

Developments with BIPV Systems in Canada

L. Stamenic

British Columbia Institute of Technology (BCIT), Technology Centre
3700 Willingdon Avenue
Burnaby, BC, V5G 3H2, Canada
Phone: +1-604-451-6934, Fax: 1-604-436-0286,
E-mail: lstameni@bcit.ca

(Received : 31 January 2004 – Accepted : 15 March 2004)

Abstract : Recognizing BIPV as the most economically attractive application for grid tied PV technology, BCIT participated in various BIPV projects across Canada. Each project highlights a different aspect of BIPV, and demonstrates the PV potential in the built environment. This paper analyzes the benefits of each BIPV system and describes the lessons learned during the design and installation process. An overriding feature of each of these BIPV projects was the amount of custom design work required to integrate the PV components into the building, and to interconnect the various components within the system. Each project required the collaboration of design engineers, architects, electricians, glaziers, inspection authorities and equipment manufacturers. Analysis of each project gave the experience to make recommendations for

changes to the code, suggest best practices for BIPV system design and development, as well as highlight some of the deficiencies in the existing PV marketplace.

Introduction

Good products should not only satisfy the end-user's needs, but also be advantageous to the environment. Electricity is no exception to this rule. Solar electricity can make a contribution to world energy supplies, while simultaneously helping us slow down global climate change.

Approximately 75% of the energy used in the developed world is consumed in cities and up to 40% of that energy is used in buildings. Photovoltaics can be integrated on virtually every conceivable structure from bus shelters to high rise buildings or even turned into landscaping elements. Although the exact analysis of the potential of PV in buildings calls for careful assessment of several factors including solar availability on building surfaces, institutional restrictions and electric grid stability, it is easy to become convinced of the large potential of this technology. Even in climates of only moderate solar radiation, such as Canada, the roof top of a single family dwelling can readily accommodate a PV array large enough for electric self-sufficiency on an annual basis.

Solar electricity is a relatively expensive means of producing electricity. Building integrated photovoltaics (BIPV) partially addresses this problem by reducing the overall cost of

solar electricity and by providing benefits in addition to energy production.

The solar energy resource in Canada is characterized by large variation between seasons. This characteristic of Canadian weather makes grid tied PV systems more efficient than off-grid systems since battery storage is not required and the energy generated can be averaged over the year. However, the low cost of utility electricity in Canada prevents grid-tied PV systems from being a viable economic choice unless other values can be obtained from the PV system. Using photovoltaic modules as building materials, BIPV partially addresses this problem by reducing the overall cost of solar electricity and by providing other benefits such as: acoustic and thermal insulation, weather proofing, aesthetics, daylighting, shading and privacy

Promoting the use of BIPV systems in Canada requires the implementation of complimentary programs, such as net metering. Equally important is certification of equipment and the personnel that design and install PV systems. Finally, BIPV consumers' acceptance also requires education and marketing to promote the non-financial benefits of BIPV. Actual uptake will depend upon consumers' willingness to pay for non-financial benefits.

Building Integrated Photovoltaics (BIPV)

Traditionally, PV arrays have been mounted on special support structures. However, they can also be an integral part of the building envelope, thus creating a natural on-site link

between the supply and demand of electricity. Once put in the building context, PV should not be viewed only from the energy production point of view. Because of the physical characteristics of the PV module itself, these components can be regarded as multifunctional building elements that provide both shelter and power.

The architectural integration of solar PV technology requires an interdisciplinary design approach. This not only imposes collaboration and the presence of highly specialized professionals on the project, but also introduces a sensitivity that goes beyond the building itself, such as social, economic, environmental, energy and ecological issues [1].

The BIPV design is a relatively new method of reducing the installed cost of PV power systems, particularly in the urban environment. By displacing conventional building materials, the photovoltaic array plays a dual role and the overall cost is less than if the PV modules are simply added to the building structure. As a form of distributed generation, BIPV has the additional benefit of producing electricity close to the point of use, thus reducing transmission and distribution losses.

There are many methods of using BIPV in a building. The BIPV roofing incorporates solar cells into conventional roofing products such as tiles or metal roofing. Glass based BIPV modules may be used in atria to replace overhead, semi-transparent glazing or in sunspaces, greenhouses and medium to large skylights. Curtain walls represent an even larger market for BIPV modules.

Successful programs around the world have shown that many residential customers are willing to pay a premium for their electricity if it is generated with environmentally sustainable technology. Customers benefit from the satisfaction they feel and the social status imparted by being a leader in their community. BIPV is a highly visible indication of a company's commitment to social and environmental values. Commercial customers benefit from PV by associating their company or product with environmentally sustainable energy generation. BIPV also sets a commercial building apart visually, thus enhancing public exposure. The environmental benefits of PV power also include green house gas (GHG) reductions.

Performed BIPV Projects

Recognizing BIPV as the most economically attractive application for grid-connected PV technology in the near term, BCIT participated in various demonstration BIPV projects over the past couple of years. Each project highlights a different aspect of BIPV, and demonstrates the potential for solar electricity in the urban environment [5].

The BCIT acted as the PV R&D consultant on each project and assisted in designing and coordinating the mechanical and electrical integration of BIPV systems. The other participants had limited knowledge of BIPV or photovoltaic systems in general, and a key part of each project

was the educational component, as well as the collaboration that was required in order to realize projects.

RetScreen and BIPV Optimizer software tools were used for estimating energy production and GHG reductions for each project. A considerable amount of experience was gained by all parties that helps further the commercialization of grid-connected BIPV systems in Canada.

Canada has benefited for years from an inexpensive supply of power generation. However, due to the environmental disruption of large-scale hydro electricity, as well as nuclear and thermal power plants and in order to meet future electricity demand and maintain low GHG emissions, the potential for renewable energy sources and their integration into the existing electricity supply network must be explored. Following is the analysis of the benefits of some BIPV systems and description of the lessons learned during the design and installation of each project.

1. Ventilated BIPV Facade

A recently completed project in downtown Vancouver demonstrates the potential of photovoltaics when used in an innovative way (Fig.1). The PEARL research team developed and installed a BIPV ventilation system as part of the refurbishment of a building belonging to the telecom company, Telus. Using principles similar to double-glazed storm windows, designers laid the building's new glazed façade over the old, creating an aesthetically pleasing, insulating air space (plenum).

The space is ventilated with fans powered by BIPV modules incorporated into the façade. The plenum was turned into a temperature-regulating façade with the installation of motorized dampers at its top and bottom. The dampers naturally ventilate the air in the summer through the “stack effect” with the help of PV powered fans at the top of the plenum to boost air movement. In the winter, when the dampers are closed, the plenum acts as an insulator [3].



Figure1. Telus BIPV ventilated façade.

The new façade enhances the thermal performance of the building envelope by controlled ventilation of the air space behind the façade. In order to achieve sufficient airflow within the façade, forced ventilation is required. The integration of a PV array within the ventilated façade is an attractive source of energy because the ventilation fans are operated directly by the PV array during sunny periods when ventilation is most required. In addition, the airflow cools the PV array and enhances its performance. Two sub-arrays of custom, semi-

transparent, PV modules are incorporated into both sides of the Telus new glazed curtain wall façade. Maximum DC power generated by this highly optimized BIPV array is 2.5 kW, which is dedicated to powering 12 high-efficiency DC ventilation fans. The power output of the array was optimized for each sub-array by the use of unique maximum-power-point (MPP) tracking controller. They are used to optimize the interface of BIPV array and ventilation fans by utilizing maximum available PV generated power.

The application of PV into buildings often depends on their ability to be integrated into common building structures such as facade elements. A building is a combination of many complex systems: architectural, structural, mechanical, electrical, etc. Changes to the parameters of one system affect the others. The BCIT carried out a multidisciplinary approach to the assessment of the performance of a BIPV system as an element of a building skin. Some lessons learned in this project are:

- The PV powered ventilation system required coordinated design efforts between the mechanical engineer, electrical engineer and photovoltaic specialist.
- PV arrays that directly operate loads must be sized based on power output under actual operating conditions to ensure adequate power is delivered to the electrical load.

- Conservative design values of irradiance and PV cell temperature must be applied to ensure sufficient power is available to operate direct electrical loads.

The integration of ventilated photovoltaic facades into the building envelope offers substantial opportunities for widely reducing the building's fossil fuel energy consumption, as well as providing power autonomy.

2. Discovery Parks BIPV System

Discovery Parks, a research incubator facility for emerging high tech companies, is located in Burnaby. The building has a 3.5 kW PV array integrated into the glass façade overlooking the entrance to the building (Fig.2). A combination of semi-transparent and opaque amorphous silicon thin-film modules are used as visual elements in the glass curtain wall façade, generating electricity while simultaneously providing interior day-lighting [4].



Figure 2. Discovery Parks BIPV system.

From the outside the solar electric modules blend seamlessly with the standard window glass. Inside, close inspection reveals the laser-scribed dots on the semi-transparent PV modules, which allow the a-Si modules to transmit up to 30% of the incident light. This light transmission provides light to the interior of the building while maintaining privacy and reducing glare. The opaque modules, which cover non-visual portions of the façade-spandrel area, are not visible from the inside.

The array of BIPV modules are assembled into the curtain wall, which conceals all the module wiring in the curtain wall mullions. The Kawneer curtain wall system with a thermal break embrace the PV modules that are electrically connected into two sub-arrays – one facing south, the other facing west. Each sub-array is connected to its own grid-tied inverter.

The project had several objectives including GHG reduction, research and public demonstration of BIPV technology. The DPI system is an attractive example of BIPV technology - the BIPV entryway enhances the architectural appeal of the building and the use of green energy in the building has been a useful sales tool for the building owner. Integration of this type of photovoltaic modules into a curtain wall was novel and new techniques had to be developed for preparing, installing and electrically interconnecting the modules. The semi-transparent modules were an untried product and the voltage mismatch between modules had the greatest impact on system performance. Nonetheless, the semi-

transparent modules are the most architecturally interesting aspect of this BIPV project. Co-operation between the architect, photovoltaic engineer, electricians, glaziers, and suppliers was required.

Monthly inspections to record the energy production and operating parameters of the system were conducted over the past couple of years. Continuous data logging was also conducted at different times to profile the performance of the system and ensure there were no transient problems that would be missed during the monthly inspections. Some of the lessons learned in this project are:

- A standard for specifying the equipment and installation of BIPV modules is needed in order to speed the development and design process. Voltage and current characteristics of PV modules must be specified and verified before the final system design is approved.
- The requirement for manual reconnection of the system after a power outage resulted in the system being occasionally off-line. Local utility has changed their interconnection requirements, allowing automatic reconnection as per UL1741.
- Computer modelling is essential for realistic estimation of BIPV performance.
- The installation required co-operation between architect, photovoltaic engineer, electricians, glaziers, and equipment suppliers.

3. Home 2000

Home 2000 (Figure 3) is a sophisticated, three-story, prefabricated modular house featuring roof integrated solar modules. In addition to being modular and transportable, the house contains many advanced energy saving features (heat recovery ventilation system, energy efficient lighting and energy efficient appliances), healthy building materials, and a flexible floor plan. The skylight covering one side of the roof is actually an array of BIPV modules. The approximately 2.5 kW BIPV array provides most of the electrical needs of the house. A hybrid grid interactive inverter feeds the solar electricity into the distribution panel of the house, while also charging a battery back-up system. The BIPV solar modules are integrated directly into the roof, replacing the standing seam metal roofing used on the remainder of the house. The blue, multi-crystalline cells are arranged in glass-on-glass modules spacing between them to allow for day lighting of the third floor attic, creating a beautiful livable space [4].



Figure 3. Home 2000 BIPV installation.

The objective of this project was to demonstrate the practical application of a BIPV system in an energy efficient modular home. In addition to demonstrating Flex Housing principles, the Home 2000 showcases Healthy Housing principles that include on-site generation of electricity by a PV array. The house is now used to raise awareness, educate and create a demand for the various technologies and concepts displayed in the house.

The main lesson learned is that there is a great need for standard BIPV module designs that fit standard building dimensions, especially in residential construction where standard stud, joist and rafter spacing is used.

4. PV Power Tower

The PV Power Tower is a unique BIPV installation that provides Canada with a first class platform for multi-disciplinary applied R&D and education in BIPV, specifically aimed at encouraging and stimulating cooperation and coordinated effort among researchers from universities and industry.

The PV Power Tower is approximately 15m tall structure, on a 2m x 2m base, that incorporates custom-made rainbow color photovoltaic modules on all four sides (Fig.4). The PV Tower is intended to serve at least three functions. It is an R&D facility, a training facility, and a commercial prototype. By making it to serve more than one purpose researchers are able to

achieve valuable synergistic benefits. The multipurpose PV Power Tower is used both as a research/testing tool and educational/training facility for researchers, students, and engineers. Although each side of the tower is currently connected to the local utility grid, the tower could also act as a stand alone power generator for remote locations for various residential, commercial and industrial applications.



Figure 4. Photovoltaic Power Tower.

The tower comprises comprehensive data acquisition system for monitoring real four sides BIPV system. Even though grid connected, the Tower also includes space for the testing and monitoring of a variety of photovoltaic system components, such as power conditioning equipment and batteries. Its innovative frame structure design allows for easy re-configuration of BIPV modules to simulate various PV system layouts. The panels and their associated wiring could be easily

accessible to a researcher/student who climbs into the inside of the tower - and in this space one can set up instrumentation and other research equipment as required. This kind of flexibility and versatility is not always available with BIPV systems mounted in or on the walls of a building.

Some of the research and related activities that will be pursued with the PV Power Tower include:

- Research into BIPV - includes broad-spectrum data acquisition and monitoring; validation of computer models, simulations and design tools; real time four sides vertical BIPV system monitoring.
- Comprehensive testing of inverters and other electronic gear in regard to PV and grid-connection;
- Development of guidelines for industry and utilities to achieve safe, cost-effective, highly efficient BIPV products, devices and systems;
- Photovoltaic training for researchers, engineers, architects and others;
- Contract research and testing for industry, utilities and academia.

Conclusion

The experience gained from these demonstration projects was broad and resulted in significant transfer of knowledge to the engineering, architectural, contracting and building

development community in Canada. All the projects required a high degree of coordination between the various engineers and contractors in order to successfully integrate PV technology into the buildings [2].

These projects highlighted the importance of recognizing the limitations of estimation or feasibility study software and the importance of using more sophisticated computer modelling to determine realistic BIPV system performance. Photovoltaic arrays are a unique energy generation technology that, unlike most other power sources, are extremely dependent upon the location and installation details of the system.

The four mentioned, as well as many other BIPV projects, continue to provoke interest in photovoltaic energy in Canada. Many visitors and students regularly visit the systems and the BCIT has participated in numerous other Canadian BIPV projects that have benefited from the lessons learned from the mentioned installations.

References

- [1] Kiss, G. and Kinkead J. (1995) Optimal Building-Integrated Photovoltaic Applications, *NREL/TP-472-20339*, November 1995.
- [2] Ayoub, J., Dignard-Bailey, L. (2000) A. Filion, Photovoltaics for Buildings: Opportunities for Canada, Report #CEDRL-72, CANMET - EDRL, NRC.
- [3] Stamenic, L., Smiley, E., Stojanovic, (2000) Optimization of the BIPV Ventilated Façade, *16th European PV Solar Energy Conference*, Glasgow, UK.

- [4] Stamenic, Lj., Smiley, E. (2000) Case Studies of Building Integrated Photovoltaic Systems in British Columbia, *26th SESCO Conference*, Halifax, NS, Canada.
- [5] Stamenic, Lj., Smiley, E. (2002) Optimization of Building-Integrated Photovoltaic-Systems, *29th IEEE PV Specialist Conference*, New Orleans, USA.