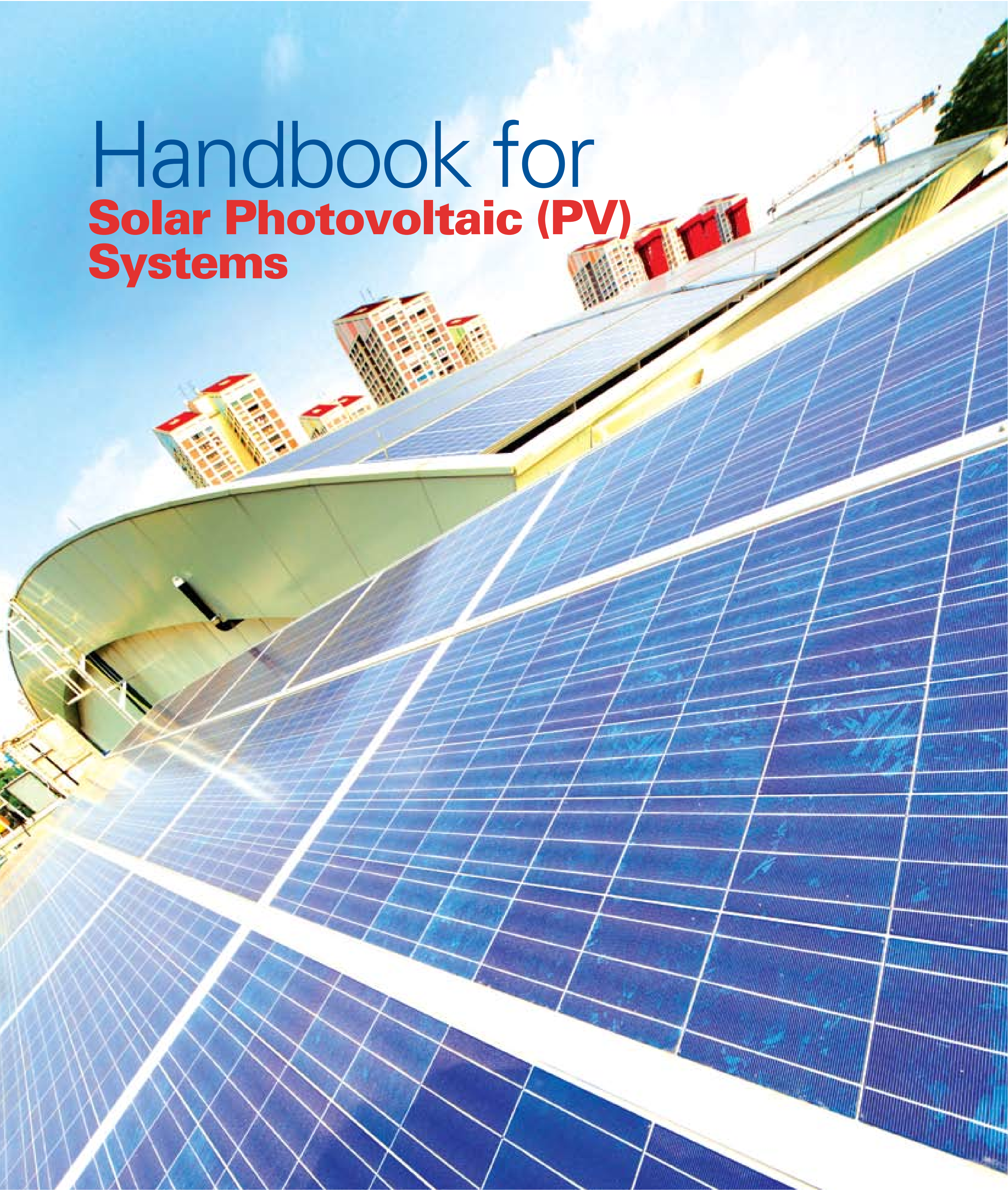
# Handbook for
# Solar Photovoltaic (PV) Systems



Energy Market Authority
Smart Energy, Sustainable Future

Building and Construction Authority
We shape a **safe**, **high quality**, **sustainable** and **friendly** built environment.

# Contents

# Appendices

# Foreword

Cognizant of the growing popularity of solar photovoltaic (PV) installations amongst residential dwellers as well as building developers, and the corresponding demand for a comprehensive set of technical and regulatory information, the Energy Market Authority (EMA) and the Building Construction Authority (BCA) got together earlier this year to work on integrating their respective solar manuals into an all-in-one reference guide for those who are keen on installing solar PV systems in Singapore.

The outcome of this joint project, which also saw the involvement of industry partners and stakeholders such as Phoenix Solar Pte Ltd, Grenzone Pte Ltd, Solar Energy Research Institute of Singapore (SERIS) and Singapore Polytechnic, is this "Handbook for Solar Photovoltaic (PV) Systems". Through this integrated and revised handbook, we hope to be able to provide a comprehensive guide to the relevant parties, including owners, developers, engineers, architects, Licensed Electrical Workers and electricians on the key issues, requirements and processes pertaining to the installation of solar PV systems.

As with the previous edition of the handbooks, this single volume covers and provides information on licensing, market and technical requirements, and building and structural issues that are related to the implementation of solar PV systems in a building environment. In addition, it provides new information on the installation requirements for solar PV systems, operations and recommended preventive maintenance works, and various incentives to promote solar PV systems in Singapore. We have also refreshed the presentation of the handbook to make it more accessible and reader-friendly, as well as to incorporate examples of completed solar PV installations in Singapore.

We hope you will find this to be a useful guide.

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# Acknowledgements

We would like to thank the following organisations for their support and contributions in the development of this handbook:

1) Grenzone Pte Ltd

2) Phoenix Solar Pte Ltd

3) Singapore Polytechnic

4) Solar Energy Research Institute of Singapore (SERIS)

5) SP PowerGrid

6) Urban Redevelopment Authority


# Note

Please note that some of the information in the solar PV handbook may be superseded. You may wish to refer to the solar PV portal www.singaporepower.com.sg/solarpv for updated information.

# 1 Solar Photovoltaic ("PV") Systems – An Overview

## 1.1 Introduction

The sun delivers its energy to us in two main forms: heat and light. There are two main types of solar power systems, namely, solar thermal systems that trap heat to warm up water, and solar PV systems that convert sunlight directly into electricity as shown in Figure 1.

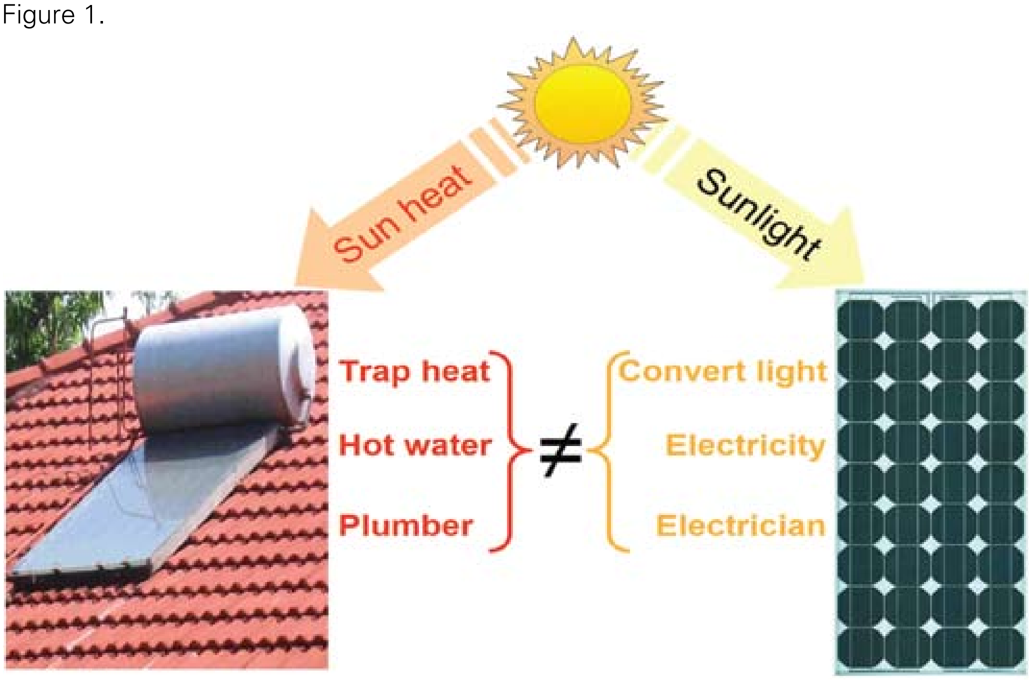



**Figure 1. The difference between solar thermal and solar PV systems**

When the PV modules are exposed to sunlight, they generate direct current ("DC") electricity. An inverter then converts the DC into alternating current ("AC") electricity, so that it can feed into one of the building's AC distribution boards ("ACDB") without affecting the quality of power supply.

## *1.2 Types of Solar PV System*

Solar PV systems can be classified based on the end-use application of the technology. There are two main types of solar PV systems: grid-connected (or grid-tied) and off-grid (or stand alone) solar PV systems.

Grid-connected solar PV systems

The main application of solar PV in Singapore is grid-connected, as Singapore's main island is well covered by the national power grid. Most solar PV systems are installed on buildings or mounted on the ground if land is not a constraint. For buildings, they are either mounted on the roof or integrated into the building. The latter is also known as Building Integrated Photovoltaics ("BIPV"). With BIPV, the PV module usually displaces another building component, e.g. window glass or roof/wall cladding, thereby serving a dual purpose and offsetting some costs.

The configuration of a grid-connected solar PV system is shown in Figure 2.

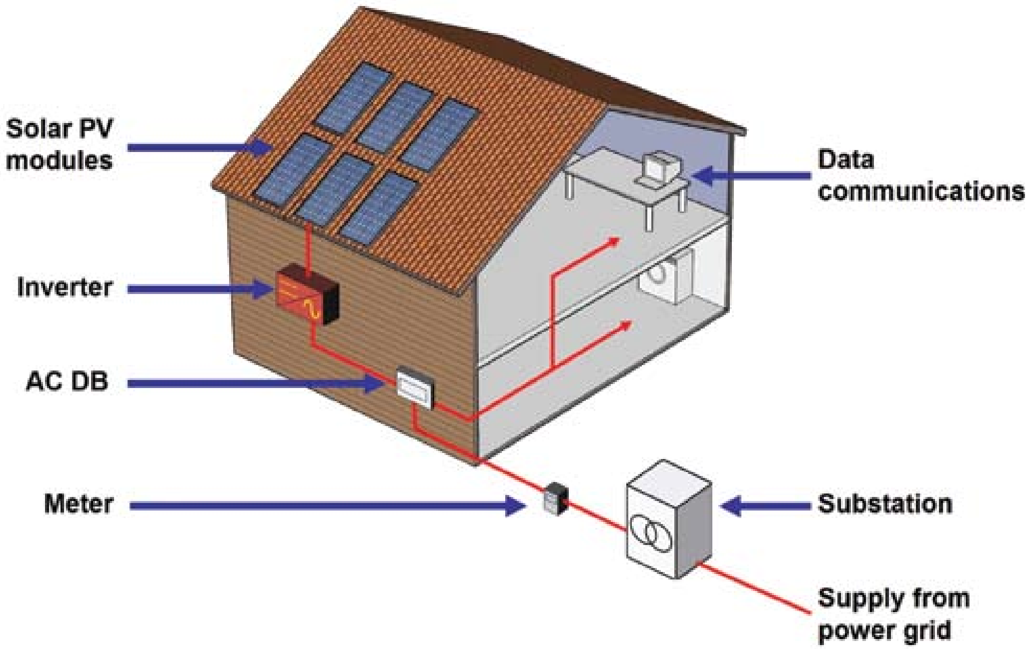



**Figure 2. Grid-connected solar PV system configuration**

A building has two parallel power supplies, one from the solar PV system and the other from the power grid. The combined power supply feeds all the loads connected to the main ACDB.

The ratio of solar PV supply to power grid supply varies, depending on the size of the solar PV system. Whenever the solar PV supply exceeds the building's demand, excess electricity will be exported into the grid. When there is no sunlight to generate PV electricity at night, the power grid will supply all of the building's demand.

A grid-connected system can be an effective way to reduce your dependence on utility power, increase renewable energy production, and improve the environment.

Off-grid solar PV systems

Off-grid solar PV systems are applicable for areas without power grid. Currently, such solar PV systems are usually installed at isolated sites where the power grid is far away, such as rural areas or off-shore islands. But they may also be installed within the city in situations where it is inconvenient or too costly to tap electricity from the power grid. For example, in Singapore, several URA parking sign lights are powered by off-grid solar PV systems.

An off-grid solar PV system needs deep cycle rechargeable batteries such as lead-acid, nickel-cadmium or lithium-ion batteries to store electricity for use under conditions where there is little or no output from the solar PV system, such as during the night, as shown in Figure 3 below.

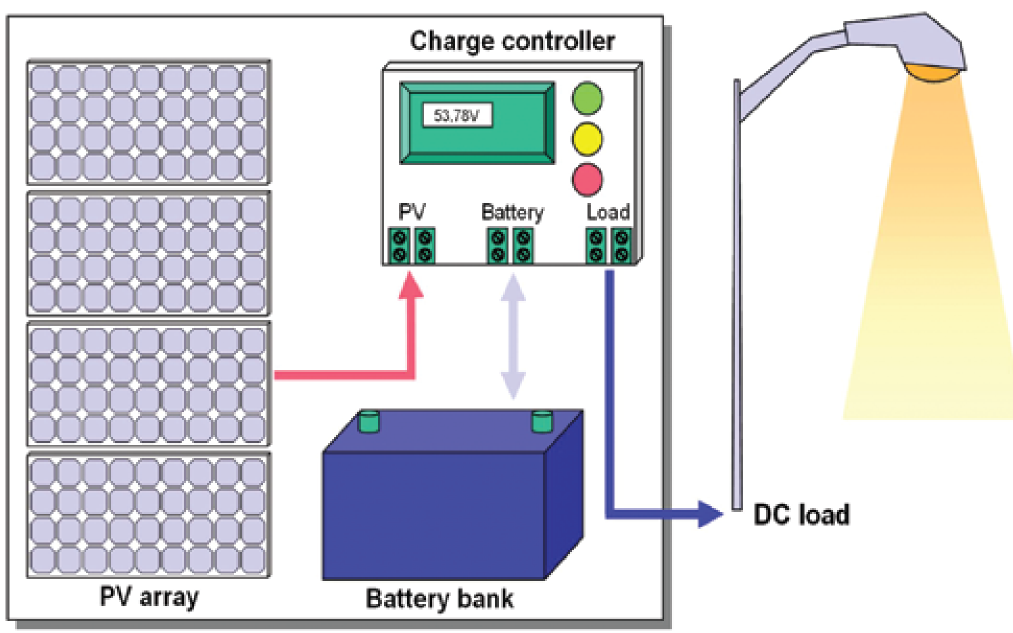


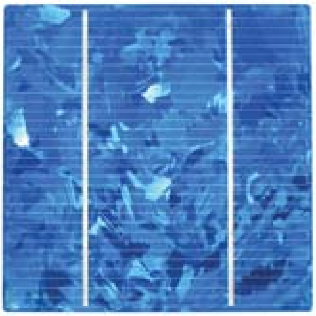

**Figure 3. Off-grid solar PV system configuration**

## *1.3 Solar PV Technology*

This section gives a brief description of the solar PV technology and the common technical terms used.

A solar PV system is powered by many crystalline or thin film PV modules. Individual PV cells are interconnected to form a PV module. This takes the form of a panel for easy installation.

**Mono-Crystalline Silicon PV Cell**



**Poly-Crystalline Silicon PV Cell**

**Figure 4. Mono-and Poly-Crystalline Silicon PV Cell**

PV cells are made of light-sensitive semiconductor materials that use photons to dislodge electrons to drive an electric current. There are two broad categories of technology used for PV cells, namely, crystalline silicon, as shown in Figure 4 which accounts for the majority of PV cell production; and thin film, which is newer and growing in popularity. The "family tree" in Figure 5 gives an overview of these technologies available today and Figure 6 illustrates some of these technologies.

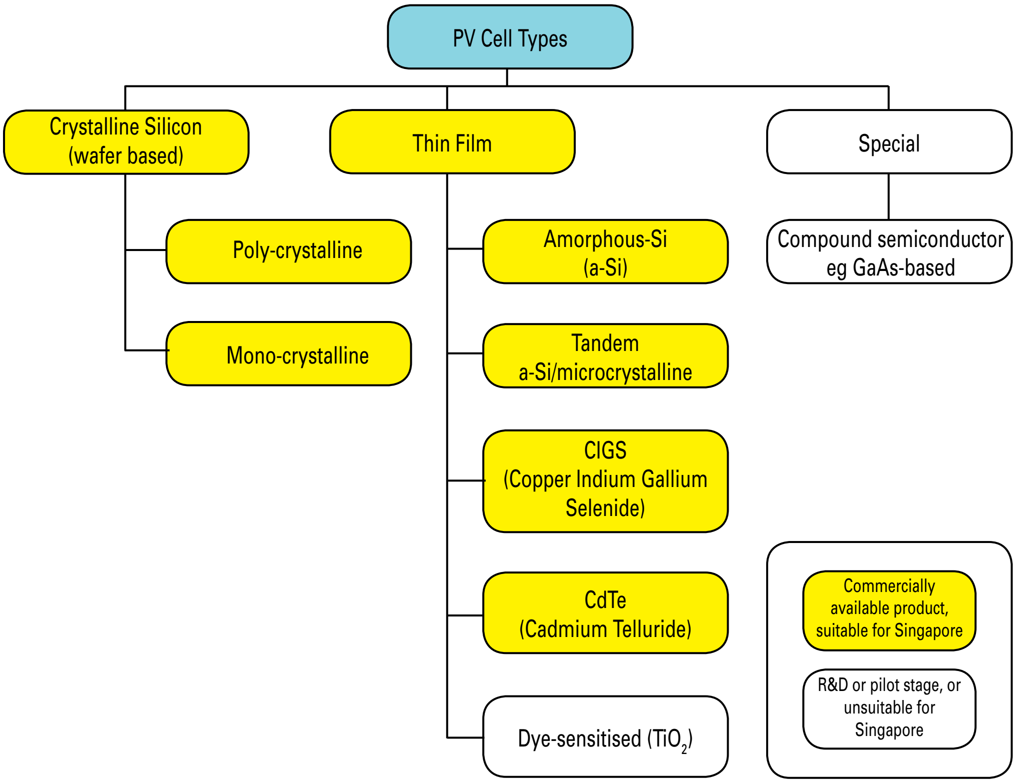
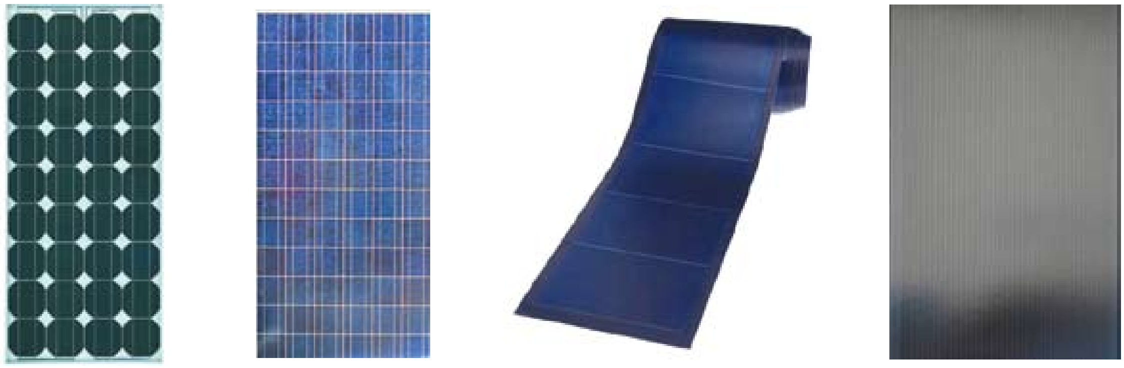



**Figure 5. PV technology family tree**



| Mono-crystalline silicon | Poly-crystalline silicon | Flexible amorphous thin film | CIGS thin film |
|---|---|---|---|

**Figure 6. Common PV module technologies**

## Crystalline Silicon and Thin Film Technologies

Crystalline cells are made from ultra-pure silicon raw material such as those used in semiconductor chips. They use silicon wafers that are typically 150-200 microns (one fifth of a millimetre) thick.

Thin film is made by depositing layers of semiconductor material barely 0.3 to 2 micrometres thick onto glass or stainless steel substrates. As the semiconductor layers are so thin, the costs of raw material are much lower than the capital equipment and processing costs.

## Conversion Efficiency

| Technology | Module Efficiency |
|---|---|
| Mono-crystalline Silicon | 12.5-15% |
| Poly-crystalline Silicon | 11-14% |
| Copper Indium Gallium Selenide (CIGS) | 10-13% |
| Cadmium Telluride (CdTe) | 9-12% |
| Amorphous Silicon (a-Si) | 5-7% |

**Table 1. Conversion efficiencies of various PV module technologies**

Apart from aesthetic differences, the most obvious difference amongst PV cell technologies is in its conversion efficiency, as summarised in Table 1.

For example, a thin film amorphous silicon PV array will need close to twice the space of a crystalline silicon PV array because its module efficiency is halved, for the same nominal capacity under Standard Test Conditions[1] (STC) rating.

[1]Standard Test Conditions refer to the following testing conditions:
- 1,000W/m$^2$ of sunlight
- 25$^0$C cell temperature
- Spectrum at air mass of 1.5

For crystalline silicon PV modules, the module efficiency is lower compared to the sum of the component cell efficiency due to the presence of gaps between the cells and the border around the circuit i.e., wasted space that does not generate any power hence lower total efficiency.

## Effects of Temperature

Another important differentiator in solar PV performance, especially in hot climates, is the temperature coefficient of power. PV cell performance declines as cell temperature rises.

For example, in bright sunlight, cell temperatures in Singapore can reach over 70ºC, whereas PV modules are rated at a cell temperature of 25ºC. The loss in power output at 70ºC is therefore measured as (70 - 25) x temperature coefficient.

Most thin film technologies have a lower negative temperature coefficient compared to crystalline technologies. In other words, they tend to lose less of their rated capacity as temperature rises. Hence, under Singapore's climatic condition, thin film technologies will generate 5-10% more electricity per year.

A PV module data sheet should specify the temperature coefficient. See Table 2 and chart in Figure 7.

| Technology | Temperature Coefficient [%/°C] |
|---|---|
| Crystalline silicon | -0.4 to -0.5 |
| CIGS | -0.32 to -0.36 |
| CdTe | -0.25 |
| a-Si | -0.21 |

**Table 2. Temperature coefficient of various PV cell technologes**

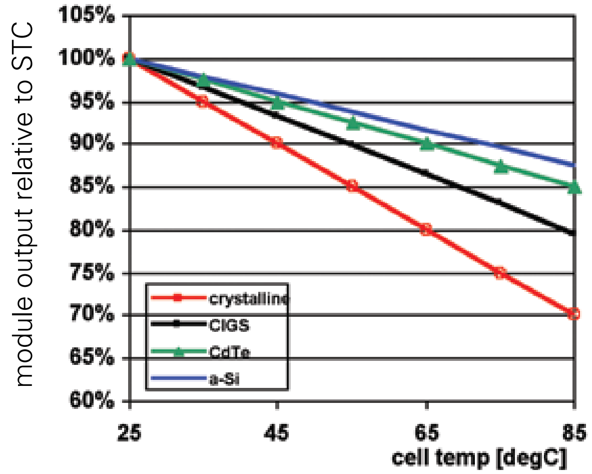



**Figure 7. The effects of a negative temperature coefficient of power on PV module performance**

The PV modules are next connected in series into a PV string as shown in Figure 8. A PV array as shown in Figure 9 is formed by the parallel aggregation of PV strings.

**Figure 8. PV String**

**Figure 9. PV Array**

### *1.4 Technical Information*

Single-core, double isolated sheathed cables that can withstand the environmental conditions, and minimise the risk of earth faults and short circuits are used to interconnect the PV strings and arrays. The cable connections are protected in enclosures known as junction box that provides the necessary connectors as shown in Figure 10.

**Figure 10. Junction Box**

Electricity produced by the solar PV installation is in the form of DC. The output of the PV installation is connected through the DC main cables to the DC terminals of the PV inverter where electricity is converted from DC into AC.

After conversion, the AC current of the PV inverter is connected through PV supply cable to the building's electrical installation (AC distribution board).

Figure 11 shows a typical PV inverter connected to the electrical installation of a building. Note that the actual configuration of the PV inverter may vary across different systems.

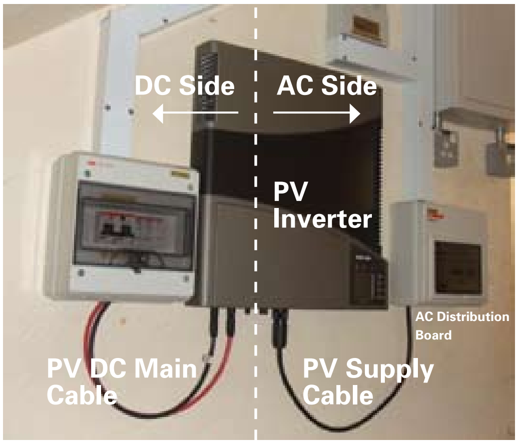



**Figure 11. Typical PV inverter connected to a building's electrical installation**

Just like any electrical installation in a building, earthing is an important safety requirement for solar PV system. Arrangement must be made for proper connection of the solar PV system to the consumer's electrical installation earthing system.

In locations susceptible to lightning strikes, a lightning protection system must be provided, and all the exposed metallic structures of the solar PV system must be bound to the lightning earthing system.

It is the responsibility of the consumers to have their solar PV systems maintained regularly to ensure safe operation of their solar PV systems and electrical installations. See Figure 12 for a diagram showing the solar PV system forming part of a consumer's electrical installation.

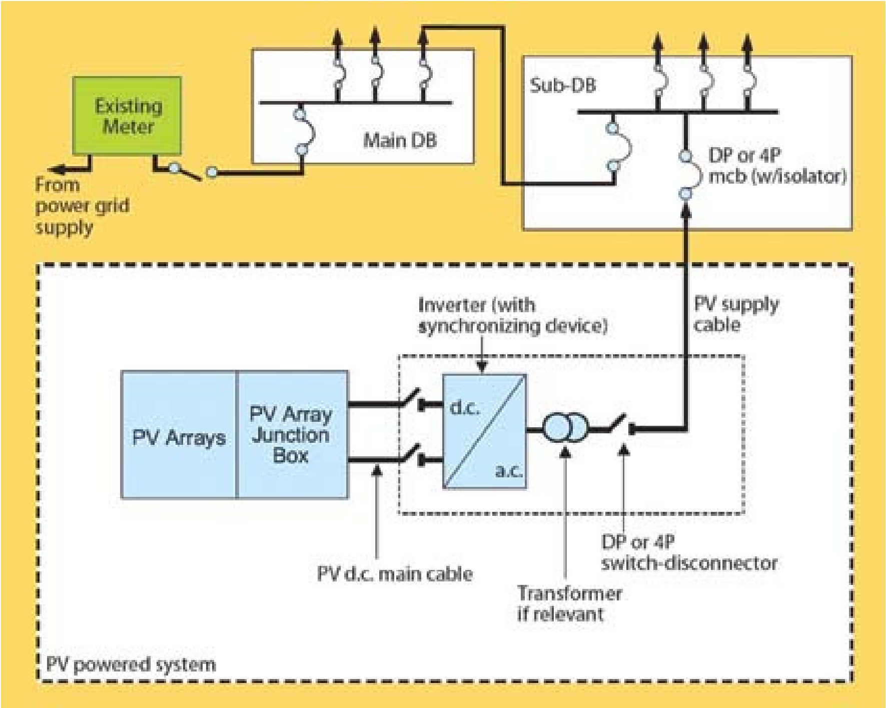



**Figure 12. Solar PV system forming part of a consumer's electrical installation**

# Solar PV Systems on a Building

## 2.1 Introduction

There are many examples overseas where PV modules are mounted on the roof and integrated into building façades. They work particularly well in Europe and North America, as south-facing façades in these regions are well exposed to the sun.

In Singapore, we have to consider that the sun passes almost directly overhead. This is because we are located near the Equator, and the path of the sun follows the Equator, with seasonal variations of up to 23.5° to the north or south. Therefore there are optimal positions to locate the PV modules that have to be taken into consideration. Refer to Appendix A for examples of solar PV systems on buildings in Singapore.

## 2.2 Installation Angle

To maximise electricity production for use in Singapore, the best location for the PV modules to be installed is right on top of a building, facing the sky. The possible installation options are shown in Figure 13.

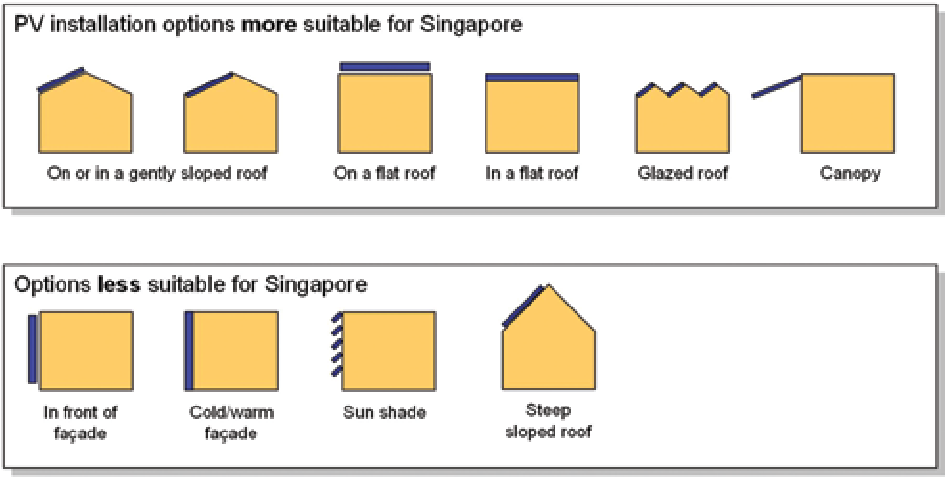



**Figure 13. Where to install PV modules on a building in Singapore**

Vertical façades and steeply sloped roofs tend to suffer a big loss in the ability to generate electricity in exchange for higher public visibility.

With the PV modules facing the sky, it is possible to improve the yield by installing PV modules on trackers to follow the sun from east to west during the day (single-axis trackers), and from north to south during seasonal changes (dual-axis trackers).

However, trackers can only improve system performance under direct sunshine, and they give no advantage in diffused sunlight conditions, such as on cloudy or hazy days.

The down side of having flat-mounted PV modules is that they tend to get dirty from rain water and dust. See Figure 14. It is therefore better to mount the PV modules at an incline (10-15$^{\circ}$ for framed modules, or as little as 3-5$^{\circ}$ for unframed modules), to allow rain water to properly drain off

**Figure 14. PV module frames trap dirt as water evaporates from a flat-mounted PV module**

### *2.3 Avoid Shading PV Modules*

PV modules should be free from shade. Shading of any single cell of a crystalline silicon PV module will drastically reduce the output of the entire PV module.

Thin film PV modules are more tolerant to partial shading than crystalline silicon PV modules. Typical culprits include shadows cast by tall trees and neighbouring buildings.

### 2.4 *Aesthetic and Creative Approaches in Mounting PV Modules*

Besides mounting PV modules on the rooftop, customised PV modules can be integrated into the building façade in a creative, aesthetically pleasing manner. They can be mounted on any part of the rooftop or external walls that is well exposed to sunlight e.g. skylights, cladding, windows, and external shading devices.

They can also be integrated into external structures such as façades and canopies, as shown in Figure 15 and Figure 16, respectively.

**Figure 15. BIPV modules integrated into a façade**

**Figure 16. BIPV modules integrated into a skylight canopy**

### 2.5 *Solar PV Output Profile*

Solar PV only produces electricity when sunlight is available. The output of a solar PV system varies with its rated output, temperature, weather conditions, and time of the day. The power output profile of the PV installation as shown in Figure 17, at a selected test site in Singapore collected over a period from 2002-2004, in terms of its capacity factor[2] , shows a high variation of solar PV output.

*[2] PV Output capacity factor = Ratio of the actual output of the PV installation at time (t) over its output if it had operated at full rated output.*

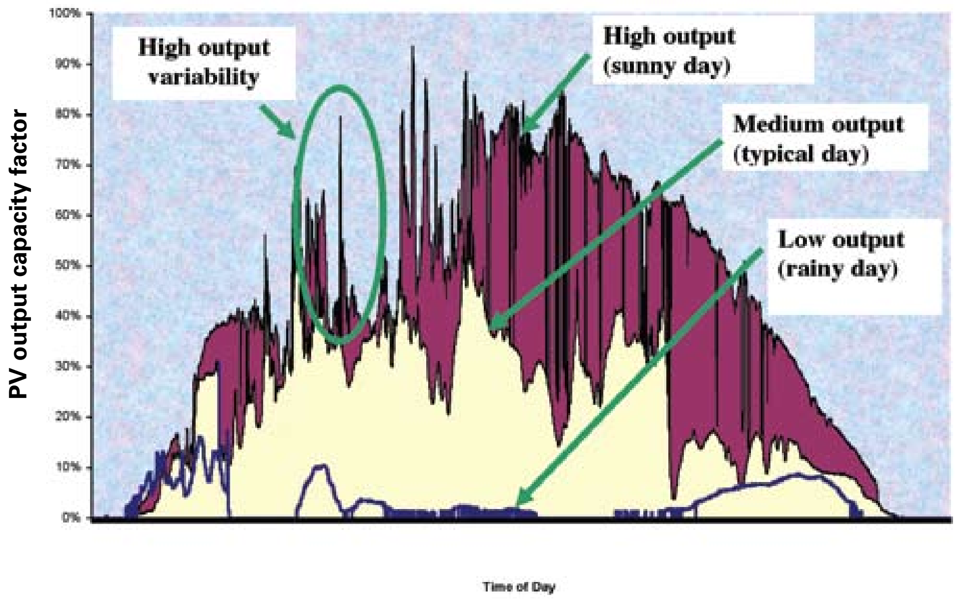



**Figure 17. Varying daily power output profile of PV installation at a selected test site in Singapore**

### *2.6 Solar PV Yield*

The amount of electricity you are able to generate from a solar PV system depends not only on the availability of sunshine but also on the technology you choose to install. For example, a typical 10-kW rooftop solar PV system in Singapore would produce about 11,000 to 12,500 kWh annually using crystalline PV modules, and 12,000 to 14,500 kWh annually with amorphous silicon thin film PV modules.

### *2.7 Cost of a Solar PV System*

The cost of your solar PV system will depend on many factors: system configuration, equipment options, labour cost and financing cost. Prices also vary depending on factors such as whether or not your home is new, and whether the PV modules are integrated into the roof or mounted on the roof. The cost also depends on the system size or rating, and the amount of electricity it produces.

Generally, solar PV systems entail high capital costs. With solar power, you can save on the purchase of electricity from the grid. But even with these savings, it will take a long time to recover the capital cost of the solar PV installation. The operating costs for solar PV installations are negligible, but the annual maintenance cost beyond the warranty period may amount to 0.5% to 1% of the capital cost of the installation.

Therefore on an overall basis, solar PV-derived electricity is still much more expensive than that from the power grid. However, the cost of solar PV has historically been falling by about 4% a year, and if this continues, solar PV may be competitive within the next 10 years. For incentives on solar PV system, please refer to Appendix D.

# 3 Appointing a Solar PV System Contractor

## 3.1 Introduction

You will need to select a contractor to install your solar PV system. If interested, you may check with the following organisations for some solar PV system designers and contractors:

- The List of Solar PV System companies in Singapore, available from Sustainable Energy Association of Singapore, by calling 6338 8578 or by visiting http://www.seas.org.sg/about-seas/our-committees/cleanenergy/54

- The Singapore Sustainable Development Industry Directory 2008/2009, available from the Singapore Business Federation, by calling 6827 6838 or by visiting http://www.sbf.org.sg/public/publications/industrydirectory.jsp

Your contractor will appoint a Licensed Electrical Worker ("LEW") who will be responsible for the design, installation, testing, commissioning, and maintenance of your solar PV system.

In the case of non-residential electrical installations that require an electrical installation licence, the appointed LEW who supervises the electrical work ("Design LEW") may not be the one who takes charge of your electrical installation ("Installation LEW"). The Design LEW will then have to work with the Installation LEW to work out the technical issues.

Please refer to Appendix B for details on how you can engage an LEW and the necessary consultation process.

### 3.2 Getting Started

First, compile a list of potential solar PV system contractors. Next, contact the contractors to find out the products and services they offer. The following pointers may give consumers a good sense of the contractor's capabilities:

Get an experienced and licensed contractor

Experience in installing grid-connected solar PV systems is invaluable, because some elements of the installation process, particularly interconnection with the grid, are unique to these systems. A contractor with years of experience will also demonstrate an ability to work with consumers, and price their products and services competitively.

It is also important to get a contractor who is an LEW.

Choosing between bids

If there are several bids for the installation of a solar PV system (it is generally a good practice to obtain multiple bids), consumers should take steps to ensure that all of the bids received are made on the same basis. Comparing a bid for a solar PV system mounted on the ground against another bid for a rooftop system is like comparing apples to oranges.

Bids should clearly state the maximum generating capacity of the solar PV system [measured in watts peak (Wp) or kilowatts peak (kWp)]. If possible, the bids should specify the system capacity in AC watts, or specify the output of the system at the inverter.

Bids should also include the total cost of getting the solar PV system components, including hardware, software, supporting structure, meter, installation, connection to the grid (if applicable), permitting, goods and services tax, warranty, and future maintenance cost (if applicable).

Solar PV system warranty

A solar PV system is an investment that should last a long time, typically two to three decades for grid-connected applications. The industry standard for a PV module warranty is 20-25 years on the power output.

There are two main components to a PV module warranty:

- A workmanship warranty that offers to repair, replace or refund the purchase in case of defects. The period varies from one to as long as ten years, depending on the manufacturer. Two to five years is typical; and

- A limited power output warranty that offers a variety of remedies in case the PV module's output under STC drops below certain level. Most manufacturers warrant at least 90% of the minimum rated output for 10 years, and 80% of the minimum rated output for 20-25 years. Take note that the minimum rated output is usually defined as 95% of the rated output to allow for manufacturing and measurement tolerances. See Figure 18 for details.

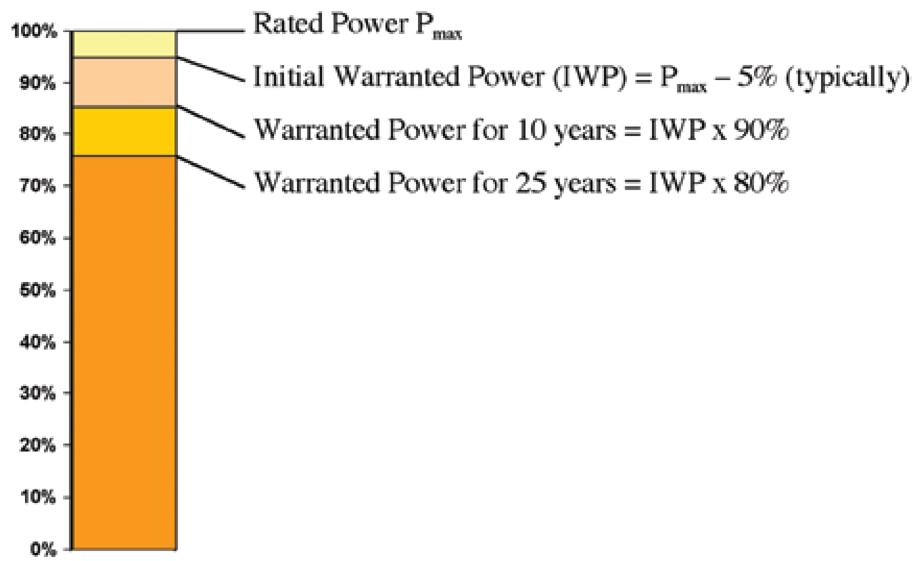



**Figure 18. Understanding a manufacturer's limited power warranty**

Take note that under the limited power warranty, manufacturers seldom offer to replace the PV module itself. Rather, at their sole discretion, they may offer to:

- Repair the defective PV modules;

- Supply enough new PV modules to replace the lost power output in a PV array. For example, if your 20kW PV array only produces 16.1kW under STC, six years after installation, the manufacturer may opt to supply you with 1kW of PV modules to make up for the shortfall; or

- Refund you for the lost power output, after deduction according to the number of years in use. For a 25-year warranty, the annual deduction is normally 4%. For example, if you find that your 20kW PV array only produces 16.1kW under STC, six years after installation, the manufacturer may opt to reimburse your purchase price minus 24% (6 years x 4%).

In all cases, the manufacturer does not cover your costs of dismounting, transporting, and reinstalling the PV modules. The warranty also excludes problems resulting from improper installations; repairs, changes or dismounting by unqualified personnel; accidental breakage or abuse; lightning strikes and other acts of God.

Significantly, most manufacturers specify that the PV module output will be determined by the flash testers in their own premises, rather than by a third party.

The solar PV system contractor should assist in determining whether a PV module defect is covered by warranty, and should handle the situation with the manufacturer.

### Regular maintenance

During the defect liability period (usually for 12 months after installation), solar PV system contractors usually use remote monitoring data to prepare monthly performance reports of the installed solar PV system. They should come on site to rectify any problems flagged by the remote monitoring service.

### Other relevant matters

Another matter to be aware of is that PV module manufacturers are constantly upgrading their products, and adapting new sizes and dimensions to suit market requirements. This means that you may no longer be able to buy an identical PV module to replace a defective one in your PV array a few years after installation. Newer PV modules are likely to be more efficient or have different physical dimensions, and may no longer fit exactly into the gap left by the old PV module.

This does not matter much on a large, ground-mounted solar PV power plant, because the new modules can form a new row. But on a building-mounted solar PV system it may spoil the aesthetics, and may cause problems to the electrical configuration.

# 4 Solar PV System Installation Requirements

### 4.1 Electrical Installation Licence

An electrical installation refers to any electrical wiring, fitting or apparatus used for the conveyance and control of electricity in any premises. A solar PV system installed within such premises forms part of the consumer's electrical installation and should comply with the requirements stipulated in the Electricity Act (Cap. 89A), the Electricity (Electrical Installations) Regulations and the Singapore Standard CP5 Code of Practice for Electrical Installations.

Under the Electricity Act, the Energy Market Authority ("EMA") licenses all non-residential electrical installations, with demand exceeding 45 kilo volt ampere or kVA. For residential electrical installations and non-residential electrical installations with demand below the threshold 45kVA, no electrical installation licence is required.

The licence requires the owner of the electrical installation to engage an LEW to take charge of the electrical installation and comply with the relevant safety standards and requirements. Your appointed LEW shall consult SP PowerGrid Ltd on their technical requirements and procedures, if you wish to operate your solar PV system in parallel with the power grid. The objective is to ensure all electrical installations, including solar PV systems, are safe to use.

### 4.2 Electrical Safety Standards and Requirements

A grid-connected solar PV system operates in parallel with the power grid supply. The power grid supply is considered the source, and the electrical installation with the solar PV system connected is considered as the load.

The technical requirement for installation of a solar PV system is given in Section 612 of the Singapore Standard CP5.

There are international product standards on PV modules and electrical components. For example, PV modules should comply with the requirements of IEC 61215 for crystalline silicon terrestrial PV modules or IEC 61646 for thin-film terrestrial PV modules. In addition, PV array junction box, PV generator junction box and switchgear assemblies should comply with the requirements of IEC 60439-1.

### 4.3 Application of Electrical Installation Licence

Your LEW will be able to advise you whether you need to apply to EMA for an Electrical Installation Licence for the use or operation of the electrical installation within the premises of your building.

If an Electrical Installation Licence is needed, your LEW will submit the licence application to EMA on your behalf. If you already have an Electrical Installation Licence issued by EMA, you need not apply for a separate licence for the solar PV system within the same premises.

The electrical licence fee payable to EMA is $100 per year (exclusive of goods and services tax).

### 4.4 Conservation and Development Control Requirements

At present, there is no specific requirement or control by the Urban Redevelopment Authority ("URA") on the use of installations such as a solar PV system. However, conservation projects, or projects within the Central Area are subject to URA's Urban Design evaluation process.

The standard development control guidelines apply to projects that may not be subject to conservation or urban design requirements, depending on which structure(s) the solar PV system is installed onto. For example, if a solar PV system is installed on the rooftop of an attic, then the attic guidelines will apply. Likewise, if a solar PV system is installed on raised structures like a pavilion, then the pavilion guidelines will apply.

### 4.5 Guidelines on Conservation and Development Control

Architects are advised to refer to the conservation and development control guidelines when designing a development with a solar PV system installation. The respective guideline is available at URA's website:

http://www.ura.gov.sg/conservation/Cons%20Guidelines.pdf
http://www.ura.gov.sg/circulars/text/dchandbook.html

Should you have further enquiries on whether your installations conflict with the Urban Design or Development Control guidelines, you may submit your enquiries to URA either in person or through a Qualified Person ("QP") — a QP is either a registered architect or an engineer — with the accompanying plans of the structures on which the solar PV system will be installed:

Conserved buildings
Email: ura_conservation_cso@ura.gov.sg
Tel: 6329 3355

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

Should a formal development application to URA be required, it must be made via a QP. The details can be checked at the two web links below:

http://www.boa.gov.sg/register.html

http://www.peb.gov.sg/peb/process/searchPe

## 4.6 *Structural Safety and Lightning Protection*

Structural Safety

To ensure safety, there are measures and steps that need to be taken or considered when installing a solar PV system onto a new or an existing building. For new building developments, the design of the structure must take into consideration the loading of the solar PV system installation, just like any other equipment mounted onto a building structure.

For existing buildings, a professional structural engineer may be required to carry out an inspection of the roof structure, and do a calculation on the structural loading. If the roof is unable to withstand the loading of the solar PV system, structural plans will need to be submitted to the Building and Construction Authority ("BCA") for approval before a building permit can be issued for commencement of installation works. The application guideline is available at the following BCA's website:

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

Lightning Protection

Given a certain location, solar PV systems are exposed to the threat of lightning strikes. As lightning can cause damage to the PV modules and inverters, extra care must be taken to ensure that proper lightning protection is provided for the solar PV system and the entire structure. The inverters should be protected by appropriately rated surge arrestors on the DC side. It is good practice to also install surge arrestors on the AC side. Structures and PV module frames must be properly grounded.

## 4.7 *Connection to the Power Grid*

If a solar PV system is designed to meet only a fraction of the electricity load, the system will need to be interconnected with the power grid to meet the remainder of the consumer's needs for electricity.

If a solar PV system needs to be grid-connected, interconnection is key to the safety of both consumers and electrical workers, and to the protection of equipment.

### *4.8 Get Connected to the Power Grid*

If you intend to connect and operate your solar PV system in parallel to the power grid, your appointed LEW will have to consult SP PowerGrid ("SPPG") on the connection scheme and technical requirements.

The following documents set out the detailed consultation process and technical requirements:

- The Transmission Code and the Metering Code are published at EMA's website:

  http://www.ema.gov.sg/media/files/codes_of_practice/electricity/transmission_code.pdf

  http://www.ema.gov.sg/media/files/codes_of_practice/electricity/Metering_Code.pdf

- SPPG's handbook, How to Apply for Electricity Connection, is published at SP PowerAsset's website:

  http://www.sppowerassets.com.sg/PDF/howtoapply.pdf

### *4.9 Sale of Solar PV Electricity*

The excess electricity generated from a grid-connected solar PV can be sold back to the power grid. The arrangements needed to enable this sale of solar PV electricity vary, depending on whether you are a contestable or non-contestable consumer.

Consumers are classified, based on their average monthly electricity consumption, into:

- Contestable consumers: These consumers are the non-residential consumers who use more than 10,000 kWh of electricity a month. Contestable consumers have a choice of who they wish to buy their electricity from. They may purchase electricity from a retailer, directly from the wholesale market (provided they are registered with the Energy Market Company as market participants) or indirectly from the wholesale market through SP Services.

- Non-contestable consumers: These consumers comprise all the residential electricity users and non-residential consumers who use less than 10,000 kWh of electricity a month. These consumers are supplied with electricity by SP Services.

Contestable Consumers

If you are a contestable consumer generating electricity from a solar PV system and wish to sell and get paid for the electricity you inject into the power grid, you will be required to register with the Energy Market Company ("EMC") to participate in the wholesale electricity market, which is called the National Electricity Market of Singapore or NEMS.

The flowchart in Figure 19 describes the circumstances under which the Generation Licence or Wholesaler (Generation) Licence is required.

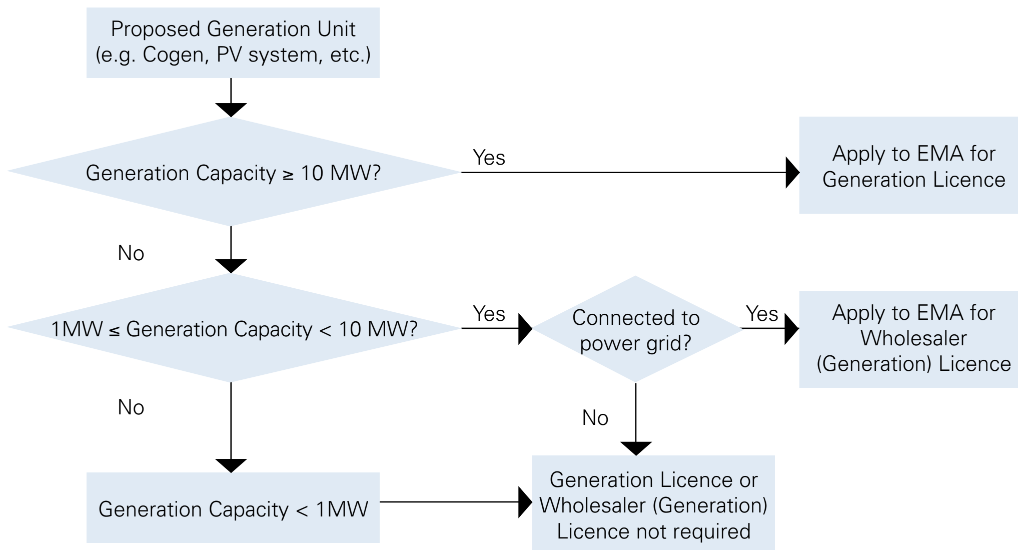



**Figure 19. Flowchart for Electricity Licences**

The application procedures to register as a Market Participant with the EMC and for generation facility registration are set out in the *Market Manual: Market Administration–Registration and Authorisation*, which is available at the EMC website:

http://www.emcsg.com/MarketRules/MarketManuals

As a Market Participant, you will need to comply with the Market Rules, which is available at EMC's website:

http://www.emcsg.com/MarketRules

By selling electricity in the wholesale electricity market, you will be paid the prevailing electricity spot price for the electricity that you inject into the power grid. The electricity spot price varies every half-hour, depending on the demand-supply situation in the wholesale electricity market.

The market will also offer services and system resources to you, but you will be subjected to market charges in respect to the gross generation output from your registered PV system, for the provision of the market services and system resources.

The EMC contact is:

Market Administration Team
Energy Market Company
238A Thomson Road, #11-01 Novena Square Tower A, S307684
Telephone: 67793000
E-mail: info@emcsg.com

Non-Contestable Consumers

If you are a non-contestable consumer generating electricity of less than 1 MW and wish to sell and get paid for the electricity you inject into the power grid, you need not apply for a Generation or Wholesaler (Generation ) Licence nor register with the EMC as a market participant.  You will have to apply to SP Services ("SPS") by following the application procedure set out in Appendix B.

Non-contestable consumers are compensated by SPS for electricity exported to the power grid by way of a credit adjustment to the consumer's monthly electricity bill, based on the prevailing low-tension electricity tariff less the grid charge.

The credit adjustment will effectively compensate the non-contestable consumer for the amount of electricity exported into the power grid during that month.

This scheme to compensate non-contestable consumers with generation capacity of less than 1MW for the electricity they export into the power grid is not applicable to those consumers whose electricity consumption is metered under the master-sub metering scheme.

Master-sub metering schemes refer to metering arrangements where there is a master-meter measuring the overall electricity consumed by the building (i.e. both the individual units and the common services), with sub-meters measuring the usage of the individual units.  Such metering schemes are typically used in private condominiums and commercial buildings.

Under a master-sub metering arrangement, the electricity that an individual unit attempts to export into the grid may in fact be used up by the common services or by other individual units. As it is not possible to track the actual flow of the electricity exported by the individual units, the credit adjustment scheme cannot be applied to those under the master-sub metering scheme.

### 4.10 Design and Installation Checklist

You are advised to refer to the following checklist once you have decided to install solar PV system in your premises.

| No. | Design and Installation Checklist | Check Box |
|---|---|---|
| 1 | Set your budget and select a location. | ☐ |
| 2 | Determine the energy requirement and estimate the size of the system. | ☐ |
| 3 | Perform a site survey for space needed, and access for maintenance. | ☐ |
| 4 | Engage a licensed electrical worker ("LEW") if your proposed solar PV system:<br>i) is to be connected to the electrical installation within the premises of the building; and /or<br>ii) to be connected and operated in parallel to the power grid.<br>The appointed LEW will be responsible for the design and implementation of the connection of your solar PV system to the electrical installation and/or power grid. | ☐ |
| 5 | Select a PV module type and mounting method. | ☐ |
| 6 | Select inverter to match PV array:<br>i) Number of inverters needed;<br>ii) Select inverter type; and<br>iii) Location of inverters (accessible for inspection and maintenance). | ☐ |
| 7 | Finalise the mounting system. | ☐ |
| 8 | Ensure there are fixing and mounting points available. | ☐ |
| 9 | Ensure the structure for mounting is safe:<br>i) Additional loading by solar PV system is considered;<br>ii) Wind loading is considered; and<br>iii) Waterproofing is not compromised during installation. | ☐ |
| 10 | Ensure solar access:<br>i) Ensure location to be mounted will get maximum exposure to sunlight; and<br>ii) Choose a location that is not shaded. | ☐ |

| No. | Design and Installation Checklist | Check Box |
|---|---|---|
| 11 | Ensure all PV modules connected to the same inverter face the same direction. | ☐ |
| 12 | Ensure PV modules are mounted at an incline (10 to 15 degrees for framed modules, or as low as 3-5 degrees for unframed modules) for self-cleaning. | ☐ |
| 13 | Ensure sufficient ventilation space behind the PV array for cooling purposes. | ☐ |
| 14 | Ensure:<br>i) Cabling used meet sufficient current-carrying capacity and are suitably rated for usage in the environment;<br>ii) DC cables are single-core and double-insulated; and<br>iii) Cable insulation on outdoor cables must withstand high temperature and UV exposure for an estimated period of more than 20 years.<br>Note that PVC and XLPE cables are inadequate on the DC side and must not be exposed to the weather elements. | ☐ |
| 15 | Determine if a Lightning Protection System is needed. | ☐ |
| 16 | Ensure the PV module frame is earthed. | ☐ |
| 17 | Finalise the Inverter and AC wiring system. | ☐ |
| 18 | During installation:<br>i) PV system should be installed by qualified/experienced installers;<br>ii) Safety rules must be observed;<br>iii) Installer must wear PPE; and<br>iv) Only proper certified safety equipment can be used e.g. scaffolding, stepladders, etc. | ☐ |
| 19 | Cables must be properly connected, secured, and routed. | ☐ |
| 20 | Ensure continuity and insulation tests are done. | ☐ |
| 21 | Completion of testing and system commissioning. | ☐ |
| 22 | Proper system, documentation/manual handover to clients. | ☐ |

# 5 Operations and Maintenance

## 5.1 *Operations of Solar PV Systems*

The most practical indicator of the performance of the solar PV systems can be obtained from the remote monitoring and data logging software supplied by most inverter manufacturers.

The data logging software will record daily, monthly, and annual output for comparison of the actual system performance against the expected system performance. See Figure 20 for typical performance monitoring displays.

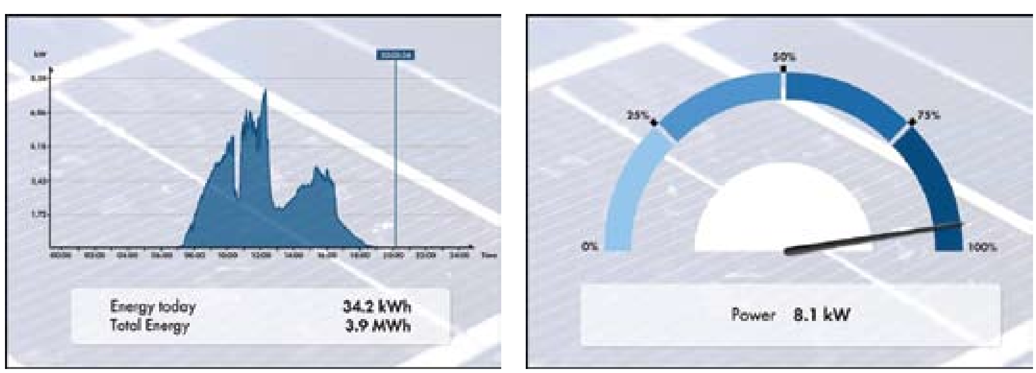



**Figure 20. Examples of performance monitoring displays (Courtesy of Phoenix Solar)**

Solar PV systems require minimal maintenance, as they do not usually have moving parts. However, routine maintenance is required to ensure the solar PV system will continue to perform properly.

It is a good practice for contractors of solar PV systems to provide an operation & maintenance ("O&M") manual for the client. The manual should include basic system data, test and commissioning data, O&M data, and warranty information.

### *5.2 Recommended Preventive Maintenance Works*

It is recommended that preventive inspection and maintenance works are carried out every six to twelve months. The PV modules require routine visual inspection for signs of damage, dirt build-up or shade encroachment. Solar PV system fixtures must be checked for corrosion. This is to ensure that the solar PV system is safely secured.

While the inverter's functionality can be remotely verified, only on-site inspection can verify the state of lightning surge arrestors, cable connections, and circuit breakers.

The following table shows some recommendations on the preventive maintenance works on the components and equipment, and the corresponding remedial actions to be carried out by qualified personnel.

| **S/N** | **Components/Equipment** | **Description** | **Remedy/Action** |
|---|---|---|---|
| 1 | PV modules | Check for dust/debris on surface of PV module | Wipe clean. Do not use any solvents other than water |
| | | Check for physical damage to any PV module | Recommend replacement if found damaged |
| | | Check for loose cable terminations between PV modules, PV arrays, etc. | Retighten connection |
| | | Check for cable conditions | Replace cable if necessary |
| 2 | PV inverter | Check functionality, e.g. automatic disconnection upon loss of grid power supply | Recommend replacement if functionality fails |
| | | Check ventilation condition | Clear dust and dirt in ventilation system |
| | | Check for loose cable terminations | Tighten connection |
| | | Check for abnormal operating temperature | Recommend replacement |

| | | | |
|---|---|---|---|
| 3 | Cabling | Check for cable conditions i.e. wear and tear | Replace cable if necessary |
| | | Check cable terminals for burnt marks, hot spots or loose connections | Tighten connections or recommend replacement |
| 4 | Junction boxes | Check cable terminals e.g. wear and tear or loose connections | Tighten or recommend replacement |
| | | Check for warning notices | Replace warning notice if necessary |
| | | Check for physical damage | Recommend replacement |
| 5 | Means of isolation | Check functionality replacement | Recommend |
| 6 | Earthing of solar PV system | Check earthing cable conditions | Recommend replacement |
| | | Check the physical earthing connection | Retighten connection |
| | | Check continuity of the cable to electrical earth | Troubleshoot or recommend replacement |
| 7 | Bonding of the exposed metallic structure of solar PV system to lightning earth | Check bonding cable conditions | Recommend replacement |
| | | Check physical bonding connection | Tighten connection |
| | | Check continuity of the bonding to lightning earth | Troubleshoot or recommend replacement |

# Appendices

# Appendix A

## A.1 ZERO ENERGY BUILDING @ BCA ACADEMY

| | |
|---|---|
| Building name | Zero Energy Building @ BCA Academy |
| Owner | Building and Construction Authority (BCA) |
| Location | 200 Braddell Road, Singapore 579700 |
| Building type | Academic Institution |
| Completion | 2009 |
| Working groups | |
| • Project architects | DP Architects Pte Ltd |
| • Principal investigators | National University of Singapore / SERIS |
| • Structural engineers | Beca Carter Hollings & Ferner (S. E. Asia) Pte Ltd |
| • M&E engineers | Beca Carter Hollings & Ferner (S. E. Asia) Pte Ltd |
| • Quantity surveyor | Davis Langdon & Seah Singapore Pte Ltd |
| • Contractors | ACP Construction Pte Ltd |
| • PV design | Grenzone Pte Ltd |
| • PV manufacturer | Various (7 manufacturers) |
| Type of PV integration | on Metal Roof, Canopy, Louver, Railing, Façade |
| Type of PV cell technology | Various (mc-Si, pc-Si, a-Si, HIT, CIGS) |
| PV area ($m^2$) | 1,540 |
| PV system peak power (kWp) | 190 |
| Estimated energy output (kWh / yr) | 207,000 |
| PV Yield (kWh / kWp / year) | 1,090 |
| Photographs and information courtesy of | BCA / Grenzone Pte Ltd |

## Appendix A.1
## ZERO ENERGY BUILDING @ BCA ACADEMY

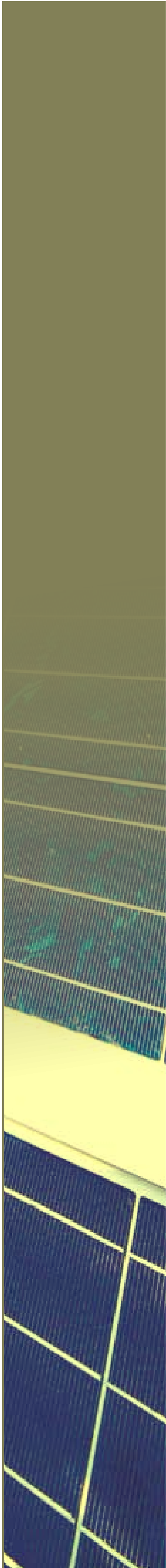
The Solar Photovoltaic System installed at BCA Academy's Zero-Energy Building (ZEB) consists of 12 systems with six systems connected to grid and six standalone systems. Featuring different types of Solar PV technology and mounting techniques, the ZEB @ BCA Academy's Solar PV system is designed to achieve zero-energy and for advance academic research on various PV performances.

**Figure A.1.1. Building exterior**

**Figure A.1.2. PV array view (PV Sunshade)**

**Figure A.1.3. PV array view (PV Main Roof)**

**Figure A.1.4. PV array view (PV Staircase Facade)**



# Appendix A

## A.2 POH ERN SHIH (TEMPLE OF THANKSGIVING)

| | | | | |
|---|---|---|---|---|
| Building name | : | POH ERN SHIH (Temple of Thanksgiving) | | |
| Owner | : | POH ERN SHIH | | |
| Location | : | 9 Chwee Chian Road, Singapore 117488 | | |
| Building type | : | Religious | | |
| Completion | : | 2006 (Phase I) | | |
| Working groups | | | | |
| • Project architects | : | Lee Coo Consultant Associates | | |
| • Structural engineers | : | KTP Consultants Pte Ltd | | |
| • M&E engineers | : | Squire Mech Pte Ltd | | |
| • Quantity surveyor | : | WT Partnership International Limited | | |
| • Contractors | : | Wee Hur Construction Pte Ltd | | |
| • PV design | : | Grenzone Pte Ltd | | |
| • PV manufacturer | : | Uni-Solar, Sharp, Mitsubishi | | |
| Type of PV integration | : | Standing Mounting Structure | | |
| Type of PV cell technology | : | Amorphous silicon | Monocrystalline silicon | Polycrystalline silicon |
| PV area ($m^2$) | : | 36.1 | 39.2 | 84.7 |
| PV system peak power (kWp) | : | 2.232 | 5.250 | 11.340 |
| Estimated energy output (kWh / yr) | : | 2,566 | 6,036 | 13,038 |
| PV Yield (kWh / kWp / year) | : | 1,150 | 1,150 | 1,150 |
| Photographs and information courtesy of | : | Grenzone Pte Ltd | | |

## POH ERN SHIH (TEMPLE OF THANKSGIVING)

**Figure A.2.1. Building exterior**

**Figure A.2.2. Building interior**

The PV arrays are mounted on the rooftop with standing mounting structure, allowing sufficient ventilation to improve PV performance. About 25% of electrical power demand in the building are supplied by the solar PV system.

**Figure A.2.3. PV array view**

**Figure A.2.4. PV array view**

# Appendix

## A.3 313 SOMERSET CENTRAL

| | | |
|---|---|---|
| Building name | : | 313 SOMERSET CENTRAL |
| Owner | : | Lend Lease Retail Investment 1 Pte Ltd |
| Location | : | 313 Orchard Road, Singapore 238895 |
| Building type | : | Shopping Mall |
| Completion | : | 2009 |
| Working groups | | |
| • Project architects | : | Aedas Pte Ltd |
| • Structural engineers | : | Meinhardt Infrastructure Pte Ltd |
| • M&E engineers | : | Bescon Consulting Engineers Pte Ltd |
| • Quantity surveyor | : | WT Partnership Pte Ltd |
| • Contractors | : | Bovis Lend Lease Pte Ltd |
| • PV design | : | Grenzone Pte Ltd |
| • PV manufacturer | : | Various (4 manufacturers) |
| Type of PV integration | : | on Trellis and Metal Roof |
| Type of PV cell technology | : | Monocrystalline, Polycrystalline, Micromorph |
| PV area ($m^2$) | : | 587 |
| PV system peak power (kWp) | : | 76 |
| Estimated energy output (kWh / year) | : | 87,381 |
| PV Yield (kWh / kWp / year) | : | 1,150 |
| Photographs and information courtesy of | : | Bovis Lend Lease |

# Appendix A.3
## 313 SOMERSET CENTRAL

313 Somerset Central is centrally located in the heart of Singapore's famous Orchard Road. The solar photovoltaic system consists of four PV arrays, with a main PV array of 60 kWp mounted on the trellis, and three smaller arrays featuring monocrystalline, polycrystalline and micromorph solar modules that are accessible by visitors.

**Figure A.3.1. Building exterior**

*Architect's Impression of Somerset Central viewed from Orchard Road*

**Figure A.3.2. Building exterior**

# Appendix A

## A.4 SENTOSA COVE

| | | |
|---|---|---|
| Building name | : | Private |
| Owner | : | Private |
| Location | : | Sentosa Cove, Singapore |
| Building type | : | Two-storey bungalow with basement |
| Completion | : | July 2008 |
| Working groups | | |
| • Project architects | : | Guz Architects |
| • M&E consultant | : | Herizal Fitri Pte Ltd |
| • PV design | : | Phoenix Solar Pte Ltd |
| • Main contractors | : | Sunho Construction Pte Ltd |
| • Roofing contractor | | Sheet Metal International |
| • PV manufacturer | : | Uni-Solar |
| Type of PV integration | : | Glued onto approved Fazonal metal roof |
| Type of PV cell technology | : | Flexible amorphous silicon |
| PV area ($m^2$) | : | 92 |
| PV system peak power (kWp) | : | 5.712 |
| Estimated energy output kWh / yr) | : | 7,100 |
| PV Yield (kWh / kWp / yr) | : | 1,250 |
| Photographs and information courtesy of | : | Phoenix Solar Pte Ltd, Guz Architects, and Sheet Metal International |

## Appendix A.4
## SENTOSA COVE

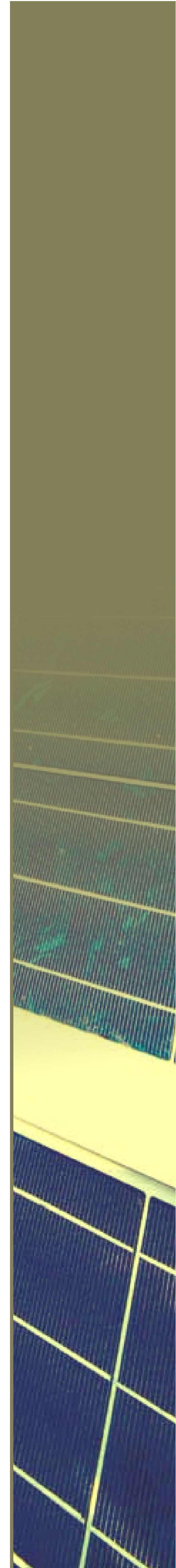
This striking house stands out for its open layout, capped with twin curved roofs. The rear roof has a turf lawn to keep it cool, while the front roof generates electricity with flexible solar laminates, bonded unobtrusively on top. This configuration meets Sentosa Resort Management's strict guidelines for roof aesthetics, which do not generally permit bare metal roofs on bungalow developments.

Thanks to the laminates' light weight (less than 4kg/m$^2$), the roof can make do with a lighter and lower substructure cost than if it had to carry conventional clay tiles.

**Figure A.4.1.**
**Twin curved roofs, green grass and PV**

**Figure A.4.2.**
**Lightweight, flexible laminates follow the curved roof**

**Figure A.4.3.**
**Testing the Uni-Solar laminates during installation**



# Appendix A

## A.5 MARINA BARRAGE

| | | |
|---|---|---|
| Building name | : | Marina Barrage |
| Owner | : | PUB, Singapore's national water agency |
| Location | : | Singapore |
| Building type | : | Flood Control |
| Completion | : | 2008 |
| Working groups | | |
| • Project architects | : | Architects Team 3 Pte Ltd |
| • Structural engineers | : | Koh Brothers Building & Civil Engineering Contractor (Pte) Ltd |
| • PV design | : | Renewpowers Technologies Pte Ltd |
| • Building services | : | Cegelec Pte Ltd |
| • Contractors | : | Koh Brothers Building & Civil Engineering Contractor (Pte) Ltd |
| • PV manufacturer | : | SolarWorld Asia Pacific Pte Ltd |
| Type of PV integration | : | Roof Top |
| Type of PV cell technology | : | Monocrystalline silicon |
| PV area ($m^2$) | : | 1200 |
| PV system peak power (kWp) | : | 70 |
| Estimated energy output (kWh / yr) | : | 76,650 |
| PV Yield (kWh / kWp/ yr) | : | 1,095 |
| Photographs and information courtesy of | : | PUB, Singapore's national water agency |

## Appendix A.5
## MARINA BARRAGE

Marina Barrage spans the mouth of the Marina Channel, creating Singapore's 15th reservoir, and its first in the city.

The barrage creates a freshwater lake to boost Singapore's water supply, acts as a tidal barrier to prevent flooding in low-lying city areas, and keeps the water level consistent, offering a venue for water-based activities in the heart of the city.

But more than an engineering showpiece, the barrage exemplifies the national water agency's commitment towards environmental and water sustainability.

One of Singapore's largest commissioned solar PV system at a single site to date, Marina Barrage's solar park houses one of the largest collection of solar panels – 405 panels in all – currently in operation in Singapore. Its 70kWp DC grid-tied solar PV system is the first to be employed on such a large scale locally, and it comes with aesthetically arranged solar panels (panels are arranged in nine arrays of 15 by three panels) on the barrage's green roof.

The solar panels generate 50% of utility grade electricity for lighting and general power in the visitor centre, control room and offices. The environmentally-friendly grid-tied solar PV system does not require batteries, hence eliminating the costs for battery replacement.

**Figure A.5.1. Aerial view of Marina Barrage**


**Figure A.5.2. Marina Barrage Solar Park**

# Appendix A

## A.6 LONZA BIOLOGICS

| | | |
|---|---|---|
| Building name | : | LBXS2 |
| Owner | : | Lonza Biologics Tuas Pte Ltd |
| Location | : | Tuas, Singapore |
| Building type | : | Biotech factory and laboratory |
| Completion | : | May 2009 |
| Working groups | | |
| • Project architects | : | RSP Architects Planners & Engineers Pte Ltd |
| • M&E engineers | : | Jacobs Engineering Singapore Pte Ltd |
| • PV design | : | Phoenix Solar Pte Ltd |
| • Contractors | : | Bovis Lend Lease Pharmaceutical Pte Ltd |
| • PV manufacturer | : | REC (framed modules) and Solar-Fabrik (frameless laminates) |
| Type of PV integration | : | Roof mounted on Bluescope Lysaght KlipLok metal roof |
| Type of PV cell technology | : | Polycrystalline silicon |
| PV area ($m^2$) | : | 1,330 |
| PV system peak power (kWp) | : | 181 |
| Estimated energy output (kWh/yr) | : | 217,000 |
| PV Yield (kWh/kWp/yr) | : | 1,200 |
| Photographs and information courtesy of | : | Phoenix Solar Pte Ltd and Lonza Biologics Tuas Pte Ltd |

## Appendix A.6
## LONZA BIOLOGICS

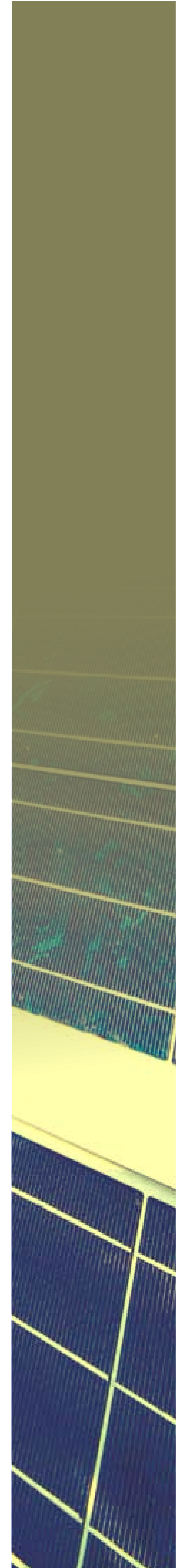
**Figure A.6.1. Building exterior (Rendering by RSP Architects Planners & Engineers Pte Ltd)**

The curved laboratory roof of the Lonza Biologic's LBXS2 factory offers prominent visibility to maximise public awareness for a 181kWp solar PV system on an industrial building. The bulk of the PV array consists of 744 pieces of REC210 modules, while the flatter upper section of the roof is covered with 104 SF130/2 frameless laminates from Solar-Fabrik. Without frames to trap water at shallow installation angles, these laminates will avoid dirt accumulation.

Roof clamps were specially engineered to attach the PV module rails to the KlipLok roof seams without any penetrations. Lonza Biologics was a recipient of one of the inaugural Solar Pioneer grants under EDB's Solar Capability Scheme.

**Figure A.6.2. Modules installed on the 6°-16° slope**

**Figure A.6.3. Installing the REC modules**



# Appendix A

## A.7 ZERO ENERGY HOUSE

| | | |
|---|---|---|
| Building name | : | Zero Energy House |
| Owner | : | Private |
| Location | : | District 15, Singapore |
| Building type | : | Residential, 2½-storey semi-detached house |
| Completion (renovation) | : | April 2008 |
| Working groups | | |
| • Project architects | : | Art & Architecture Collaborative |
| • Structural engineers | : | Portwood & Associates |
| • PV design | : | Phoenix Solar Pte Ltd |
| • Contractors | : | MCL Construction & Engineering Pte Ltd |
| • PV manufacturer | : | Mitsubishi Heavy Industries and Phoenix Solar |
| Type of PV integration | : | Roof mounted on metal roof |
| Type of PV cell technology | : | amorphous silicon and micromorph silicon thin films |
| PV area ($m^2$) | : | 120 |
| PV system peak power (kWp) | : | 8.58 |
| Estimated energy output (kWh/year) | : | 12,000 |
| PV Yield (kWh/kWp/yr) | : | 1,400 |
| Photographs and information courtesy of | : | Phoenix Solar Pte Ltd |

## Appendix A.7
## ZERO ENERGY HOUSE

This 1960s semi-detached house was converted into Singapore's first modern zero-energy home by reducing solar heat gain, improving natural ventilation and adding a rooftop solar PV system, which generates more electricity than the 6-person household consumes.

The PV modules are mounted on rails that are clamped to the seams of the aluminium Kalzip roof without any roof penetrations. As an important added benefit, the PV modules shade the roof, keeping the attic rooms much cooler than they would be under a roof fully exposed to the sun.

**Figure A.7.1. Building roof with two types of PV module**

**Figure A.7.2. West roof flank with micromorph PV modules**

# Appendix A

## A.8 TAMPINES GRANDE

| | | |
|---|---|---|
| Building name | : | Tampines Grande |
| Owner | : | City Developments Ltd |
| Location | : | Tampines, Singapore |
| Building type | : | Office building |
| Completion | : | May 2009 |
| Working groups | | |
| • Project architects | : | Architects 61 Pte Ltd |
| • M&E engineers | : | Conteem Engineers Pte Ltd |
| • PV design | : | Phoenix Solar Pte Ltd |
| • Contractors | : | Dragages Singapore Pte Ltd / BYME Singapore |
| • PV manufacturer | : | Suntech (rooftop) and Schott Solar (BIPV) |
| Type of PV integration | : | Roof mounted and Building Integrated façade |
| Type of PV cell technology | : | Monocrystalline silicon and amorphous silicon thin film BIPV |
| PV area ($m^2$) | : | 934 |
| PV system peak power (kWp) | : | 107 |
| Estimated energy output (kWh/yr) | : | 120,000 |
| PV Yield (kWh/kWp/yr) | : | 1,200 |
| Photographs and information courtesy of | : | Phoenix Solar Pte Ltd and City Developments Ltd |

## Appendix A.8
## TAMPINES GRANDE

101kWp of monocrystalline PV modules form the main rooftop PV array on Towers 1 and 2, while the west façade of Tower 2 has 6kWp of BIPV comprising 40 large, custom-built amorphous silicon thin film modules.

At the time of completion, this was Singapore's largest PV system, and the first commercial application of a thin film BIPV façade.

The building also boasts a solar air-conditioning system powered by solar thermal collectors.

Tampines Grande was a recipient of one of the inaugural Solar Pioneer grants under EDB's Solar Capability Scheme.

**Figure A.8.1. 6kWp BIPV façade on Tower 2**

**Figure A.8.2. Partially completed PV array**

**Figure A.8.3. Aerial view of both towers**

# Appendix A

## A.9 HDB APARTMENT BLOCKS AT SERANGOON NORTH PRECINCT

| | | |
|---|---|---|
| Building Name | : | HDB Apartment Blocks at Serangoon North Precinct |
| Owner | : | Ang Mo Kio- Yio Chu Kang Town Council |
| Location | : | Serangoon North Avenue 3 Block 548 to 554 and 550A (Multi-storey Carpark) |
| Building type | : | Residential |
| Completion | : | 2008 |
| Working groups | | |
| • Contractors | : | King Wan Construction Pte Ltd & Asiatic Engineering Pte Ltd |
| • PV manufacturer | : | Sunset Energietechnik GmbH |
| Type of PV integration | : | Roof top |
| Type of PV cell technology | : | Mono-crystalline silicon |
| Precinct PV area ($m^2$) | : | 667.61 |
| Precinct PV system peak power (kWp) | : | 75.75 |
| Estimated energy output (kWh / yr) | : | 80,300 |
| PV Yield (kWh / kWp/yr) | : | 1,060 |
| PV Photographs and information courtesy of | : | HDB |

# Appendix A.9
# HDB APARTMENT BLOCKS AT SERANGOON NORTH PRECINCT

The Serangoon North Precinct consists of five blocks of 16 storey and two blocks of nine storey residential apartments and a multi storey car park (MSCP). Sixty-nine pieces of solar PV panels are mounted at the rooftop of each residential block and 22 pieces of the panel at the staircase roof of the MSCP.

**Figure A.9.1. Typical rooftop PV array layout at Serangoon North Precinct**

# Appendix A

## A.10 HDB APARTMENT BLOCKS AT WELLINGTON CIRCLE PRECINCT

| | | |
|---|---|---|
| Building Name | : | HDB Apartment Blocks at Wellington Circle Precinct |
| Owner | : | Sembawang  Town Council |
| Location | : | Wellington Circle 508A-C, 509A-B, 510A-B & 508 (MSCP) |
| Building type | : | Residential |
| Completion | : | 2008 |
| Working groups | | |
| • Contractors | : | King Wan Construction Pte Ltd & Asiatic Engineering Pte Ltd |
| • PV manufacturer | : | Sunset Energietechnik GmbH |
| Type of PV integration | : | Roof top |
| Type of PV cell technology | : | Mono-crystalline silicon |
| Precinct PV area ($m^2$) | : | 667.61 |
| Precinct PV system peak power (kWp) | : | 75.75 |
| Estimated energy output (kWh / yr) | : | 80,300 |
| PV Yield (kWh / kWp/ yr) | : | 1,060 |
| Photographs and information courtesy of | : | HDB |

The Wellington Circle Precinct consists of seven blocks of 12 storey residential apartments and a MSCP. Sixty-nine pieces of solar PV panels are mounted at the rooftop of each residential block and 22 pieces of the panel at the staircase roof of the MSCP.

**Figure A.10.1. Typical rooftop PV array layout at Wellington Circle Precinct**

# Appendix B

## B. ENGAGING A LICENSED ELECTRICAL WORKER

### *1. Engaging a Licensed Electrical Worker (LEW)*

1.1 There are three classes of LEWs: Licensed Electrician, Licensed Electrical Technician, and Licensed Electrical Engineer. The various classes of LEWs are authorised to design, install, repair, maintain, operate, inspect and test electrical installations according to the conditions stated below:

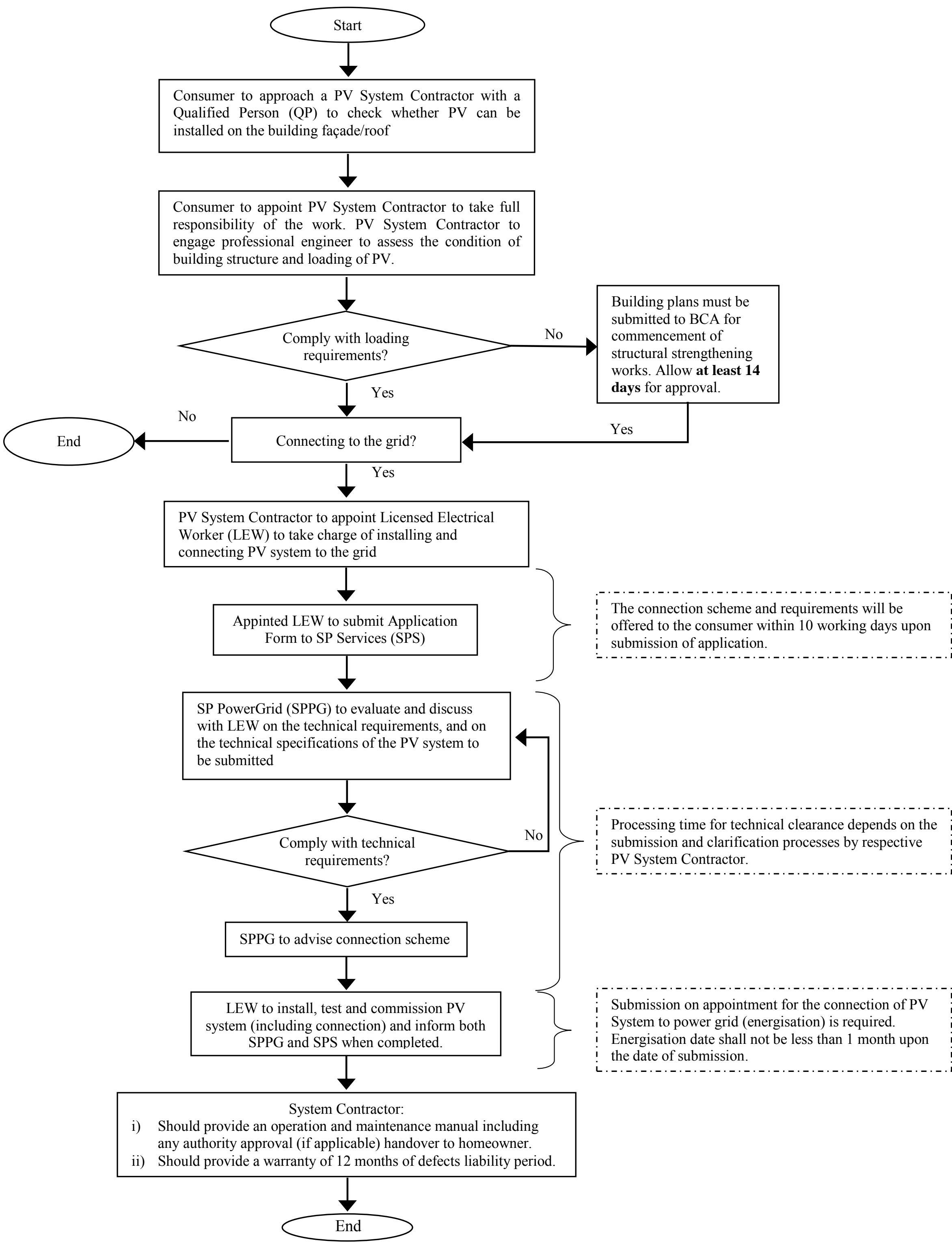
| Class of LEW | Approved Load | Voltage Level |
|---|---|---|
| Electrician | Not exceeding 45 kVA | 1000V & below |
| Electrical Technician | Not exceeding 150 kVA (Design); not exceeding 500 kVA (Operation) | 1000V & below |
| Electrical Engineer | No limit | Subject to license conditions |

1.2 The Singapore Standard for electrical safety applicable to solar PV Systems is set out in the Code of Practice for Electrical Installations (Singapore Standard CP5:2008), which is published by SPRING Singapore. The LEW whom you appoint to carry out or supervise the electrical works associated with your PV system will be responsible for the compliance with the relevant safety standards and requirements.

1.3 You can search for LEWs and their contact particulars at the following EMA website:
http://elise.ema.gov.sg

1.4 For enquiries on LEWs, you can contact EMA's Electricity Inspectorate Branch at:
Tel: 6835 8060
Email: ema_enquiry@ema.gov.sg

## 2 Guide for consumers – Installation of Solar PV Systems



# Appendix C

## C.1 CONTACT INFORMATION

**For enquiries on the following matters pertaining to Solar PV systems, please contact:**

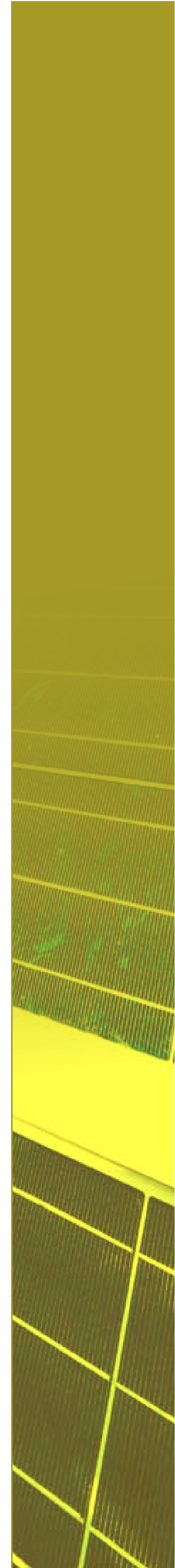
| | | |
|---|---|---|
| (1) | Buildings issues | **Building And Construction Authority (BCA)**<br>Email: bca_equiry@bca.gov.sg<br>Tel: 1800-3425222 (1800-DIAL BCA) |
| (2) | Development Planning Control – Conserved Buildings | **Urban Redevelopment Authority (URA)**<br>Building Conservation<br>Email: ura_conservation_cso@ura.gov.sg<br>Tel: 6329 3355 |
| (3) | Development Planning Control – Non-conserved Buildings | **Urban Redevelopment Authority (URA)**<br>Non-conserved buildings<br>Email: ura_dcd@ura.gov.sg<br>Tel: 6223 4811 |
| (4) | Electricity Generation Licences | **Energy Market Authority (EMA)**<br>Economic Regulation & Licensing Department<br>Email: ema_enquiry@ema.gov.sg<br>Tel: 6835 8000 |
| (5) | Licensed Electrical Workers ("LEWs") | **Energy Market Authority (EMA)**<br>Electricity Inspectorate Branch<br>Email: ema_enquiry@ema.gov.sg<br>Tel: 6835 8060 |
| (6) | Electricity market rules, market registration process, and market charges | **Energy Market Company (EMC)**<br>Market Administration Team<br>Email: MPregistration@emcsg.com<br>Tel: 6779 3000 |
| (7) | Connection to the power grid | **SP Services Ltd (SPS)**<br>Email: install@singaporepower.com.sg<br>Tel: 6823 8283 / 6823 8284 |
| (8) | Connection to the power grid | **SP PowerGrid Ltd (SPPG)**<br>Email: dgconnection@singaporepower.com.sg<br>Tel: 6823 8572 |

# Appendix D

## D.1 SOLAR CAPABILITY SCHEME (SCS)

*The Economic Development Board (EDB) unveiled the Solar Capability Scheme to spur demand and build up expertise for this young but growing field. The scheme – the latest by Clean Energy Programme Office (CEPO) – seeks to strengthen critical capabilities of companies engaged in activities such as engineering, architecture and system integration through increased implementation of solar energy technologies by lead users in Singapore.*

| | | |
|---|---|---|
| Agency | : | EDB |
| Quantum | : | $20 Million (Overall); $1 Million per project or up to 40% of total capital cost of solar technology. |
| Target Group | : | Engineering;<br>Architecture;<br>System Integration<br>(With implementation of solar energy technologies) |
| For Reading | : | http://www.edb.gov.sg/edb/sg/en_uk/index/news/articles/cepo_launches_solar.html<br><br>http://www.edb.gov.sg/edb/sg/en_uk/index/news/articles/Award_Ceremony_for_Solar_Testbeds.html |
| For Details | : | http://www.edb.gov.sg/etc/medialib/downloads/industries.Par.98811.File.tmp/Solar%20Capability%20Scheme%20Factsheet.pdf |



# Appendix D

## D.2 MARKET DEVELOPMENT FUND (MDF)

*The MDF seeks to incentivise the use of clean and renewable energy resources among non-residential consumers and developers by offsetting the market charges and related costs associated with selling clean and renewable energy into the power grid. This will help to promote energy efficiency as well as help in the market integration of innovative clean and renewable energy resources.*

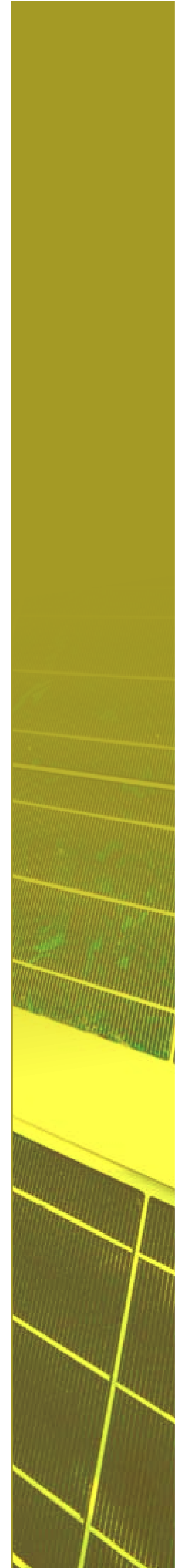
| | | |
|---|---|---|
| Agency | : | Energy Market Authority (EMA) |
| Quantum | : | $5 million; $50,000 over a span of 5 years or 90% of incurred market charges for approved projects, whichever is lower. |
| Target Group | : | Non-residential consumers and developers who choose to sell excess electricity generated from clean and renewable energy technologies to the power grid. |
| For Details | : | http://www.ema.gov.sg/index.php?option=com_content&view=article&id=125&Itemid=141 |

# Appendix D

## D.3 GREEN MARK SCHEME

*The Green Mark Scheme was launched to promote environmental awareness in the construction and real estate sectors. It is a benchmarking scheme that aims to achieve a sustainable built environment by incorporating best practices in environmental design and construction, and the adoption of green building technologies.*

| | | |
|---|---|---|
| Agency | : | Building and Construction Authority (BCA) |
| Target Group | : | Developers<br>Designers<br>Builders |
| For Reading | : | http://www.greenmark.sg<br><br>http://www.bca.gov.sg/GreenMark/green_mark_buildings.html |
| For Details | : | http://www.bca.gov.sg/greenmark/others/gmtc.pdf |



# Appendix D

## D.4 GREEN MARK GROSS FLOOR AREA (GM-GFA) INCENTIVE SCHEME

*To encourage the private sector to develop buildings that attain higher tier Green Mark ratings (i.e. Green Mark Platinum or Green Mark Gold$^{PLUS}$), BCA and the Urban Redevelopment Authority (URA) have introduced a set of Gross Floor Area (GFA) incentives on 29 Apr 2009. For developments attaining Green Mark Platinum or Gold$^{PLUS}$, URA will grant additional floor area over and above the Master Plan Gross Plot Ratio (GPR) control.*

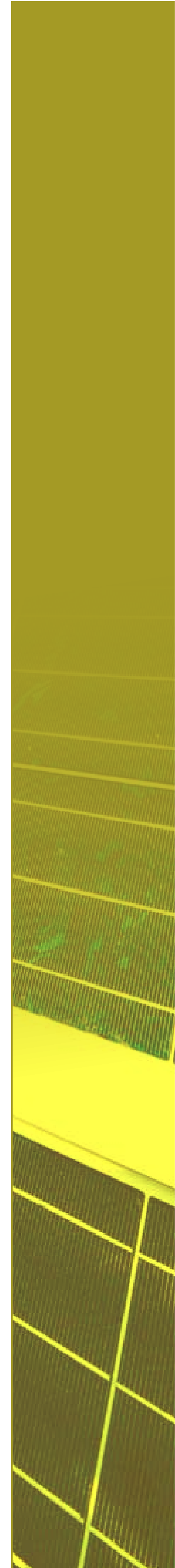
| | | |
|---|---|---|
| Agency | : | BCA and URA |
| Target Group | : | All new private developments, redevelopments and reconstruction developments submitted on or after the effective date. |
| For Details | : | http://www.bca.gov.sg/GreenMark/gmgfa.html |

# Appendix D

## D.5 $100 MILLION GREEN MARK INCENTIVE SCHEME FOR EXISTING BUILDINGS (GMIS-EB)

*The GMIS-EB aims to encourage private building owners of existing buildings to undertake improvements and/or retrofits to achieve substantial improvement in energy efficiency. It provides a cash incentive that co-funds up to 35% (capped at $1.5 million) of the upgrading/retrofitting costs for energy efficiency improvement in their existing buildings.*

| | | |
|---|---|---|
| Agency | : | BCA |
| Target Group | : | Building owners/developers of private existing non-residential developments that is centrally air-conditioned, with gross floor area of 2,000 sqm above e.g. energy intensive buildings such as shopping malls, hotels, office buildings, hospitals, and other centrally air-conditioned buildings. |
| For Details | : | http://www.bca.gov.sg/GreenMark/gmiseb.html |



# Appendix D

## D.6 ENHANCED $20 MILLION GREEN MARK INCENTIVE SCHEME FOR NEW BUILDINGS (GMIS-NB)

*The GMIS-NB is to help accelerate the adoption of environmentally-friendly green building technologies and building design practices. The enhanced scheme offers cash incentives.*

| | | |
|---|---|---|
| Agency | : | BCA |
| Target Group | : | Developers, building owners, project architects and M&E engineers who make efforts to achieve at least a BCA Green Mark Gold rating or higher in the design and construction of new buildings. |
| For Details | : | http://www.bca.gov.sg/GreenMark/GMIS.html |

**Disclaimer**

Smart Energy, Sustainable Future

We shape a **safe**, **high quality**, **sustainable** and **friendly** built environment.

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ISBN: 978-981-08-4462-2