery of thermal energy at the right time and temperature can be problematic. Heat may not always be needed, and the temperature specific nature of any application – such as taking a shower versus boiling water – means that the available heat may not always meet the requirements. Pre-heating ventilation fresh air for buildings, as in the JMSB building, assures that all of the solar heat is recovered as usable energy.

High-grade energy in the form of electricity can be used for wide variety of applications, and can be easily transported. Converting the sun's rays to electricity, however, can be 3 to 4 times less efficient than that of thermal conversion. Due to this, the design of a solar energy project must consider the type of energy required, the end use, and attempt to **maximize efficiency**.

Aside from the obvious environmental benefits associated with using renewable solar energy, the ability to generate heat and electricity at the site of consumption eliminates the cost and inefficiencies inherent in off-site generation. These include electric line transmission losses, and the energy required to pump oil and compress natural gas.

Buildings are ideal platforms for renewable solar energy generation systems. They can provide the support structure for the technology, with little or no extra cost, and the energy produced will most likely be consumed immediately on site. It is a somewhat overlooked fact, but buildings consume about 30% of all secondary energy produced in Canada, in the form of natural gas, oil and electricity. Half of all the electricity generated in Canada is consumed in buildings[1] (NRCan, 2007). Building integrated renewable energy systems allow for the construction of buildings that can provide their own heat and electricity, while relying less on external sources.

In an urban environment, access to the solar resource may not always be readily available. Shading from neighbouring structures is always an issue in project design. When a well-oriented and un-shaded surface is available, an ideal system will recover the solar energy incident on this surface with a high efficiency. Building Integrated Photovoltaic/Thermal (BIPV/T) systems can simultaneously produce both heat and electricity, and are thus a solution that values well-exposed solar surfaces.

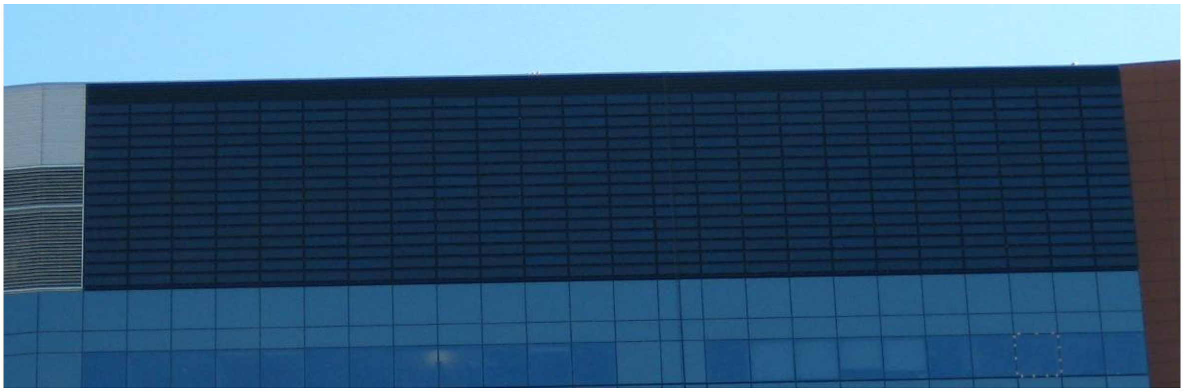
[1] Natural Resources Canada: Office of Energy Efficiency (2007). Energy use data handbook tables, *Technical Report OEE 2952*.

JMSB Building PV/T System

The John Molson School of Business (JMSB) building-integrated photovoltaic/thermal (BIPV/T) installation is the first of its kind – a fully integrated installation that uses a high efficiency distributed air inlet method to recover heat from the PV panels.

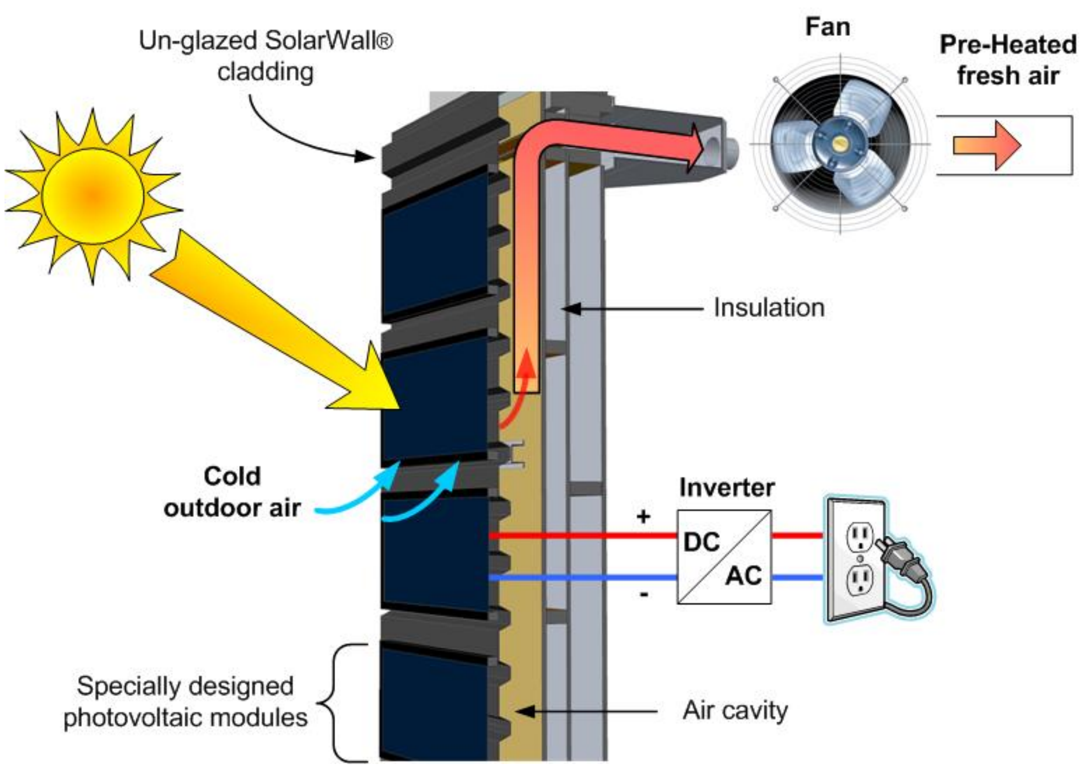
JMSB Building from street level showing the integrated BIPV/T facade

The combined generation of heat and electricity optimizes the useful energy generated from the sun, producing up to three times more heat than electricity. For the thermal aspect, the system will act as a large solar air collector that preheats fresh air to meet the ventilation needs of the building's occupants. As the system operates, the photovoltaic panels – those that create electricity – will be cooled. As is commonly known, cooling electrical equipment, such as computer chips, increases the electrical performance. The same is true for photovoltaic panels.



JMSB Photovoltaic/Thermal Solar Wall

On sunny days during the heating season, large amounts of fresh air will be heated with a temperature increase of about 20°C. This low temperature application of fresh-air heating has high energy recovery efficiencies, and for institutional buildings such as the JMSB, fresh air is always required for ventilation. The warmed air is then delivered to the building HVAC system, where it is further heated, if required.



JMSB PV/T Process Flow Diagram

As mentioned, a great deal of the heat supplied to the fresh air is removed from the photovoltaic panels. This heat removal will increase the total number of watts produced by each panel. Typically, the efficiency of the PV panels can be increased by 5% on cold sunny days, compared to a traditional installation.

The JMSB BIPV/T installation will allow for the production of up to approximately 100 MW-hr per year, displacing both natural gas and electricity from the grid. The vertical installation will allow for high energy production in the winter season and reduce maintenance requirements, especially those caused by snow loads. This innovative installation will be continuously monitored to properly quantify the annual energy produced, and to determine the applicability of future projects in Canada. An energy display, located in the lobby of the JMSB, will allow for students and the public alike to view the real-time energy captured from the sun and supplied to the building.

The system will be monitored by a research team at Concordia headed by Dr. Athienitis, the Scientific Director of SBRN. A monitoring room has been allocated to house monitoring equipment in the mechanical equipment floor of the JMSB building. Through monitoring of this innovative system new simulation models will be developed for its design and optimal control.

Custom PV modules being installed on the transpired solar thermal air collector

Project Partners

NSERC Solar Buildings Research Network

The NSERC Solar Buildings Research Network (SBRN) based at Concordia University is the lead organization in this collaboration. Natural Resources Canada's CanmetENERGY located in Varennes has been a significant partner on this initiative and others. SBRN is currently the major Canadian research effort focused on solar energy and buildings. It brings together 26 Canadian researchers from 11 universities to develop the solar-optimized homes and commercial buildings of the future. The Network also includes researchers and experts from Natural Resources Canada (NRCan), the Canada Housing and Mortgage Corporation (CMHC) and Hydro-Québec. The budget of the Network between 2005 and 2010 is about $7 million, with $5.1 million from NSERC; about $1.6 million from NRCan; $250,000 from CMHC; $75,000 from Hydro-Québec; and more than $1.5 million in-kind support from more than 20 industrial partners. Industrial partners from the energy and construction sectors are involved in most projects, developing the know-how that will help them compete in the global market.

Day4 Energy

Day4 Energy, located in Burnaby, BC, is the PV module supplier and industrial SBRN partner. Day4 Energy produced custom polycrystalline modules for the JMSB project based on the recommendations of the design team. The Day4 Electrode, Day4 Energy's core innovation, improves power output, cost, lifetime and aesthetic appearance of photovoltaics and enables next generation innovations. The Day4 Electrode enables a lower cost module with conversion efficiencies of 14.7%.

SolarWall® by Conserval Engineering

Conserval Engineering commercialized the transpired solar air collector branded as "SolarWall". This system is a high efficiency solar air heater that works very well for low temperature applications. For the JMSB BIPV/T project, the application of this product was extended to also act as the collector of the air heated by the photovoltaic panels, as well as acting as the support structure for the PV. The use of the SolarWall® product, and the support of Conserval Engineering, allowed for the design and manufacture of a completely building integrated photovoltaic/thermal system.

Sustainable Energy Technologies

Sustainable Energy Technologies (SET) is the project partner that supplied five 5kW inverters for this project, and offered valuable advice on the optimum layout and connections of the photovoltaic panels. The SET SUNERGY™ inverters are unique in the industry for their extra low operating voltages that enables PV modules to be wired in parallel, eliminating mismatch losses and improving energy yield from PV systems.

John Molson School of Business: Building Integrated PV-Thermal System

SOLAR BUILDINGS RESEARCH NETWORK

RÉSEAU DE RECHERCHE SUR LES BÂTIMENTS SOLAIRES

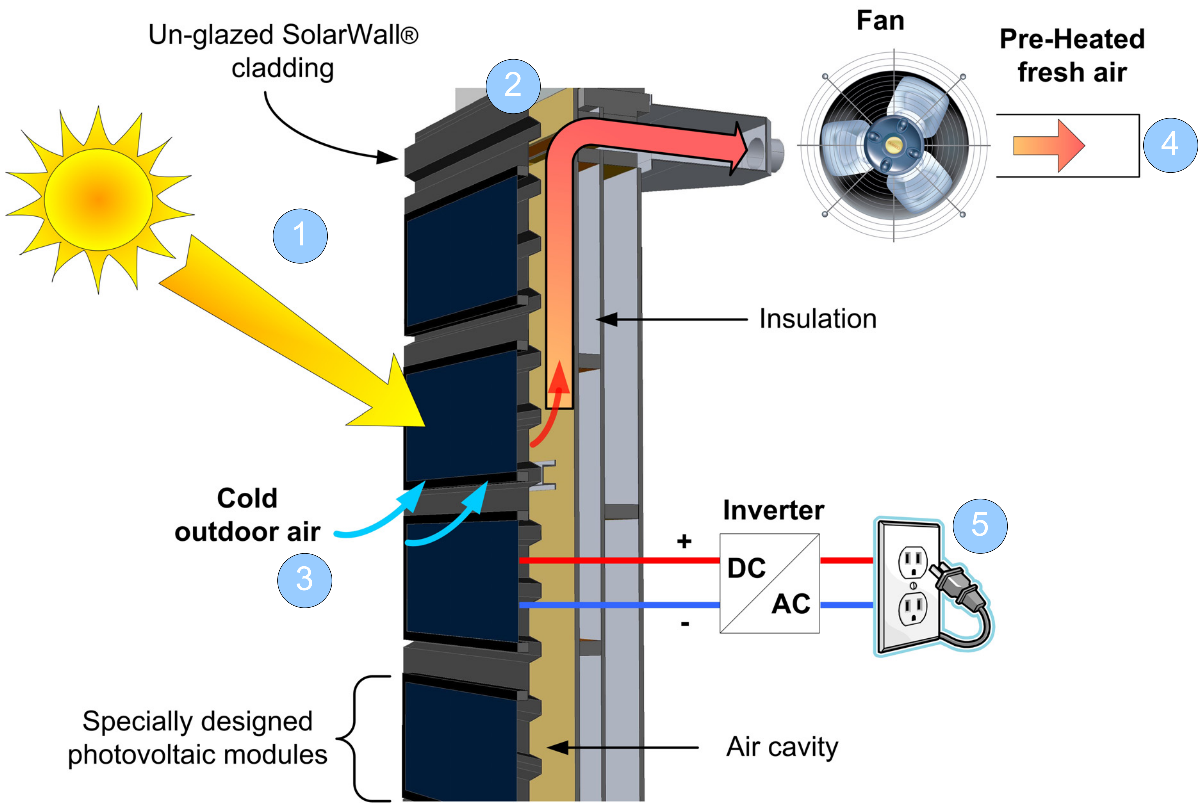
Building Integrated Photovoltaic / Thermal (BIPV/T)

PV/T is a process whereby solar energy is converted to electricity and heat from the same surface. These surfaces can be integrated on a building's facade, and contribute to powering and heating the interior.

When the sun is shining, our system can provide up to 25 kW of electricity and 75 kW of heat: enough energy to turn on 1,250 CFL light bulbs, and provide heat for 7 Canadian homes throughout the year.

Making this system a functional part of the building façade is advantageous as it creates renewable energy at a lower cost, and the combined efficiency can be higher than that of two separate systems.

1. Solar energy strikes the façade surface. The PV panels and SolarWall collector can be 40°C warmer than the outdoor air.
2. The SolarWall collector has many small holes that allow air to pass through.
3. Using a fan, cold outdoor air is forced behind the PV panels where it warms up. The heat removed from the PV panels allows for better electrical performance.
4. The warm air is delivered to the building's mechanical room, which is directly behind the façade.
5. More electricity is created by the PV panels because they are now "cool". This electricity is converted from DC to AC, and consumed by the building or fed to the utility grid.



Process Schematic: Solar heated air and electricity are delivered to the building

JMSB Building and the BIPV/T Renewable Energy System Architecturally Integrated into the Façade

Close-up of BIPV/T Façade