

GREEN

Handbook

- Photovoltaic (PV) systems in buildings



Artist's impression of Zero Energy Building

A close-up photograph of a green leaf, likely a palm frond, with a grid pattern overlaid on it. The grid is composed of small squares, some of which are a darker shade of green, creating a subtle, pixelated effect. The leaf's veins are clearly visible, and the overall color is a vibrant, natural green.

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Note:

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FOREWORD

With the formation of the Clean Energy Programme Office, a whole of government effort to develop capability in clean energy, the Building and Construction Authority (BCA) took the initiative to prepare this document as a handbook to complement EMA's Handbook for Photovoltaic Systems. As this is a relatively new area in Singapore, the document will be updated as and when there is new development.

The aim of this guide is to share and provide the industry and homeowners the procedures and the good practices in the design, planning and implementation of a photovoltaic system in a building development.

This guide also provides examples of how photovoltaic (PV) are successfully integrated into buildings overseas, illustrating how BIPV can both be an energy generator as well as a versatile building material for the envelope.



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1 Introduction

- 1.1 Photovoltaic (PV in short) is a form of clean renewable energy. Most PV modules use crystalline silicon solar cells, made of semiconductor materials similar to those used in computer chips. Thin film modules use other types of semiconductor materials to generate electricity. When sunlight is absorbed by these materials, the semi-conductor material in the PV cells is stimulated by the photons of the sunlight to generate direct electrical current (DC). They will work as long as they are exposed to daylight. The electricity generated is either used immediately or is stored (eg. in batteries) for future use. Solar modules themselves do not store electricity.
- 1.2 The objective of this handbook is to provide developers, architects, other professionals as well as interested homeowners with some basic information on how to approach, plan and implement a photovoltaic system to generate electric power in a building development.
- 1.3 The contact information for enquiries on installation of PV systems in building is summarised in **Appendix A**.
- 1.4 For general information on BIPV, the IEA (International Energy Agency) *website*, <http://www.bipvtool.com> is a useful reference.

2 Design and Installation

2.1 Types of Photovoltaic System

Photovoltaic systems can be classified based on the end-use application of the technology. There are two main types of PV systems; grid-tie system and off-grid system.

Grid-Tie System

2.1.1 In a grid-tie system (Figure 1), the output of the PV systems is connected in parallel with the utility power grid. In this way, the power supply drawn from the utility grid will be correspondingly reduced by the amount of power generated by the PV system. On the other hand when there is little or no output from the PV system due to cloudy weather or at night, the electricity drawn from the utility grid will be correspondingly increased. Hence there is no need to have storage batteries.

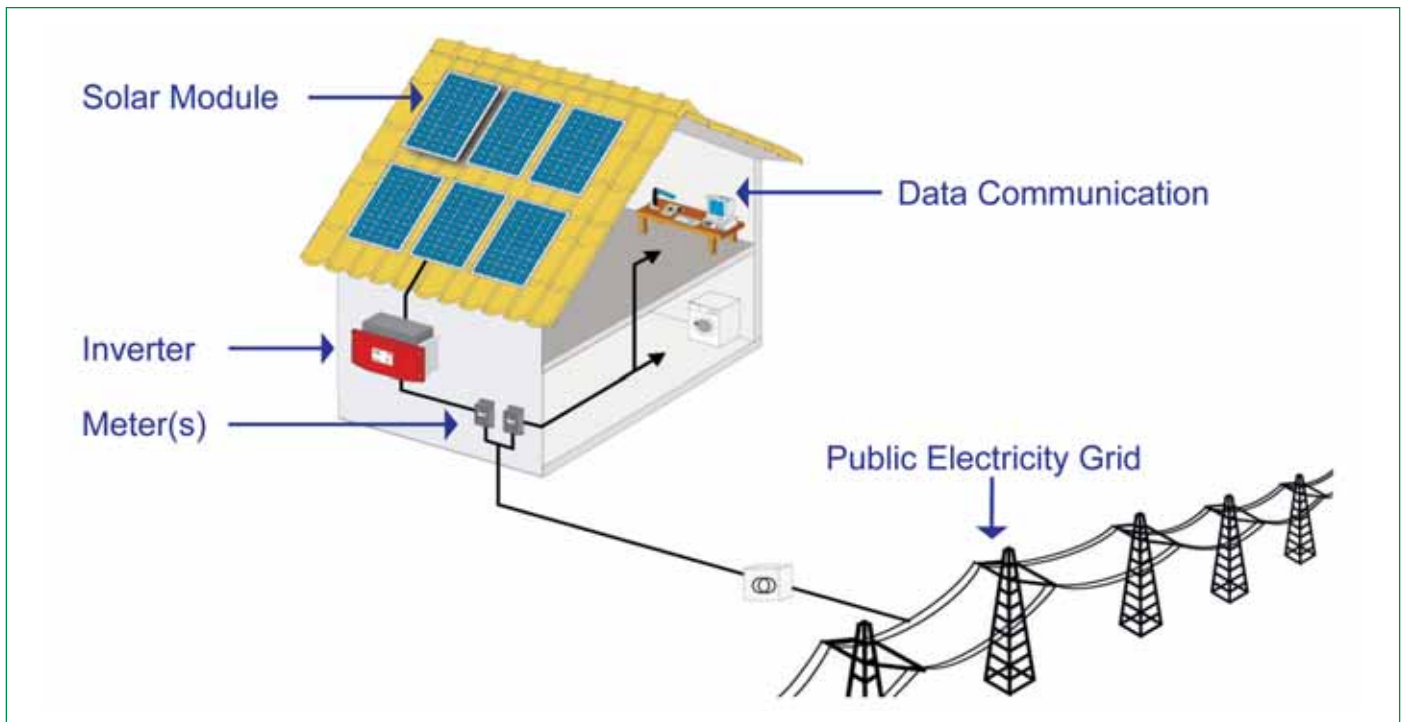


Figure 1: Basic grid-tie system (Courtesy of SMA)

Off-Grid System

2.1.2 In an off-grid system (Figure 2), batteries for energy storage are required to provide electricity under conditions when there is little or no output from the PV system. Currently, such PV systems are already competitive in isolated sites where the electricity grid is far away. Off-grid systems usually power DC loads, such as telecoms systems, rural lighting systems, parking sign lights, lightings in parks etc.

If required, off-grid systems can also include an inverter to drive AC loads.

2 Design and Installation

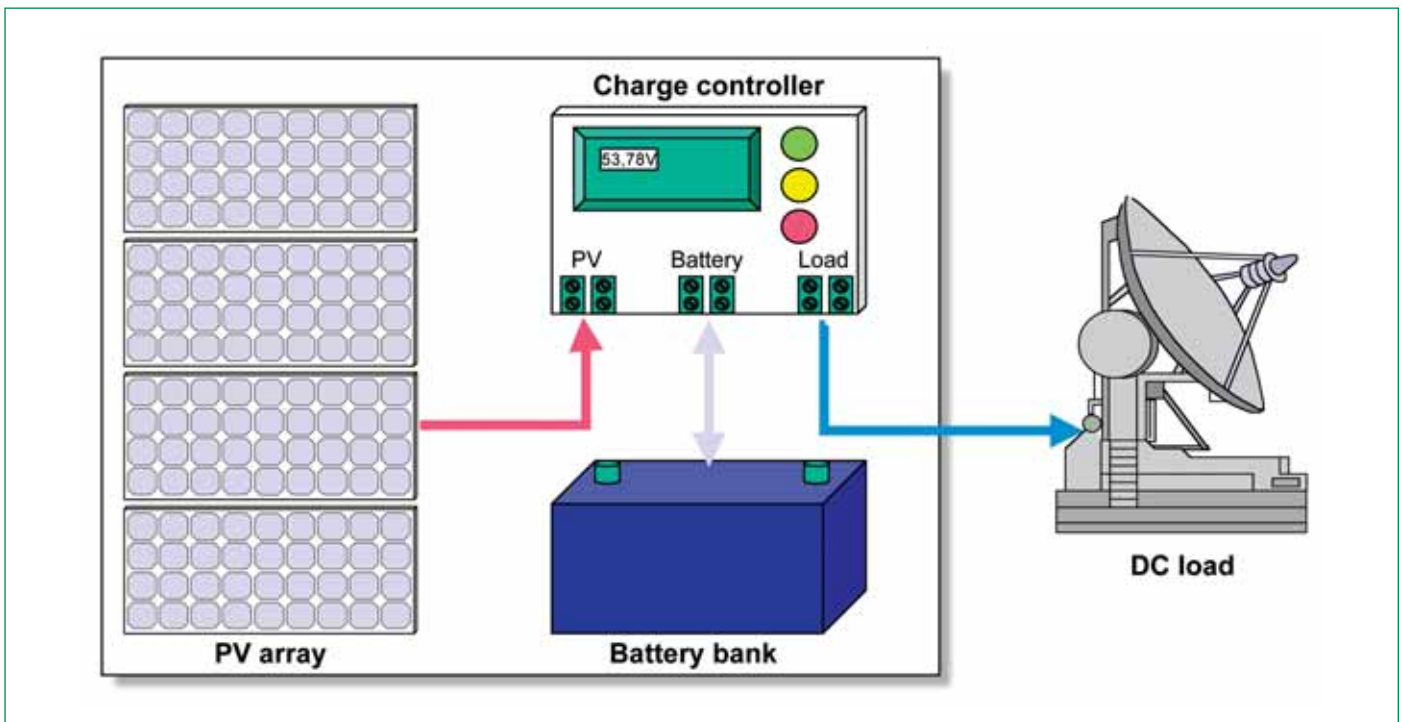


Figure 2: Basic off-grid system

2.2 EMA's requirements

Being electrical power systems, PV installations must meet EMA's requirements. The Energy Market Authority (EMA) has published on its website, a Handbook for PV Systems to cover the electrical aspects of PV systems¹. The Handbook provides information on the licensing, market and technical requirements to ensure safety, reliability and power quality of consumers' electrical installations and of the power grid.

2.3 Where PVs can be installed in a building

There are many ways to install PV systems in a building. For existing buildings, the most common manner without drastically affecting its appearance is to mount the PV modules on a frame on the roof top. Typically, they are mounted above and parallel to the roof surface with a standoff of several centimetres (recommended ≥ 10 cm) to reduce module temperature through air circulation. Ideally, they should also be installed facing north-south orientation to maximise the amount of solar energy received. Singapore's proximity to the Equator means the module's compass orientation is not critical. Laying the modules flat will maximise exposure to the sun. As flat-mounted modules may get dirty from trapped rain water and dust, it is better to mount the modules at an angle (10-15° for framed modules, or as little as 3-5° for unframed modules) to allow rain water to run off properly. The PV modules should be free of shade. Shading of any cell of a module may reduce the output of the entire module drastically. Therefore, shadows cast by tall trees and neighbouring buildings (including those to be built in future) should be avoided.

¹ The Handbook for Photovoltaic (PV) Systems is available at the following EMA website: <http://www.ema.gov.sg/Consultation/consultation.php>



Figure 3: Roof Mounted PV System (Courtesy of Interlink Power System)



Figure 4: PV array mounted at an angle on the building roof top

In a new development, besides mounting on the roof top, the PV modules or panels could in a creative, aesthetically-pleasing manner be integrated into the building facade (this form of PV is commonly known as Building Integrated Photovoltaic or BIPV in short). This could be on any part of the roof or external walls that is well-exposed to sunlight e.g. skylights, claddings, windows, external shading devices. It could also be integrated into external structures such as canopies, car park shelters and railings.



Figure 5: PV modules integrated into facade (BIPV) (Courtesy of Biopolis)



Figure 6: PV modules integrated into skylight canopy (Courtesy of Savannah Condominium)

More examples of how BIPVs can be integrated into a building are found in Appendix B.

2 Design and Installation

2.4 URA's requirements on development planning control

At present, there are no specific requirements or controls by URA (Urban Redevelopment Authority) on the use of materials such as PVs. However, conservation projects or projects within the Central Area are subject to URA's Urban Design evaluation process.

Guidelines on Conservation and Development Control

2.4.1 Architects are advised to refer to URA's guidelines on conservation, urban design and development control. The guidelines are available at the following URA website respectively:

Conservation guidelines:

<http://www.ura.gov.sg/conservation/Cons%20Guidelines.pdf>

Urban Design guidelines:

http://www.ura.gov.sg/cudd/ud_handbook/ud_handbook.html

Development Control guidelines:

<http://www.ura.gov.sg/circulars/text/dchandbook.html>

2.4.2 The URA general email address and contact number on Development Control matters is:

- Email: ura_dcd@ura.gov.sg
- Tel: 6223 4811

The respective telephone contact and email address of the Planner-In-Charge, by planning area, for enquiries on Development Control matters can be assessed through the following website:

http://www.ura.gov.sg/dc/phone_email/contact_planner.html

2.5 BCA's requirements on structural safety and lightning protection

Structural Safety

2.5.1 For new building developments, the design for the structure must take into consideration the loading of the PV installations, just like any other equipment mounted on the building structure.

2.5.2 For existing buildings, the service of a professional structural engineer may be required to carry out an inspection of the roof structure and do a calculation on the structural loading. This could be through the PV contractor (System integrator or SI in short) or directly by the building owner. If the roof is unable to withstand the loading² of the PV system, there will be a need for structural plans to be submitted to BCA for approval. The application guideline is available at the following BCA website:

http://www.bca.gov.sg/StructuralPlan/structural_plan_application.html

2.5.3 If BIPV glass is used as a glazing material and not as an add-on to existing facade, it will be treated like any other glazing material. No special approval for the use of BIPV will be needed. If BIPV is installed on an existing facade as an add-on, the design for the mounting system must comply with building and structural design code.

Lightning Protection

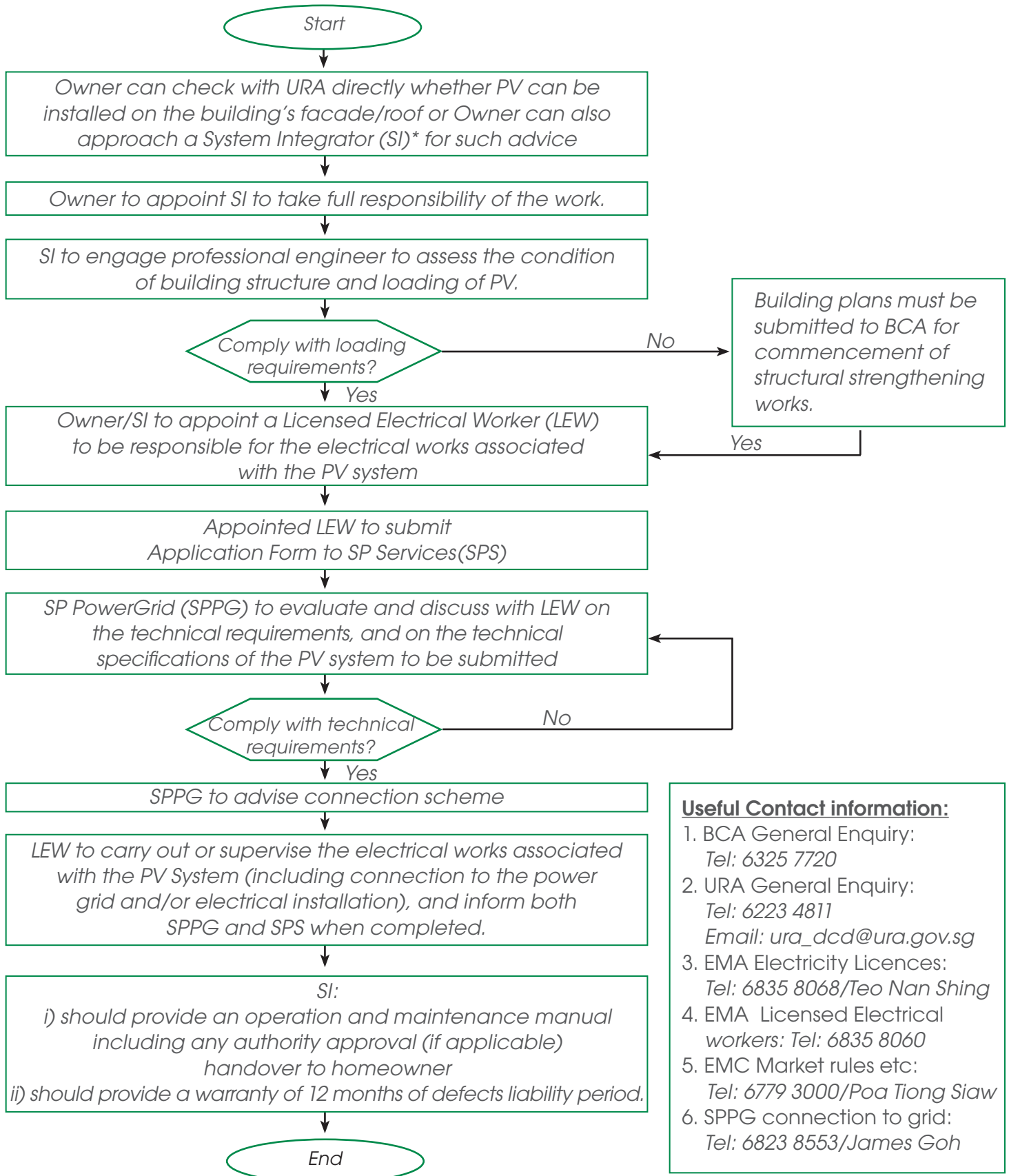
2.5.4 Given its location, PV systems are likely to be hit when lightning strikes in the vicinity. As lightning surges in the PV system can cause damages to the PV modules and inverters, care must be taken to ensure that proper lightning protection is provided for the system and entire structure. The inverters should be protected by appropriately rated surge arrestors on the DC side. Structures and module frames must be properly grounded.

² The structural loading requirement is as follows:

(a) For non-accessible roof, the loading must be below 0.5 kN/m².
(b) For accessible roof, the loading must be below 1.25 kN/m².

2 Design and Installation

2.6 Guide For Owners - Installation Of Solar Panels or Photovoltaic (PV)



* **System Integrator (SI)** in PV industry refers to a person or company that provides design, supply, delivery, installation, commissioning and maintenance of a photovoltaic power system.

2.7 Design and Installation Checklists

No.	Checklist for Design and Installation	Completed
1	Select a location, check with URA whether PV can be installed in building's facade/roof and set your budget	<input type="checkbox"/>
2	Determine energy requirement and estimate of system size	<input type="checkbox"/>
3	Site survey for space needed and access for maintenance	<input type="checkbox"/>
4	Engage a licensed electrical worker(LEW) if your proposed PV system: i) is to be connected to the electrical installation within your premises; and /or ii) is to be connected and operated in parallel to the power grid The appointed LEW will be responsible for the design and implementation of the connection of your PV system to the electrical installation and/or power grid	<input type="checkbox"/>
5	Selection of module, type and mounting method	<input type="checkbox"/>
6	Inverter selection to match PV array <ul style="list-style-type: none">• No. of inverters needed• Select inverter type• Location of inverters (accessible for inspection and maintenance)	<input type="checkbox"/>
7	Finalise the mounting system	<input type="checkbox"/>
8	Ensure there are fixing and mounting points available	<input type="checkbox"/>
9	Ensure the structure for mounting is safe <ul style="list-style-type: none">• Additional loading by PV system is considered• Wind loading is considered• Waterproofing is not compromised during installation	<input type="checkbox"/>
10	Solar access <ul style="list-style-type: none">• Ensure location mounted will get maximum sunlight• Choose a location that is unshaded	<input type="checkbox"/>

2 Design and Installation

2.7 Design and Installation Checklists

No.	Checklist for Design and Installation	Completed
11	Modules are installed at optimum orientation (North-south)	<input type="checkbox"/>
12	Modules are mounted at a tilt angle (10 to 15 degrees for framed modules, or as low as 3-5° for unframed laminates) for self-cleaning	<input type="checkbox"/>
13	Sufficient ventilation space behind array for cooling purposes	<input type="checkbox"/>
14	Cables used must meet sufficient current-carrying capacity and are suitably rated for the environment usage. DC cables must be single-core, double-insulated. Cable insulation on outdoor cables must withstand high temperatures and UV exposure for 20+ years. PVC and XLPE cables are inadequate and must not be exposed to the elements. (Cable design must comply with CP5)	<input type="checkbox"/>
15	Determine if lightning Protection System is needed (Design must comply with CP16 and CP33)	<input type="checkbox"/>
16	Ensure that the PV module frame is earthed	<input type="checkbox"/>
17	Finalising the Inverter and AC wiring system	<input type="checkbox"/>
18	During installation <ul style="list-style-type: none">•PV system should be installed by qualified/experienced system installers•safety rules must be observed, installer must wear PPE•only proper certified safety equipment can be used e.g. scaffolding, stepladders etc.	<input type="checkbox"/>
19	Cables must be properly connected, secured and routed	<input type="checkbox"/>
20	Ensure continuity and insulation tests are done	<input type="checkbox"/>
21	Completion of testing & system commissioning	<input type="checkbox"/>
22	System, documentation/manual handover to owners	<input type="checkbox"/>

3 Operation & Maintenance

- 3.1 As there are usually no moving parts in PV installations, minimal maintenance is needed. However, routine maintenance is required to ensure that the system is performing properly. It is a good practice for PV contractor (or System Integrator) to provide an Operation & Maintenance manual to the owner. The manual should include basic system data, test & commissioning data, O&M data and warranty information.
- 3.2 The PV modules require routine visual inspection for signs of damage, dirt build-up or shade encroachment. Although it is usually designed and installed to be self-cleaning through rain-water, the modules should be hosed down if there is a build-up of dust. It is not uncommon for PV performance to improve slightly the next day after rain.
- 3.3 Periodically, system fixtures must be checked for corrosion. This is to ensure the PV system is safely secured.
- 3.4 Any PV system connected to the electrical installation of a building, is considered part of the electrical installation. The licensed electrical worker (LEW) appointed by the building owner is responsible for maintaining the electrical installation to ensure electrical safety.

Recommended Preventive Maintenance Works for Photovoltaic System

- 3.5 Preventive maintenance works should be carried out every six (6) months.
- 3.6 The following table indicates the components/equipments and the corresponding remedial actions to be carried out during the preventive maintenance works.

S/No.	Components/ Equipments	Descriptions	Remedy/Action
1.	Photovoltaic Modules	<ol style="list-style-type: none"> 1. Dust/debris on surface. 2. Ensure no physical damage on surface. 3. Check for loose wire connection. 4. Check for wiring conditions. 	<ol style="list-style-type: none"> 1. Wipe clean. Do not use any solvents other than water! 2. Recommend replacement. 3. Retighten connection. 4. Replace wiring when necessary.
2.	Inverter	<ol style="list-style-type: none"> 1. Check functionality. 2. Check for loose wiring connection. 3. Check for abnormal operating temperature. 	<ol style="list-style-type: none"> 1. Recommend replacement. 2. Retighten connection. 3. Recommended replacement.
3.	Lightning / Surge Voltage Protection	<ol style="list-style-type: none"> 1. Check for loose wiring connection. 2. Check for all wiring conditions. 3. Check fuses, blocking diodes, circuit breakers, surge arrestors. 4. Check functionality. 	<ol style="list-style-type: none"> 1. Retighten connection. 2. Replace wiring when necessary. 3. Replace when necessary. Ensure to use dc-rated components on the dc side! 4. Replace when necessary.
4.	Cabling / Junction Box	<ol style="list-style-type: none"> 1. Visually check for wear and tear. 2. Check for loose connections. 	<ol style="list-style-type: none"> 1. Replace when necessary. 2. Retighten connection.

Appendix A: Contact Information

For enquiries on installation of PV systems in building:

<p>(1) General Enquiry on Buildings issues</p>	<p>Building And Construction Authority (BCA) Email: bca_enquiry@bca.gov.sg Tel: 6325 7720</p>
<p>(2) General Enquiry on Development Control</p>	<p>Urban Redevelopment Authority (URA) Email: ura_dcd@ura.gov.sg Tel: 6223 4811</p>
<p>(3) Development Control, by Planning Area</p>	<p>Urban Redevelopment Authority (URA) Planner-In-Charge, by planning area: www.ura.gov.sg/dc/phone_email/contact_planner.html</p>

Appendix B: Examples of BIPV Applications in Buildings

1.0 Building Integrated Photovoltaics

Photovoltaics when integrated in buildings serve many functions. It not only generates electricity but also serves as building envelope, structural support, waterproofing, insulation, shading, solar thermal collection and also as Photovoltaic art.

European experience has so far proven Photovoltaics system as an energy generator as well as versatile building material. Its integration in building envelope is possible in different ways and recent developments in solar technology are further set to widen its application in buildings. With so many different shapes, sizes, color and applications to choose from designers are able to uplift their creativity to a level which is environmentally friendly, energy efficient, comfortable, multi-functional and aesthetically attractive.

Applications of photovoltaics in following areas of building are possible;

- Facade and balustrades
- Roof, Skylight and Canopy
- Shading devices
- Photovoltaic Art

Following sections illustrate the design potential of photovoltaics by looking at examples of how PV systems can be integrated into buildings.

1.1 PV Facade and balustrades

1.1.1 Zero Energy Building, Singapore

This would be Singapore's first retrofitted Zero energy building and is a research collaboration between National University of Singapore and Building & Construction Authority. The building entirely operates on clean energy from the photovoltaics. Energy generation being main objective, the project a) also serves as a BIPV demo site to present solutions for adoption by local building industry and b) it provides opportunity for research including quantitative and qualitative performance evaluation and comparison.

PV panels in the roofs of large curved PV roof, Walkway shelter and Carpark shelter generate almost 100% of the electricity used by the building. PV panels with first generation and second generation silicon cells are utilized in these areas to maximize the energy generation.

Based on their applicability and suitability PV panels of different generations are applied in various building components; first generation PV modules over large curved PV roof and Walkway shelter, Amorphous PV laminates over Carpark shelter and Sunshades, Amorphous PV modules in balustrade, and unique story-telling of evolution of Photovoltaics by facade integrated PV panels ranging from "first generation to third generation" in staircase facade both opaque and semi-transparent.

Appendix B: Examples of BIPV Applications in Buildings

Building name:	Zero Energy Building
Owner:	Building and Construction Authority of Singapore
Location:	Singapore
Building type:	Institutional
Completion:	Expected to be completed by middle of 2009
Working groups:	
• Lead organization:	Building and Construction Authority
• Principal:	A/P Stephen Wittkopf (BIPV and Daylighting)
Investigators:	A/P Lee Siew Eang (Energy efficiency and management)
	A/P Wong Nyuk Hien (Natural ventilation and Greening)
• Project Manager:	Beca Carter Hollings & Ferner (SE Asia) Pte Ltd
• Project architects:	DP Architects Pte Ltd
• M&E engineers:	Beca Carter Hollings & Ferner (SE Asia) Pte Ltd
• Structural engineers:	Beca Carter Hollings & Ferner (SE Asia) Pte Ltd
• Quantity Surveyers:	Davis Langdon & Seah Singapore Pte Ltd
Type of PV integration:	All major BIPV areas: Roof, Facade, Shading device, Balustrade and Canopy
Type of PV cell technology:	All major PV cell technology: First generation (Mono crystalline and Polycrystalline Silicon cells), Second generation (Amorphous Silicon cells) and Third generation (Dye-sensitized cells) both opaque and semi-transparent
PV area:	1295 m ²
PV system power:	171 kWp
Estimated energy output:	186,000 kWh / yr
Estimated Yield:	1088 kWh / kWp/ yr



Fig (1) East Elevation of Zero Energy Building

1.1.2 Doxford Solar Office, United Kingdom

Building name:	Doxford Solar Office
Owner :	Akeler Developments Ltd
Location:	Sunderland, United Kingdom
Building type:	Commercial
Completion:	1998
Working groups	
• Project architects:	Studio E Architects Ltd
• Structural engineers:	Whitby and Bird Partnership Ltd
• PV design:	Studio E Architects + Rybka Battle
• Building services:	Rybka Battle
• Contractors:	Bowmer and Kirkland
• PV manufacturer:	Kyocera
Type of PV integration:	Facade
Type of PV cell technology:	Polycrystalline silicon
PV area:	640 m ²
PV system power:	73 kWp
Estimated energy output:	113,000 kWh / yr
Yield:	1548 kWh / kWp
Information courtesy of:	Schüco International KG and : IEA Photovoltaic Power Systems Programme

The building's south facade is inclined, blue colored curtain wall. Almost 70% of it is covered by semi-transparent silicon crystal cells photovoltaic panels. The facade encloses an atrium which gets an interesting light and shadow effect from the PV facade.



Fig (2) Building exterior³



Fig (3) Building interior view⁴

³ Photographs courtesy of Schüco International KG

⁴ Photographs courtesy of Dennis Gilbert and IEA Photovoltaic Power Systems Programme

Appendix B: Examples of BIPV Applications in Buildings

1.1.3 Solar-Fabrik AG, Germany

Building name:	Solar Fabrik AG
Owner :	Solar Fabrik AG
Location:	Freiburg, Germany
Building type:	Commercial
Completion:	1999
Working groups	
• Project architects:	Rolf & Hotz, Freiburg
• General contractors:	Freyler Industriebau GmbH, Kenzingen
Type of PV integration:	Facade
Type of PV cell technology:	Mono-crystalline Silicon
PV area:	575 m ²
PV system power:	56.5 kWp
Estimated energy output:	45,000.0 kWh / yr
Yield:	800 kWh / kWp
Information courtesy of:	Solar Fabrik AG

Twenty percent of the building's electrical power is supplied by solar modules. Photovoltaic has multiple functions. It is used to shade and prevent the glass-clad factory from overheating whilst generating electricity. It serves as a major architectural design element of the building as well as a showcase of the latest PV technologies of that time.



Fig (4) Building exterior⁵



Fig (5) Building interior view⁵

⁵Photographs courtesy of Solar Fabrik AG

1.1.4 Zara Fashion House, Germany

Building name:	Zara Fashion House
Owner :	BFW GmbH & Co KG
Location:	Cologne, Germany
Building type:	Commercial
Completion:	2003
Working groups	
• Project architects:	Feinhals Architects
• PV manufacturer:	SOLON AG für Solartechnik
:	Schüco International KG
• Structural engineers:	Fassade Hohe Straße
Type of PV integration:	Facade
Type of PV cell technology:	Poly-crystalline Silicon
PV system power:	12 kWp
Information courtesy of:	SOLON AG für Solartechnik

Facade consists of 16 different types of special modules, which are imbedded in insulation glass panes. This allows the photovoltaic module to generate electricity while acting as a part of the building's cladding. Point brackets hold the laminated solar insulation glass panes in the mullion-and-transom construction, and electrical circuit points and ventilation slits are located discreetly on the back of the module. To prevent output loss through shading, the whole structure was designed with multiple independent power units.



Fig (6) Building exterior⁶



Fig (7) Building exterior⁶

⁶Photographs courtesy of Constantine Meyer and SOLON AG für Solartechnik

Appendix B: Examples of BIPV Applications in Buildings

1.1.5 Private Residence in Rosrath, Germany

Building name:	Private residence in Rosrath
Location:	Cologne, Germany
Building type:	Residential
PV manufacturer:	Schott Solar GmbH
Type of PV integration:	Facade, skylight and canopy
Type of PV cell technology:	Amorphous Silicon
Information courtesy of:	WIBATEC GmbH and Schott Solar GmbH

Transparent glass-glass amorphous silicon PV panels resemble tinted glass. They are available in various color and transparency. They are also available in different thickness and composition of the glass. This allows building owner and designers to design energy efficient, aesthetically pleasant and electricity generating buildings.



Fig (8) Building exterior⁷



Fig (9) Building interior view⁷



Fig (10) Canopy⁸

⁷ Photographs courtesy of WIBATEC GmbH and Schott Solar GmbH

⁸ Photographs courtesy of WIBATEC GmbH and Schott Solar GmbH

1.1.6 Großhadern Clinic, Germany

Building name:	Großhadern clinic
Owner :	Großhadern clinic
Location:	Munich, Germany
Building type:	Hospital
Working groups:	Schüco International KG
Type of PV integration:	Balustrade
Type of PV cell technology:	Multi-crystalline Silicon
PV area:	53 m ²
PV system power:	5 kWp
Information courtesy of:	Schüco International KG

Semi-transparent glass/glass Photovoltaic modules were used in balconies. The Photovoltaic integrated balustrade has enhanced the facade design whilst ensuring safety of the occupants and energy generation. They are also perfect in allowing good visibility whilst protecting privacy.



Fig (11) Building exterior °

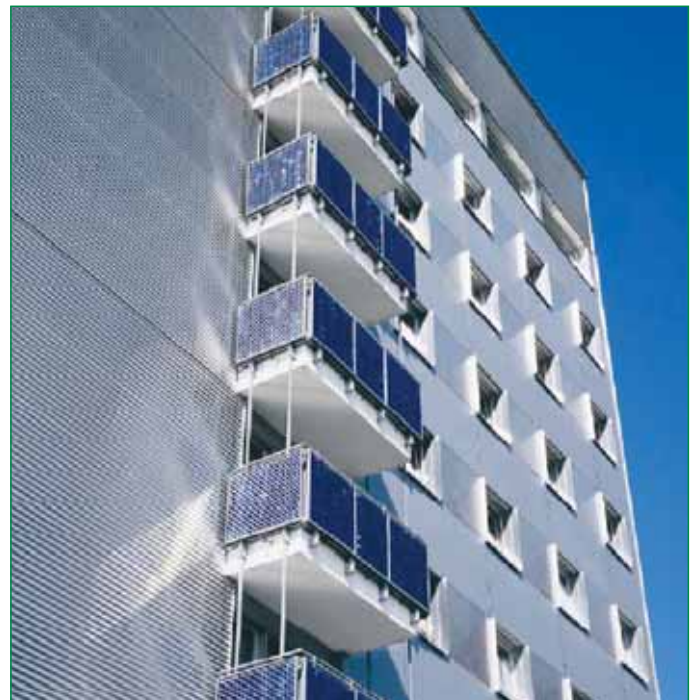


Fig (12) Building exterior °

°Photographs courtesy of Schüco International KG

Appendix B: Examples of BIPV Applications in Buildings

1.2 PV roof, skylight and canopy

1.2.1 Sydney Olympic Village, Australia

Building name:	Sydney Olympic village
Owner :	Olympic Co-ordination Authority
Location:	Newington Suburb, Homebush Bay, Sydney, Australia
Building type:	Residential
Completion:	1999
Working groups	
• Project architects:	Henry Pollack Architects (co-ordinators), Virginia Kerridge, Grose Bradley, Gordon & Valich, Order Architects, Howard Tanner & Associates, Tonkin Zulaikha, Richard Huxley
• Project engineers:	Connell Wagner, BP Solar and Pacific Power
• Building developers:	Mirvac LendLease
• PV installers:	BP Solar Structural installation
• Contractors:	Civil & Civil (Lend Lease Projects)
• PV manufacturer:	BP Solar
Type of PV integration:	Roof
Type of PV cell technology:	Mono-crystalline silicon
PV area:	575 m ²
PV system power:	629 x 1 kWp
Estimated energy output:	1400-1500 kWh / yr per system
Information courtesy of:	IEA Photovoltaic Power Systems Programme



Fig (13) Building exterior ¹⁰



Fig (14) Building exterior ¹⁰

¹⁰Photographs courtesy of BP Solar and and IEA Photovoltaic Power Systems Programme

The project is the world's largest solar village showcase for the Olympics. Following extensive prototyping and full scale mock ups of various roof integrated (PV) system design options the final product consisted of a metal sub-tray waterproof roof sheet on which frameless BP Solar high efficiency Saturn PV module laminates were fastened down using six custom designed diamond shaped mounting clips.



Fig (15) Building exterior ¹¹

¹¹ Photographs courtesy of Mirvac lendlease and and IEA Photovoltaic Power Systems Programme

Appendix B: Examples of BIPV Applications in Buildings

1.2.2 Mont Cenis Academy, Germany

Building name:	Mont-Cenis Academy
Owner :	Akademie Mont-Cenis, Entwicklungsgesellschaft Mont-Cenis, Herne
Location:	Herne, Germany
Building type:	Public / Commercial
Completion:	1999
Working groups	
• Project architects:	Jourda Architects, Paris
:	HHS Planer + Architekten BDA, Kassel, Germany
• Project management:	dmp architekten gmbH, Stuttgart, Germany
• Climatic design:	Universität Dortmund, Fakultät für Bauwesen, Dortmund
:	Schmidt Reuter Partner, Köln
:	Institut für Licht und Bautechnik, Köln
• PV engineers:	Flabec Solar International GmbH, Köln
:	abakus energiesysteme gmbH, Gelsenkirchen
• Contractors:	Wicon Bausysteme GmbH, Ulm (aluminium profiles),
:	Rheinelekttra Technik GmbH, Essen (electrical connection team),
:	ARGE Urban & Langwehr GmbH, Datteln (mounting of PV-modules and glass rains)
Type of PV integration:	Skylight, Facade and overhang
Type of PV cell technology:	Combination of monocrystalline and polycrystalline silicon
PV system power:	1000 kWp
Estimated energy output:	700,000 kWh / yr
Yield:	700 kWh / kWp
Information courtesy of:	IEA Photovoltaic Power Systems Programme

The Mont Cenis academy building is a huge glass greenhouse structure that includes accommodation, classrooms, a cafeteria, and a library. Glass-glass Photovoltaic panels with crystalline panels makes up whole envelop and overhang. Balance between daylighting and incoming solar heat is maintained by the choice of different cell densities in the panels.



Fig (16) Building exterior ¹²



Fig (17) Building exterior ¹²



Fig (18) Building interior ¹³



Fig (19) Building interior ¹³

¹² Photographs courtesy of Flabec Solar International GmbH and IEA Photovoltaic Power Systems Programme

¹³ Photographs courtesy of Ingo B. Hagemann and IEA Photovoltaic Power Systems Programme

Appendix B: Examples of BIPV Applications in Buildings

1.2.3 Daito University Itabashi Campus, Japan

Building name:	Daito University Itabashi Campus
Owner :	Daito Bunka University
Location:	Itabashi-ku, Japan
Building type:	Institutional
Completion:	2003
Architect:	Ben Nakamura and Yamamoto Hori Architects
Type of PV integration:	Facade and Skylight
Type of PV cell technology:	Mono-crystalline Silicon
PV area:	750 m ²
Information courtesy of:	http://www.iceice.com/ben/daitodaiposter.pdf

Located in Tokyo, Japan the Daito Bunka University's Itabashi Campus has been refurbished with environmentally conscious features that employ several energy saving and harnessing mechanisms. One of them is the extensive use of Photovoltaics for facade and Skylight.



Fig (20) Building interior view ¹⁴



Fig (21) Building interior view ¹⁴



Fig (22) Building exterior ¹⁵

¹⁴ Photographs courtesy of A/P Stephen K. Wittkopf (Dr.)

¹⁵ Photographs courtesy of A/P Stephen K. Wittkopf (Dr.)

1.2.4 Bayerische Landesbank, Germany

Building name:	Bayerische Landesbank
Owner :	Bayerische Landesbank
Location:	Munich, Germany
Building type:	Commercial
Architect:	Stibale Architectural Practice
PV engineers and contractors:	Schüco international KG
:	Frener & Reifer Metallbau GmbH, Brixen, Italy
:	Wennemuth Elektrotechnik, Wehretal
Type of PV integration:	Facade, canopy and shading device
Type of PV cell technology:	Poly-crystalline Silicon
PV area:	538 m ²
PV system power:	73.5 kWp
Information courtesy of:	Schüco International KG

The semi-transparent PV modules are integrated in different areas of the building; Canopy, facade and Sunshades.



Fig (23) Building exterior ¹⁶



Fig (24) Building exterior ¹⁶

¹⁶Photographs courtesy of Schüco International KG

Appendix B: Examples of BIPV Applications in Buildings

1.3 PV Shading Devices

Building name:	Clinical Molecular Biology Research Centre
Owner :	Universitätsbauamt Erlangen
Location:	Erlangen, Germany
Building type:	Institutional
Architect:	Christoph Präg
PV manufacturer:	SOLON AG für Solartechnik
Type of PV integration:	Shading device
Type of PV cell technology:	Poly-crystalline Silicon
PV system power:	29.8 kWp
Information courtesy of:	SOLON AG für Solartechnik

Fixed solar blind and Sun-tracking solar lamella were solutions to the challenge to combine improved aesthetic solar building integration and a high power output.

A total of 120 photovoltaic modules form a shady and translucent solar blind covering the glass facade. Linear motors move the 140 glass-glass modules, adapting them to the exterior lighting conditions.



Fig (25) Building exterior ¹⁷



Fig (26) Building interior view ¹⁷

¹⁷ Photographs courtesy of Wolfram Murr and SOLON AG für Solartechnik

1.4 Photovoltaic Art

1.4.1 Northern Light, Canada

Building name:	Northern Light
Owner :	Concordia University
Location:	Montreal, Canada
Building type:	Institutional
Working Group:	
Architect:	Sarah Hall
Type of PV integration:	Photovoltaic art in Façade
Type of PV cell technology:	Poly-crystalline Silicon
PV system power:	36 kWp
Yield:	19 kWh
Information courtesy of:	Sarah Hall, Sarah Hall Studio



Fig (27) Building exterior ¹⁸

Hall's work, installed in Canada's entry "Northern Light" merges the ancient art of stained glass with cutting edge technology to produce a window that not only looks magnificent, but works for its living as well by gathering and storing electricity for later use. Embedded in the window is an array of photoelectric cells (thin silicon and metal squares that convert light into electricity), and these collect enough energy to illuminate the building's foyer 24 hours a day, 7 days a week, 365 days a year.

Although the window components (art glass, photovoltaic cells, low-E and tempered glass) are well known, they are combined here using a patented method that produces a reliable and attractive source of energy. Solar cells come in a wide range of colors, allowing an unlimited range of designs, and the technology that collects and stores the energy is concealed, allowing the beauty of Hall's art and glass to shine through.



Fig (28) Building interior ¹⁸



Fig (29) Building interior ¹⁹

¹⁸ Photographs courtesy of Sarah Hall, Sarah Hall Studio

¹⁹ Photographs courtesy of Sarah Hall, Sarah Hall Studio

Appendix B: Examples of BIPV Applications in Buildings

2.0 Non-building Photovoltaic Structures

Beyond its application in buildings, photovoltaics have itself become a phenomenon which occurs at every level of urban architecture; from “non-building photovoltaic public utility structures” such as lamp posts, bus stops, car parking, signboards to “non-building photovoltaic art” such as art installations in parks.

Following sections illustrates the design potential of photovoltaics by looking at examples of how PV systems can be integrated into non-building photovoltaic structures.

2.1 Non-building photovoltaic public utility structures

Owner : UNIVER (UNiversidad VERde)
Location: Jaen, Spain
Structure type: Car Parking
PV manufacturer: Isofoton
Information courtesy of: IEA Photovoltaic Power Systems Programme

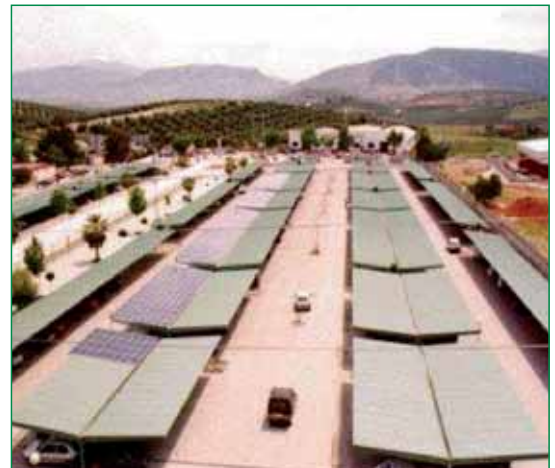


Fig (30) PV Car Parking ²⁰

2.2 Non-building photovoltaic art

Owner : Private
Location: USA
Structure type: “Electric Sunflowers”
Electricity generating solar trackers
PV manufacturer: BP Solar
Information courtesy of: IEA Photovoltaic Power Systems Programme



Fig (31) Electric Sunflowers ²¹

²⁰ Photographs courtesy of Jorge Aguilera and IEA Photovoltaic Power Systems Programme

²¹ Photographs courtesy of Solar Design Associates Inc. and IEA Photovoltaic Power Systems Programme

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