Options for Integrating PV into Your Building

By Niels Wolter, Director of WisconSUN
1999, updated 2003

Introduction

Building integrated photovoltaic (BIPV) systems are both electric generating systems and part of the building shell. Examples of BIPV systems are roofing, atriums, and shade screens that integrate PV modules into their design. Besides generating electricity integrated BIPV systems can also enhance a building's beauty, visibility, and prestige.

BIPV systems offer many advantages compared to adding a PV system onto an existing building. BIPV systems

- Require no additional support structures because they use the building's frame
- Have limited additional construction expenses
- Are easily designed to provide daylighting, heat control, and other benefits
- Can be easily designed in an aesthetically appealing manner to maximize visibility or educational impacts.
- Can be financed as part of the entire building

In addition, a BIPV system is usually less expensive than a retrofit. This is because the PV panels replace building materials such as roofing, thus avoiding the cost of those materials.

Retrofitted PV systems

Most building PV systems are retrofitted. The PV system is mounted on ballasted structures that sit on or are attached to the roof.

Retrofitted PV systems cost more than integrated PV. These additional costs include:

- Wiring. All PV systems require additional wiring, but retrofitted systems must be integrated into an electrical system that was not designed for PV.
- Mounting structures. This is equipment like ballasted pans which support and orient the modules.
- Rooftop reinforcement. Many roofs are not designed to support the additional weight of a PV system and must be improved. The rooftop must be able to support the PV system, snow and ice accumulation, wind stress, and increased traffic due to maintenance.
- Increased rooftop maintenance. Roofs have a life span of about 20 years, while PV systems may last 25 years or more. Replacing the roof would mean removing and

then reinstalling the PV system, increasing the system's lifecycle cost. In addition, installing a retrofitted system can result in penetration of the building's shell. This can result in water leaks--a serious problem, particularly for flat roofed buildings.

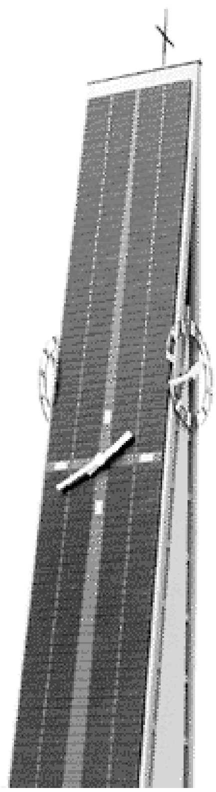
Options

There are several ways to integrate PV into a building's design:

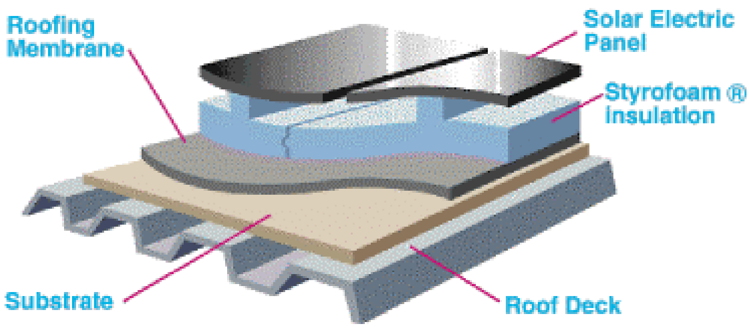
- Roofing
- Facades
- Atriums, skylights and greenhouses
- Shade screens

PV roofing

PV roofing systems perform the functions of a roof—such as water tightness, drainage, and insulation—while also generating electricity. Roof tiles, slates shingles and standing seam roofing are the most common systems. PV tiles are generally used on flat roofs while PV slates, shingles and standing seam units are used on sloped roofs. PV on flat rooftops will generate less electricity than PV on south-facing sloped roofs.



Solar church tower in Steckborn, Switzerland



Cross section of a PV tile. (PowerLight Corporation)

PV tiles on the roof of a commercial building (PowerLight Corporation)

PV slates were developed in Europe, where slate rooftops are common. PV slates can also replace shingles (Atlantis Solar Systems)

Standing seam PV roofing. These systems are available as structural or architectural standing seam panels. (Uni-Solar)

PV shingles on a sloped rooftop.(Uni-Solar)

There are also other ways of incorporating PV modules into rooftops. For example, the PV modules used in the Carlisle House and Georgetown University were mounted onto steel plates and installed over the roof substrate.

For better performance, PV roofing is often insulated, which increases the roof's R-value and reduces cooling loads.

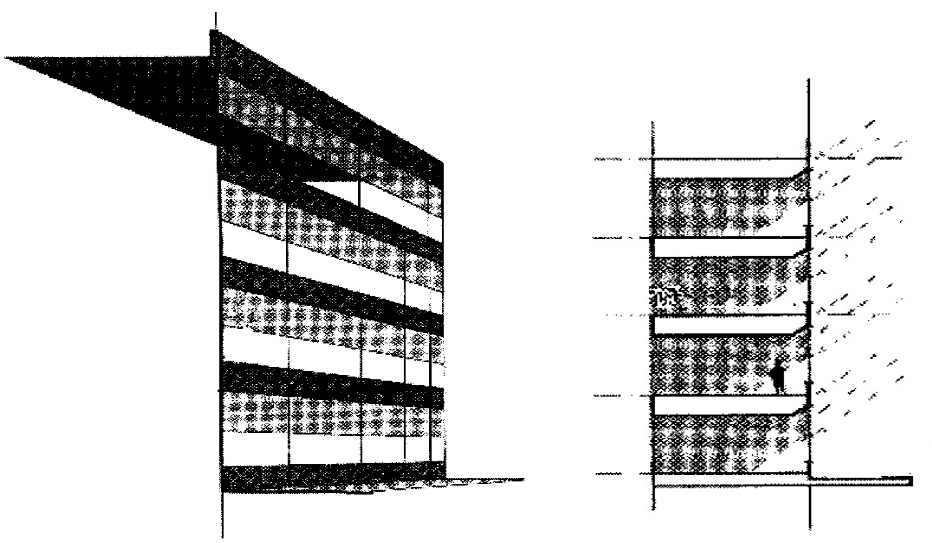
The Carlisle House in Carlisle, Massachusetts

Georgetown University’s 300 kW PV roof in Washington D.C.

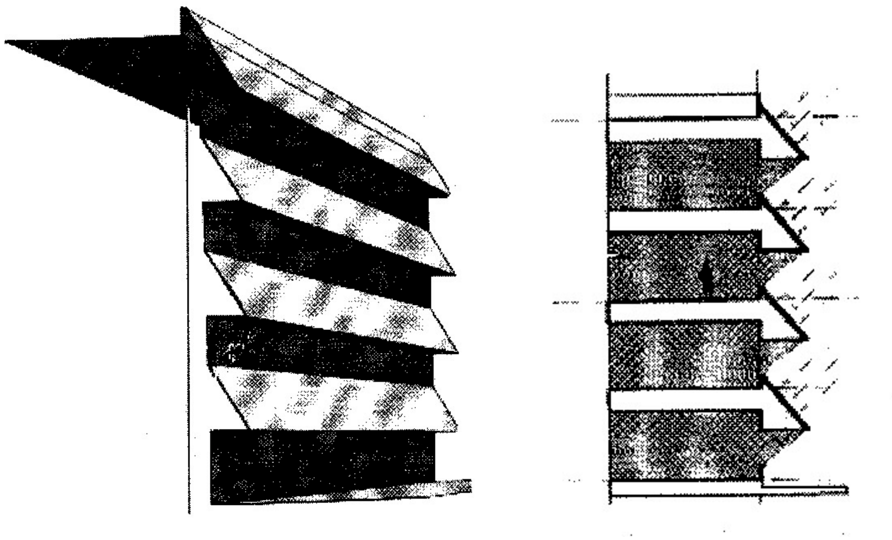
PV facades

Facades offer a large area for PV modules. Besides generating electricity PV facades must look appealing and protect the building from weather. They can be integrated with windows, daylighting, and shading schemes to provide multiple benefits.

The typical BIPV facade is vertical and faces southward. However, vertically oriented PV panels at the latitude of Wisconsin have much reduced electricity output compared to panels sloped toward the sun. The reduction is greatest in the summer when the sun is high in the sky; this is also when electricity is most valuable. To overcome this problem, facades can be sloped using a saw tooth design.



Vertical PV facade integrated with clear glazing and semitransparent PV modules. The semitransparent glazing prevents direct sunlight from entering the building, which reduces cooling loads and glare (From Erge, 1996)



Sawtooth PV facade consisting of overhanging PV shade screens and clear windows. The overhang reduces direct sunlight in the summer but allows solar heating in the winter. (From Erge, 1996)

Opaque PV materials can be used to cover walls, building structural members, and mechanical infrastructure. Semi-translucent PV glazing applied directly to the glass can replace windows not used for viewing. Many off-the-shelf PV modules are suitable for this application.

Facades can include:

- Structural mullion/transom curtainwall systems (Curtainwalls are non-load bearing external walls that provide a watertight building envelope. Mullions and transoms are the vertical and horizontal framework on which the curtainwall is mounted.)
- Pressure plate mullion/transom (stick) curtainwall systems
- Panel curtainwall systems
- Rain screen over cladding

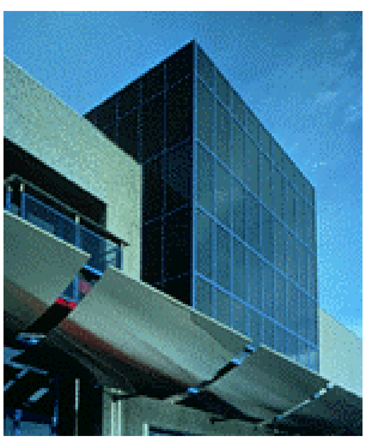
PV glazing mixed with clear glass on a mullion and transom framework (Aachen municipal utility, Aachen

Germany)

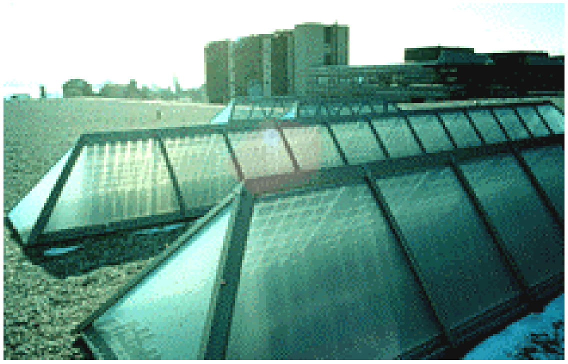
PV facade integrated with clear glass (Sanyo Building, Japan)

PV atria, skylights, and greenhouses

These glazing systems, though best suited for small capacity PV systems, can be very visually appealing and provide great visibility. Because skylight, atrium and greenhouse glass is often heavily tinted to minimize glare, semitransparent PV glazing can make a good substitute. The glazing panels consist of PV material attached to the glass. Many off-the-shelf PV modules are suitable for this application. Open-air PV atriums are especially economical because the PV modules do not require extra ventilation.



Advanced Photovoltaics Systems' "PV cube," located in California. Notice that the windows and PV modules have a similar tint.



PV integrated into a skylight (Germany)

A PV atrium (California)

PV shade screens

PV shade screens provide a large area for generating electricity and also reduce solar heating in the summer, which cuts cooling loads and glare. Shade screens cost less than other BIPV systems because extra ventilation of the PV modules is not needed. They can be retrofitted onto existing buildings or integrated into a new building's design.

PV shade screens (Finland)

PV shade screens (Switzerland)

Costs

Though more economical than retrofitted systems, a building with BIPV will cost more than a building without PV. These extra costs include

- Additional design time to integrate PV into the building.
- PV modules. The cost of a BIPV module equals the cost of the module less the cost of the building material it replaces. For example, using an amorphous silicon PV glazing costing $\$160/m^2$, rather than a window costing $\$65/m^2$, has a net cost of $\$95/m^2$. (Kiss and Kinkead, 1995). This “materials credit” reduces the panel’s cost 40 percent.
- Inverter. The inverter changes the direct current produced by the cells into the alternating current used by building equipment.
- Ventilation. PV modules heat up under the sun, resulting in both lower efficiency and heating of walls or roofs. For these reasons some BIPV systems need extra ventilation.
- Controls, monitoring systems, and wiring (balance of system)

Installed costs

The following table compares the installed cost of BIPV and retrofitted PV systems. These costs will vary significantly depending on the system’s design, the materials replaced by the BIPV modules, and the complexity of the installation and construction.

	Rooftop BIPV replacing low-e skylight glazing	Rooftop PV system retrofitted on building with ballasted pans
Module	3600	3600
Materials credit ($/kW)	-1000	0
Inverter ($/kW)	500	500
Balance of system ($/kW)	400	1000
Construction and installation	1000	1500
Total	4,500	6,600

Lifecycle benefits

BIPV systems also provide other benefits compared to retrofitted systems:

- Additional energy savings. BIPV systems can provide daylighting, shading, and increased rooftop insulation. These benefits reduce lighting and cooling requirements.

- Public relations and education. Because BIPV system are integrated into a building they are more visible from the street, while many retrofitted systems are hidden on rooftops. Thus BIPV systems can have a high profile, increasing opportunities for education and marketing.

- Lower maintenance. Some BIPV systems can increase the life of the roof.

Most economical options

One analysis of BIPV atria, sloped glazing (such as skylights), and building facades found that BIPV atriums are the most economical option (Kiss and Company Architects, 1995). According to this study, BIPV atriums had a 70 percent shorter payback period than BIPV facades. This is due primarily to the large material credit that reduces the PV atrium’s first cost.

Insulated PV tiles and slates may have good economics as well. They are relatively simple and inexpensive, prolong roof life, and reduce heating loads. Shade screens may also have promising economics because they reduce cooling loads and glare.

More information

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Posbic and Rever. 1998. Economic optimization of building integrated photovoltaic systems. Presented at the American Solar Energy Society annual meeting. Available at www.solarex.com/paper/asmepap.htm

Exposition Center for Photovoltaic Integration. Supported by the Swiss Institute of Technology and the Swiss Federal Office of Energy. www.demosite.ch

Bear Architects: www.bear.nl/bearhome.htm

Manufacturers:

- Atlantis Energy: www.atlantisenergy.com/asusa.htm
- Unisolar: ovonic.com/unisolar.html
- PowerLight: www.powerlight.com