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BUILDING INTEGRATED PHOTOVOLTAIC SYSTEMS:

TECHNICAL & ARCHITECTURAL ISSUES

1. INTRODUCTION

Photovoltaic (solar electric) modules are clean, safe and efficient devices that have long been considered a logical material for use in buildings.
Recent technological advances have made PVs suitable for direct integration into building construction. PV module size, cost, appearance and reliability have advanced to the point where they can function within the architectural parameters of conventional building materials. A building essentially provides free land and structural support for a PV module, and the module in turn displaces standard building components.
This report identifies the highest-value applications for PVs in buildings.
These systems should be the first markets for BIPV products in the commercial buildings, and should remain an important high-end market for the foreseeable future.
Optimizing BIPV applications is a function of many variables: construction methods and materials, photovoltaic technology and module fabrication, insolation levels and orientation, and electrical costs. This report addresses these variables in the following order:

- Architectural application (curtain walls, skylights, etc.).
- Construction material credits (the type and value of conventional building materials displaced).
- Additional BIPV construction costs (wiring, ventilation).
- Location parameters (insolation, construction costs, electrical rates).
- PV technology (crystalline silicon, amorphous silicon, advanced thinfilms).

Using these variables,the most promising BIPV applications, building locations and PV technologies are selected and evaluated in a simple payback analysis.

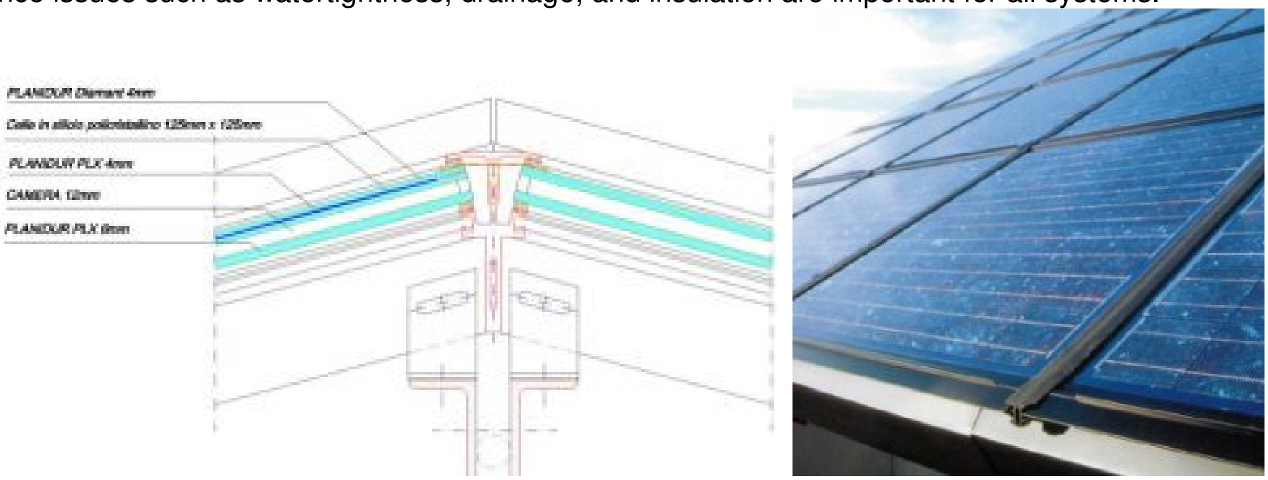
This paper wishes to raise questions that aim at comparing the potential of photovoltaic material to conventional construction materials, and to suggest the possible steps needed to overcome the barrier of acceptance of PV in different urban contexts, different historic centres and different cultures.

2. Technologies for building integration of PV

There are several existing building elements which can readily accommodate PV, such as curtain walls, atria and roofs. In addition to these, new products are being developed with PV as an integral component, such as active shading elements and combined heat and power units. This section briefly discusses the main building elements so far used for BIPV and the specific issues arising. More details, including case studies, are provided in appendices available separately.
Each BIPV product either is integrated into or completely replaces existing building elements. The building value of the BIPV element can be assessed by comparison with typical building elements without the PV component. The merits of each product can also be analysed with regard to the construction type (retrofit, refurbish, new construction) and also the building sector (residential, commercial, industrial) in which the element is used. In general, the trend in most applications is towards prefabrication of BIPV elements, which require few additional skills at installation beyond standard practice.

3. Rooftops

At present, most roof mounted systems are designed to take advantage of the retrofit market and hence are not fully integrated into the roof structure but are mounted onto existing roofs. The slow turnover of building stock in many areas of the world will ensure that the retrofit market will remain significant, even when integrated products are well established.
Issues of importance to roof-mounted systems vary between roofing technologies.
However, fully integrated BIPV roofing systems must perform the function of a standard roof and hence issues such as watertightness, drainage, and insulation are important for all systems.



Saint Gobain Glass Solar system integration (Solardesign – Italy) and MSK PV Roof system

Installation on Flat roofs

Flat roofs would seem to present the least degree of engineering difficulty for BIPV installations, largely because the technology for ground based arrays is generally applicable. Flat roofs differ from inclined ones primarily in the nature of the watertight layer (eg. asphalt, membrane). Roof mounted systems which are not fully integrated may be either ballast mounted or rack mounted, as shown in Figure .

Powerlight flat roof system

4. Facades

The primary roles of a building facade are weather protection and appearance.
Although dependent upon regional construction techniques, five general types of building facade into which PV could be integrated have been identified [Sick & Erge, 1996, Lord, 1993]:

- rainscreen overcladding,
- pressure plate mullion/transom (stick) curtainwall systems,
- structural glazing mullion/transom curtainwall systems,
- panel curtainwall systems, and
- profiled metal cladding.

Some of these are illustrated below:

Atlantis and Prosol Solar PV Facade

5. Atria and Skylights

Atria or “glass roofs” are typically constructed by securing and sealing transparent glazing units to a preinstalled metal frame (aluminium or steel). The technique is similar to that used in glasshouse construction. Atria in commercial buildings usually span large areas and are considered to be the roofing structure. As the glass roof becomes more inclined, the building technology becomes increasingly similar to that of a facade, particularly in the methods used to secure laminates.
Skylights, on the other hand, penetrate a conventional roof structure to provide light and in some cases ventilation. Some skylights, especially in domestic buildings, consist of only a framed single glazing unit opening from a roof space. Other skylight systems, such as those that are more common in warehouses and large open plan buildings (eg. shopping centres), consist of long stretches of glazing units and contribute substantially to the lighting requirements of the building. Clear windows may be used on the side facing away from the sun and opaque panels facing the sun.
Both atria and skylight technologies are well established and are very suitable for PV integration, with semitransparent PV laminates directly replacing the glazing units.
Any interconnecting wiring can be passed through the frame. In the case of single glazing unit skylights, a Module Integrated Inverter (MIC) can be built into the frame.
Since the PV cell limits the amount of light transmitted, semitransparent modules are made either by spacing opaque cells in an otherwise transparent module, or by adjusting the deposited layer thickness of amorphous silicon. Assessing the lighting and heating requirements enables the appropriate spacing or the desirable transmissivity of cells to be determined.

Milan (Enerpoint) and Niewland (Novem) Skylight application

6. Shading elements

Shading elements are typically secured to the outside of the building envelope to limit the amount of daylight and heat entering through a window. They may be permanently fixed or moveable to track the sun over the day or year. Shading elements are well suited to accommodate PV laminates, as they are oriented towards the sun, often have a flat surface and allow rear ventilation. Several systems have been installed where standard PV modules have been secured to the building envelope using a metal frame.

Several innovative concepts have also been considered.

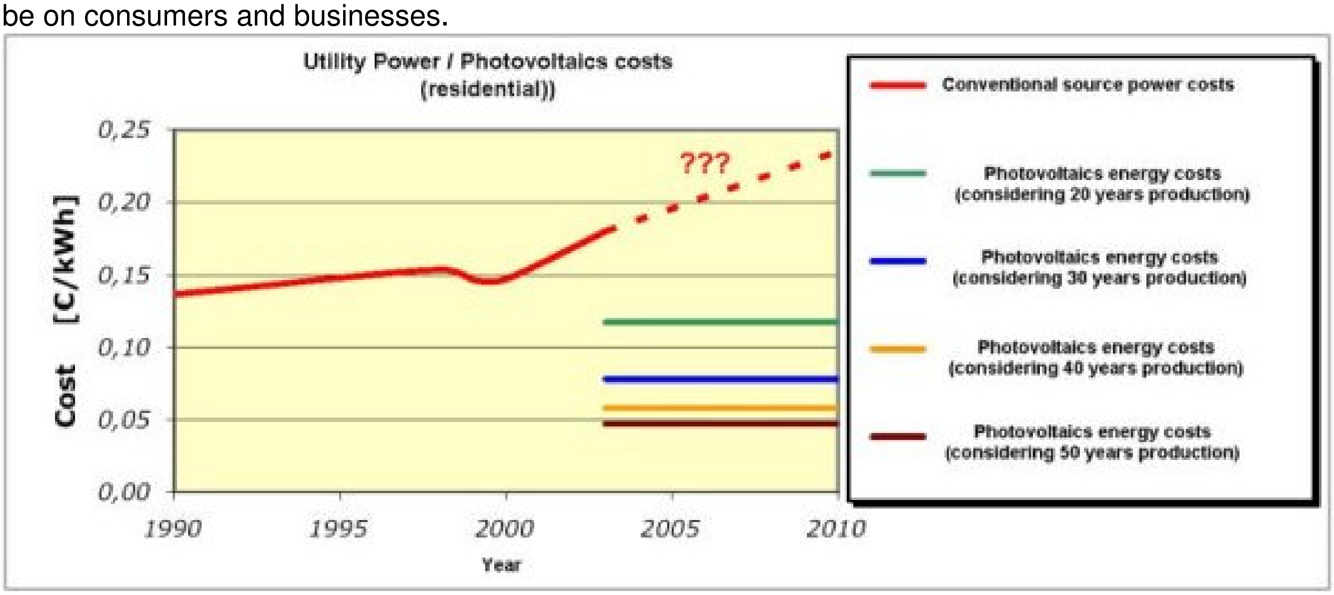
For shading elements which track the sun, a trade-off between daylighting requirements and photovoltaic generation can be achieved by the use of holographic concentrating devices. These concentrate direct radiation onto the cell, which may occupy only a fraction of the total shading element area, and allow diffuse light to pass through the remainder of the element, for daylighting [von Busse *et al*, 1996].

PV covered window blinds for use inside the building (ie behind window glass) have also been suggested [Sala *et al*, 1996]. Vertical slats of different sizes and materials have been considered. These systems takes advantage of blinds generally being oriented towards the sun, but place certain requirements upon the window glass and also on the window structure (beams and struts).

7. ECONOMIC PERSPECTIVE

The full value for BIPV systems is realized when multiple economic perspectives are combined. Many value streams have been analyzed by stakeholder or ownership scenario.

The following discussion identifies value streams by stakeholder and the potential for accruing multiple value perspectives to a single ownership scenario. Graphic illustrates this concept. Residential consumers, commercial businesses, utilities, and governments all have both tangible and intangible values. Energy and building integration values are realized by all stakeholder groups when the BIPV system is installed on their own facilities. However, to simplify the discussion, the ownership focus will be on consumers and businesses.



8. CONCLUSIONS - REALIZING THE VALUE

If a properly design BIPV system shades building components, especially glazing, and is net metered to reduce high utility tariffs, it can have high values for socially conscience consumers. Similar systems can provide attractive corporate branding, cash flow, present value and return on investments for businesses. If strategically located, these systems can provide utility distributed generation value, risk reduction, and increased energy diversity. Local, state and federal governments obtain environmental, jobs creation, energy security and social values from BIPV.

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