

INTRODUCTION AND PROSPECTS FOR BIPV DESIGN IN JAPAN

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Abstract – This paper introduces developments in BIPV design in Japan. Japan is a major contributor to total worldwide PV installed capacity. A number of solar electric building designs are provided. The examples highlight the versatility and intelligent use of PV products within built environments. From such demonstrations and a healthy Japanese government and collaborative industry support mechanism and targeted programmes, there is much optimism for BIPV growth. Future BIPV design prospects are also discussed. However, there is still much to be achieved to create challenging designs, utilising BIPV, that both explore cultural possibilities and deliver environmental benefits.

1. INTRODUCTION

PV installed capacity worldwide as of 1998 was 392 MW_p, of which 133 MW_p was in Japan, putting the country top in terms of installed capacity. However, Japan must make further efforts to reach the target of 500 MW_p in 2010. Housing manufacturers have been developing roof PV systems for houses in Japan, which have become popular and sales are being actively promoted. Over 30,000 PV systems have already been installed on houses, and many BIPV manufacturers are now developing and marketing various PV modules for the residential sector. Furthermore, PV systems with architecturally superior designs are increasingly being used on larger buildings in Japan. This section outlines the current situation and future prospects of PV systems, and gives examples of mainly building applications.

2. INTRODUCTION OF ACTUAL APPLICATIONS OF BIPV DESIGN

2.1 *Yagi Junior High School* (*Yagi-cho, Funai-gun, Kyoto-fu; Tanaka Shozo Design Office, Inc.*)



Fig. 1: Yagi Junior High School

This shows a 50 kW_p PV system installed on the roof of Yagi Junior High School. Many standard modules were installed on the R-shaped flat roof in view of the design. This shows how an architectural roof design can blend in with the surrounding views, although the design is not actually integrated with the building. This was a remarkable plan in Japan that used a PV roof design to shield the sun. Educational facilities such as schools are often in good sunlight conditions, and serve dual roles as local community centers or as evacuation centers in case of natural disasters. Good educational benefits are also expected. The use of PV systems for public facilities should be promoted.

2.2 Passage Garden Shibuya - Investment Promotion Building (Shibuya, Tokyo; Nihon Sekkei, Inc., Jiro Ohno)

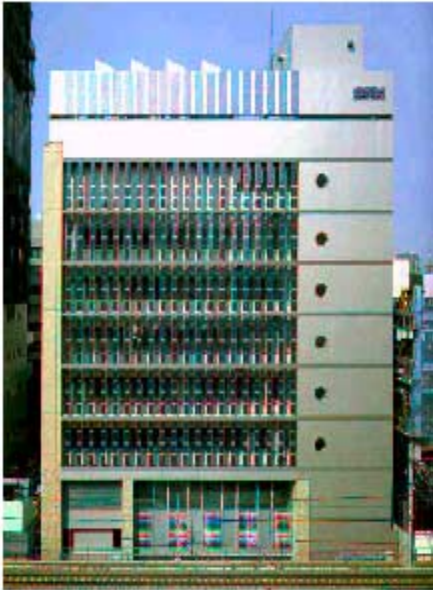


Fig.2: Investment Promotion Building

The Investment Promotion Building was the first example of BIPV architectural design in Japan. The total PV system capacity is 29.7 kW_p and four kinds of modules are installed.

1) Transparent PV Vertical Light-shielding Louver (19.8 kW_p) - Combined glass modules, in which black mono-crystalline silicon cells are placed interval, are simply installed with DPG support. The louver is designed to shield sunlight from the west that negatively affects thermal conditions in rooms, and is also designed to shield light while in harmony with the entire design.

2) Transparent PV Horizontal Light-shielding Pergola (0.8 kW_p) A transparent module is installed on the roof as a horizontal pergola over plants. The top of the building has a marked silhouette, and has good lighting conditions. The light and shadows viewed through the module against the sky are integrated into the architectural design.

3) Roof-top Shielding PV Furring (4.0 kW_p) This poly-crystalline silicon cell module is gray in accordance with the colour design of the building, and is supported by an aluminum frame. This array receives plenty of light on the top of the building, and also serves as a shielding furring to cover facility equipment.

4) Inclined Roof-top Array (5.1 kW_p). In order to integrate the standard blue poly-crystalline silicon cell module with the design of the top part, the triangular panels on the outer side are arranged at different angles.

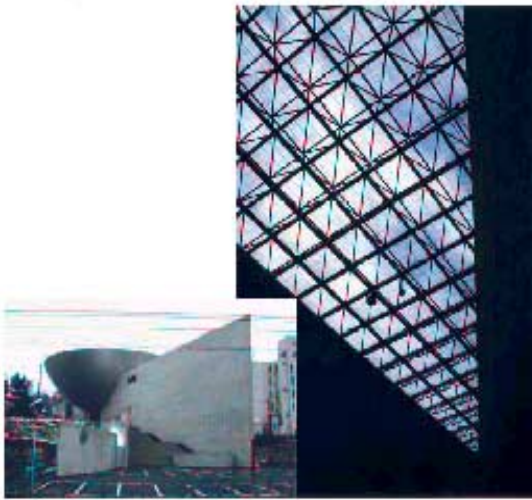
2.3 2-3 Ohta City Hall (Ohta city, Gunma prefecture; Kume Design, Inc.)



Fig. 3: Ohta City Hall

Ohta city, Gunma prefecture installed 31kW_p PV modules on the new city hall to increase public awareness of global environmental issues. Energy conservation is achieved by power generation and shielding, with translucent amorphous PV glass modules (15 kW_p) integrated into the curtain wall and top light. Surrounding landmarks can be seen through the amorphous lounge glass with small holes. Also, semi-transparent modules are used as design elements on the round top light in the public centre.

**2.4 2-4 Tamatsukuri Hot Spring "Yu-Yu" (Tamayu-machi, Shimane prefecture)
(Shin Takamatsu Architects & Associates)**



The atrium at the entrance of Tamatsukuri Hot Spring "Yu-Yu" features translucent amorphous silicon modules natural top light effect. The elements of this solar product design have micro diffusion holes that allow 30% of sunlight to pass through, thus maintaining internal brightness by natural light and providing clear views of the surrounding landscape. Also by shielding 70% of strong sunshine in the summer, air conditioning load is reduced. In the entrance hall, gently sloping stairs are built with rough-surface concrete walls, and the translucent PV modules are supported by three-dimensional ball joint trusses in a simple design.

Fig. 4: Tamatsukuri Hot Spring "Yu-Yu"

**2.5 "Houou High School Budo-kan gymnasium" Kibogaoka Gakuen
(1997, Kaseda city, Kagoshima prefecture)
(Shimo, Mainaka & Tashiro Sekkei JV)**



This BIPV features built into the steel plate roof used for the Budo-kan gym of the high school, with the large Japanese-style roof design matching the surroundings. A surface PV design often has a strong character, so a BIPV that enables various designs needs to be developed. The modules face the four directions of north, south, east and west. As a result, power generation of approximately 60% can be achieved, even when facing north in Japan.

Fig. 5: Budo-kan gym of Houou high school

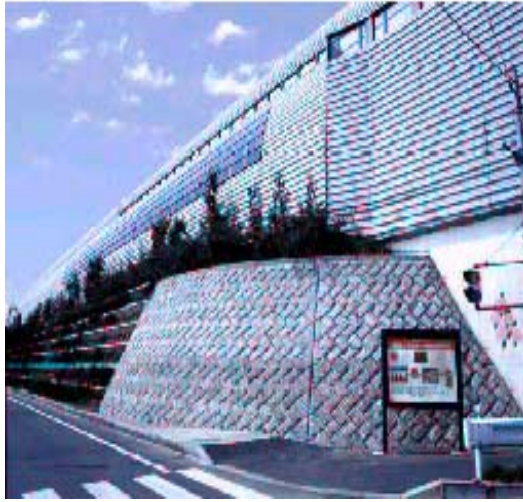
2.6 Suntory Museum (Osaka city, Osaka-fu; Tadao Ando)



This museum was built as a gift from Suntory, a leading liquor manufacturer in Japan. It is rare to be able to see the roof of a building, but in this case the designer made it a significant part of the overall design. Tadao Ando, one of the world's famous architects, designed the museum.

Fig. 6: Suntory Museum

2.7 National Road 298, Tokyo Outer Circular Highway
(Souka city, Saitama prefecture)
(Ministry of Architecture, North Capital Highway Construction Office)



PV modules are installed on the noise-shielding wall in the Souka city section of the outer-circular highway of the capital. Since the sidewalls of highways often receive good lighting and their total length is 6,560 km, they have good potential for introducing PV modules. Noise-shielding walls are built on supporting poles or structures, and so it is relatively easy to install modules along the sideways. The cost of PV can be reduced further by integration with the shielding wall. Distributed PV systems sometimes have cost advantages in mountainous or rural areas, and PV installation should be promoted in these areas.

Fig. 7: Outer-circular Highway

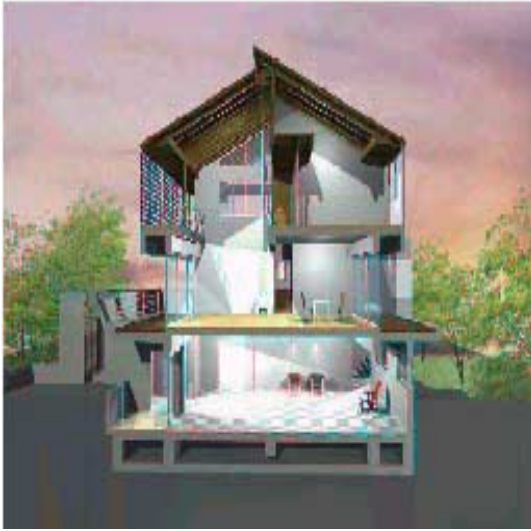
2.8 NTT DoCoMo Yoyogi Building
(Under construction in Shibuya-ku, Tokyo; NTT facilities Co.)



This building houses communication equipment for mobile systems and offices. The design features a steel tower for microwave transmission integrated with the building, in order to blend in with the urban landscape due to its location in the centre of the city. Solar cell panels are installed vertically in the spandrel part of the slit windows of the south elevator shaft and also in the side of the steel tower on the roof. To minimise shadowing from sidewalls in the morning and evening, the modules are divided into three parts and generate electricity separately. Electric power generated by this system will be supplied to facilities in the emergency evacuation zone of the site for people living in the area, and also for the radiowave-based disaster-prevention display system.

Fig. 11: NTT DoCoMo Yoyogi Building

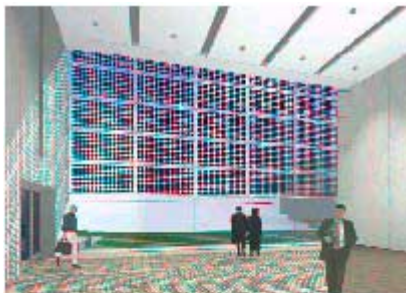
2.9 J-House (Under construction in Shinjuku-ku, Tokyo; Designed by Jiro Ohno)



J-House is an architect's own house built in the center of Tokyo. There are many low wooden houses in the surrounding area, so the shadow effects of building, trees and telegraph poles were considered in the design. A polycrystalline silicon cell BIPV (4 kW_p) is built integrally with the steel roof and covered by glass. Semi-transparent pair-glass BIPV (1 kW_p) is installed in the glass wall facing south. J-House incorporates various ways of using natural energy. The entire house is highly air-tight and thermally insulated, while air flow and lighting are maintained by halls and windows on the roof. Also, a passive solar system, using warm and cool air in the roof and base, is utilised.

Fig. 9: J-House

2.10 Tsukuba OSL (Under construction in Ibaraki prefecture; Nihon Sekkei, Jiro Ohno)



Tsukuba OSL is located in Tsukuba Centre of the Agency of Industrial Science and Technology, and the Electronics Technology Laboratory is the centre of photovoltaic research in Japan, attracting many researchers and visitors. Therefore, it will serve to promote awareness and use of PV power. Emphasis was placed on the architectural design of the building.



1) Glass CW circular cell module - Combined-glass type modules with circular cells are used on the MPG glass curtain wall supported by tension wires on the south side of the entrance hall. The unique BIPV, designed to show light and shadows like a light-shielding blind, efficiently conserves energy (9 kW_p).



2) Translucent amorphous silicon top-light array - Pair-glass amorphous silicon PV modules having a 30% lighting effect and are used in the top-light of the central atrium (3 kW_p). Methods of keeping air comfortable are significant in temperate Japan, so semi-transparent PV modules that can simultaneously moderate shield light and generate power were installed.

Fig. 10: Tsukuba OSL

2.11 NTT Musashino Lab (Musashino city, Tokyo; NTT facilities Co.)



This is the piping-shaft blind-louver, featuring the multi-functional material, installed at NTT Musashino R & D Center. Its upper-wise angle of 10-degree improves the efficiency by 15%, while it was vertically placed on the wall. Ventilation holes of the louver can restrain temperature increase of the solar cells. The holes are shaped not to cause noises with wind.

Fig. 11: NTT Musashino Lab

3. CURRENT STATUS OF BIPV DESIGN

The development and use of photovoltaic systems in Japan are progressing rapidly. In the housing sector, approximately 10,000 houses are fitted with a PV array every year, and module manufacturers are actively conducting development and reducing cost. The subsidy system is considered to be working well, and as a result, housing manufacturers are now keenly developing roof designs. These market trends are the result of efforts to promote environment-friendly PV houses.

In industry, spurred by the two oil shocks, efforts to conserve energy are yielding results. On the other hand, the domestic housing and transportation industries are witnessing rising energy consumption as the demand for better lifestyles and more comfortable living grows; these will be major areas for energy-saving in the future. In the housing sector, zero-emissions will be achieved by introducing completely airtight, thermally-insulated house designs. Both cell manufacturers and module manufacturers have been developing high performance, low cost and nicely designed modules. In the future, architects, carpenters and local builders that account for 70% of the market are should introduce various beautiful modules for use in domestic houses.

The use of photovoltaic power in the building industry has been promoted, and there is growing awareness of the need to build environment-friendly facilities. In the early stages, the focus was on power efficiency, but more recent applications are incorporating design considerations. Architects need to demonstrate awareness of environmental issues in their designs, and the number of architects creating PV designs is increasing. However, there have been many cases where PV designs were abandoned due to high cost, as well as examples where architects have been unable to proceed with their designs due to lack of understanding. Beautiful PV designs are needed to encourage owners to install such systems.

4. OUTLOOK FOR BIPV DESIGN

Buildings protect humans from the outside elements. Since the Industrial Revolution, architecture has been based on iron, concrete and glass. However, architects are

finally starting to produce unique designs utilising materials and structures that meet social and cultural trends and functional requirements. However, modern buildings typically require huge amounts of energy, and global warming and resource depletion issues have reached a critical stage. Urgent action in each country, in accordance with the Kyoto Protocol, is required. For human beings, PV, especially BIPV, is a building material that allows us to obtain energy from the building materials themselves for the first time in history. BIPV is expected to play a major role in the transformation of our energy-consuming world into a sustainable energy-producing society. In architectural design in the 21st century, energy will surely be the crucial design theme. Architects need to create challenging designs utilising BIPV that both explore cultural possibilities and consider environmental issues.

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