PV Cell – Working Principle and Applications

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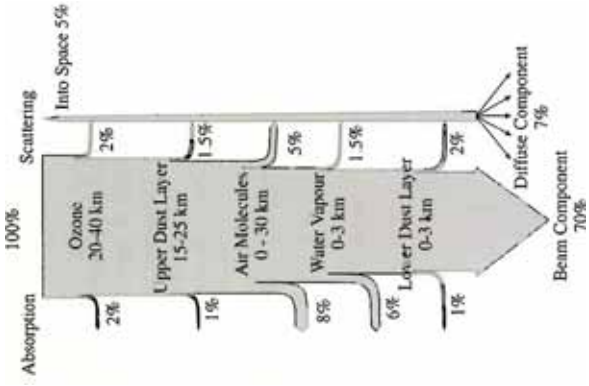
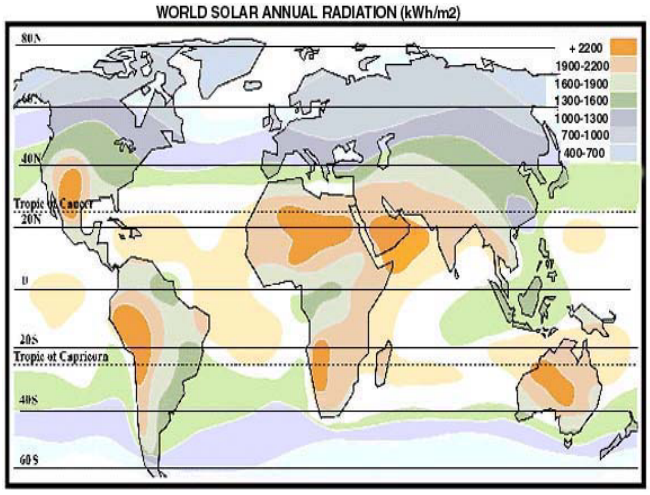
How Powerful is Solar Power?

- Solar power intensity just outside the atmosphere of the Earth: 1.353 kW/m^2. This value is also called ***solar constant***.
- With the known radius of Earth ~=6380 km, solar power falling on The Earth ~=173000TW
- While the current global power consumption average over a year is only ~ 16TW as in 2005

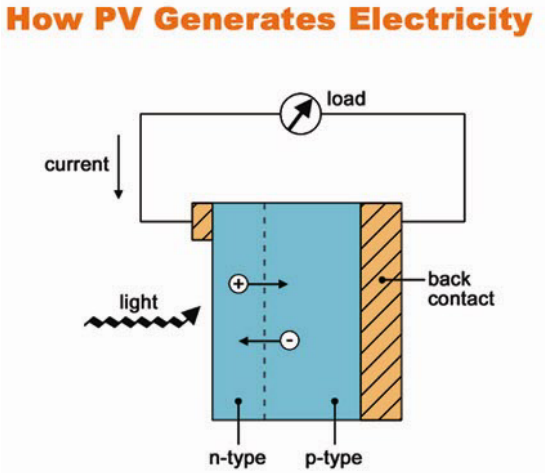
Solar power intensity ~ 1kW/m^2 at sea level in sunny day





First application of PV cells

How PV Generates Electricity



Common Types of PV cells

Monocrystalline silicon (m-Si):
sliced from single-crystal ingot silicon, highest conversion efficiency among all technologies

Polycrystalline silicon (p-Si):
sliced from blocks of cast silicon, less efficient and expensive than m-Si

Amorphous Silicon (a-Si):
thin-film type, non-crystalline form of silicon, slightly less efficient and much cheaper than p-Si, holds great promise in BIPV systems.

Copper Indium Diselenide (CIS):
a thin-film technology using materials other than silicon, close to the cost of p-Si

PV panels are already modular and so well suited to the concept of PV as a building component both as cladding and roofing elements.

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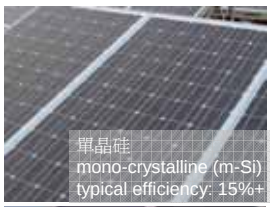
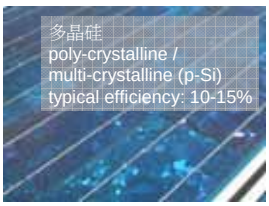
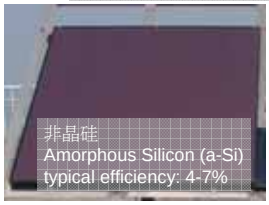
Different PV technology







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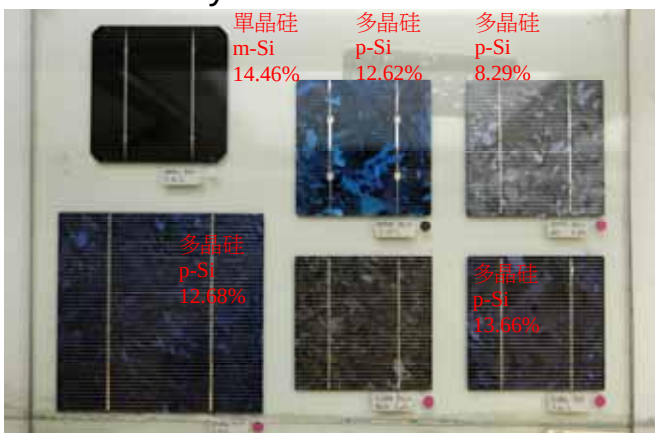
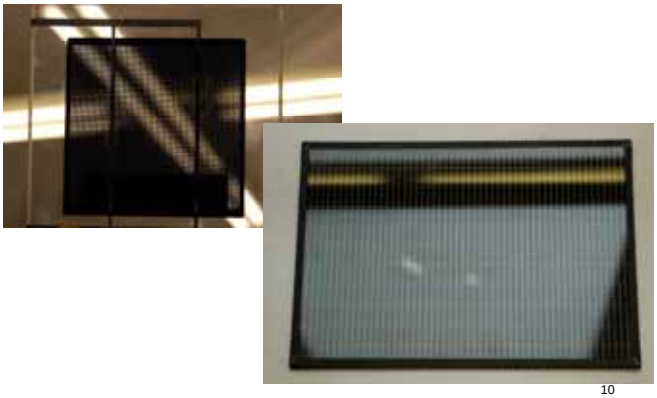
crystalline PV cells



Semi-transparent PV cells



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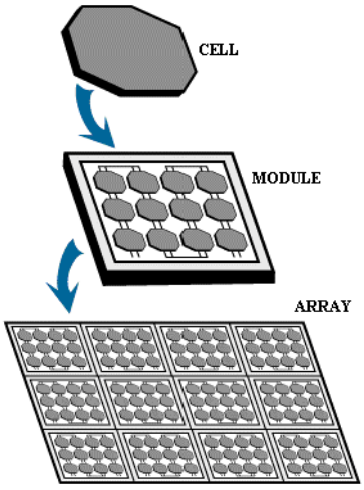
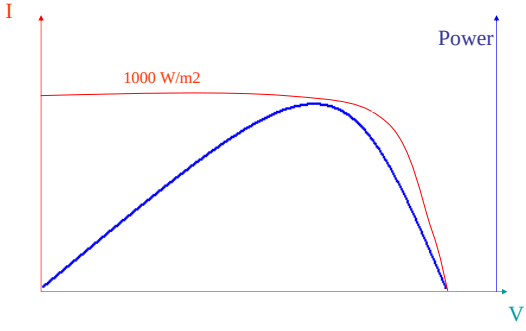
Cell, Module, Array



Typical I-V & P-V Curve of a PV Cell at a given solar irradiance



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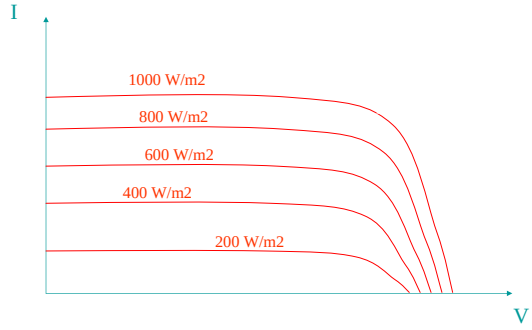
Typical I-V Curve of a PV Cell at different values of solar irradiance



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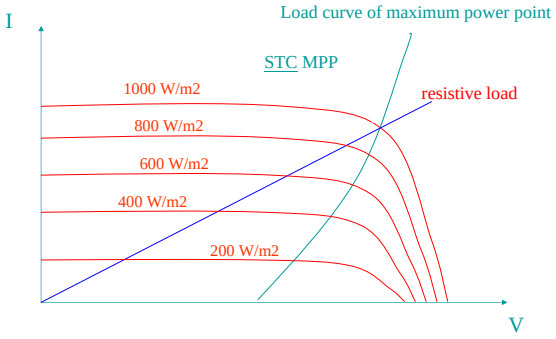
Electrical properties, I-V curve



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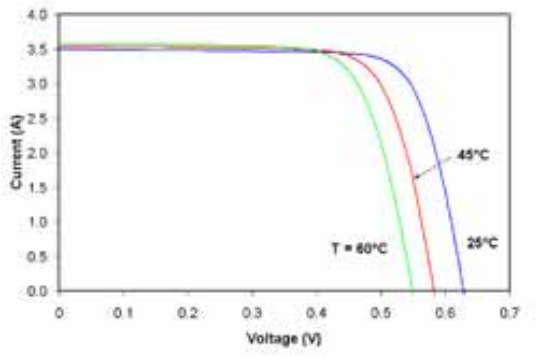
Effect of cell temperature on the V-I Curve (at given solar irradiation)



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Name Plate Rating of a PV Panel

- It is the maximum power output at STC (Standard Test Condition)
- Usually STC = 1000 W/m², 25°C Panel Temperature

Made in USA

Nominal Power (+/-5 %)	60 W
Current at mpp	0.97 A
Voltage at mpp	62 V
Short Circuit Current	1.15 A
Open Circuit Voltage	90 V
Maximum System Voltage	(600V UL) 1000 V
Max Source Circuit Fuse	(2A UL) 10 A
Protection Class	Class II
Cell Type	CdTe

specifications (+/- 10 %) at STC: Irad. 1,000 W/m², AM 1.5, Cell T 25 °C

Warning - Electrical shock hazard

This solar module produces high voltages in sunlight. Read and observe all intstructions before attempting installation or service. Do not disconnect under load.

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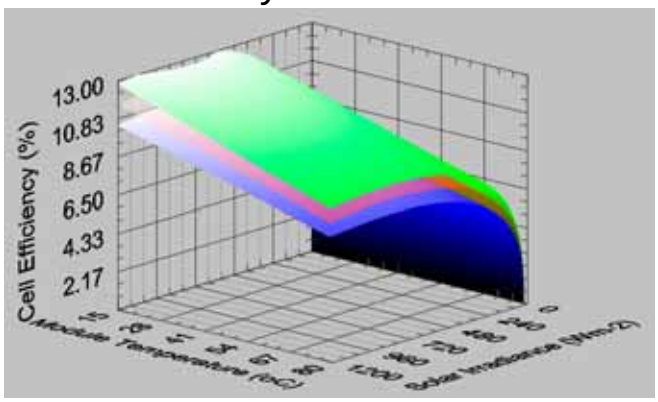
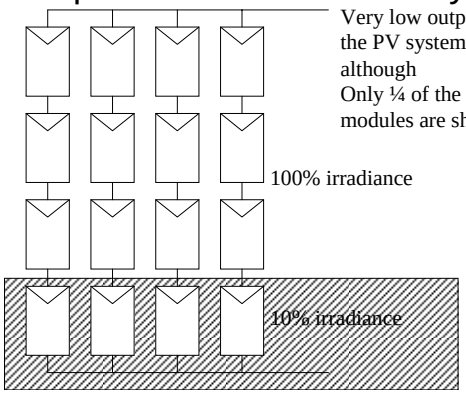
efficiency characteristics



Effect of partial shading on performance of PV array



Very low output from the PV system, although
Only ¼ of the modules are shaded

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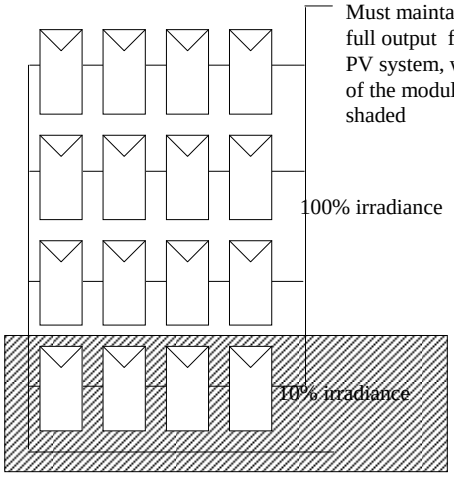

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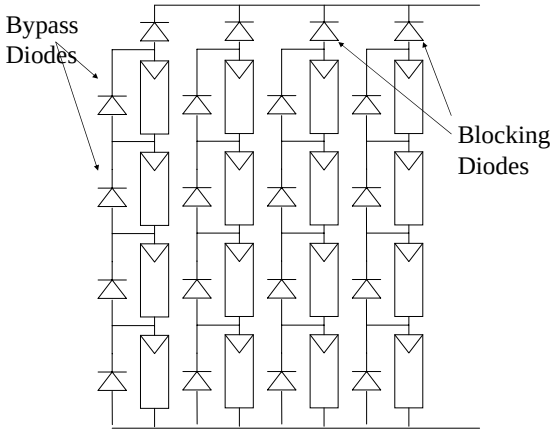

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BIPV Building Integrated Photovoltaic System

The Plus Points:

- Act as other building functions other than generating electricity
- No harmful side effects
- No moving parts – silent, solid state device
- No (low) maintenance
- Modular format /non-intrusive
- Versatile
  - Locations Rural/Urban
  - Applications for stand alone applications
    - Water pump, Lighting, Desalination plants

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Barriers to BIPV application

The HK scenario:

- Relatively high capital cost of the PV panels.
- Module efficiency is still relatively low
- Little understanding of PV system design
- Less real experience of installations
- Incentives (in HK) not yet in place

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Why BIPV? (1)

- *Replace* conventional building materials – concept of "avoided cost"
- Does not require any extra land area
- Does not require any additional support or infrastructure installation

The above three points ⇒ small "incremental" cost for BIPV systems

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Why BIPV? (2)

- May cover part of the electricity consumption of the building.
- Can provide electricity during peak demand time times and thus reduce the utility's speak delivery requirements.
- May reduce transmission and distribution loss.

These points reduce the electricity bills of the building and delay the need for construction of new power plants.

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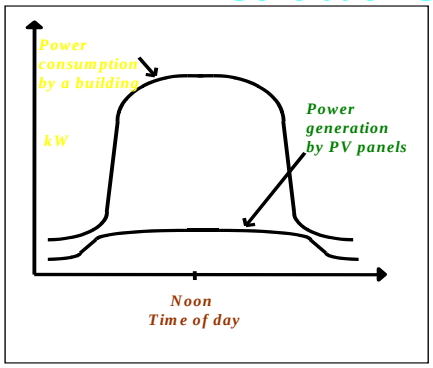
Consumption Curve and Generation Curve



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Why BIPV ? (3)

- Can provide an improved aesthetic appearance in an innovative way.
- Can integrated with maintenance, control and operation of the other installations and systems in the building.
- Can provide reduced planning costs.

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Why BIPV ? (4)

- With grid connection, the system can totally eliminate the storage batteries and its associated problems.
- Hence lower capital, replacement and maintenance cost.

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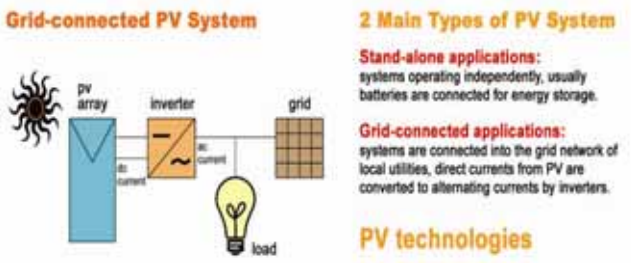
PV system: stand-alone vs. grid-connected



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Grid-connected systems (G-BIPV)

- PVs connected to the public grid via an inverter.
- Eliminate the expensive and bulky batteries.
- Involve local regulatory issues.
- Must compete against the cost of the conventional energy source used to supply the grid.

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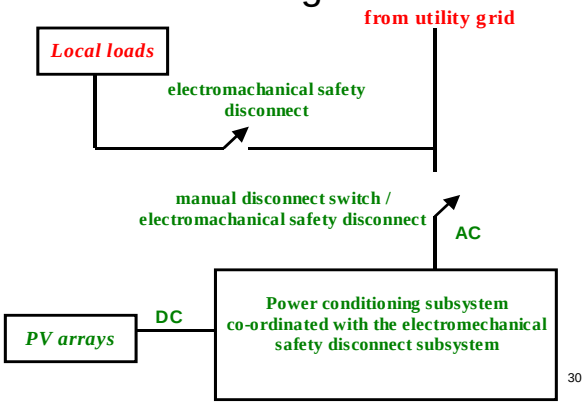
Block diagram of G-BIPV



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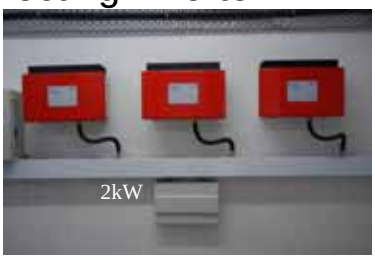
Grid-connecting inverter



convert DC to AC

capacity ranges from 100W to 500kW

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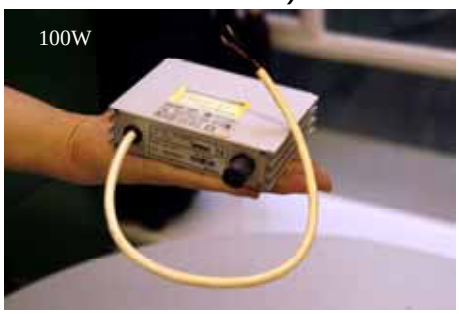
New generation inverters (string inverter)



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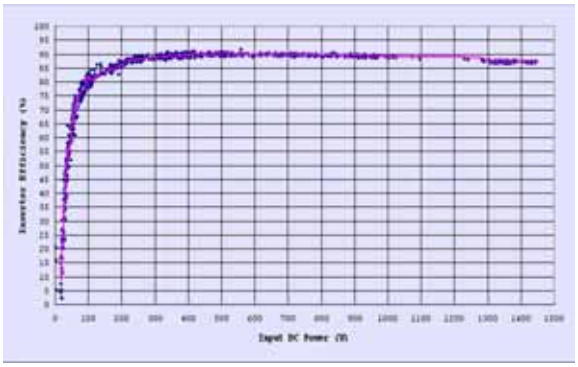
Characteristics of an inverter



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inverter selection

- high efficiency (of course)
- selection of inverter nominal P_{in} with array's rated kW_p (e.g. vertical facade array)
- read the data-sheet carefully

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BIPV system at Wan Chai Tower

- Three systems:
  - Rack type at the roof
  - Sun shading type at mid-floors
  - Skylight type at the lift lobby of ground floor

The site: 22°16′50″N and 114°10′30″E

Orientation: south facing about 5 degree off south toward east

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Wanchai Tower of HK Government Building –

3 BIPV Systems

Wan Chai Tower
Roof Rack BIPV System

Location	Roof
Orientation	10 degree to horizontal, facing south
Type of panels	Polycrystalline
No. of panels per string	18
No. of strings	7 strings per group, 2 groups
Total no. of panels	252
Total PV panel area	164.70 m^2
System rated power	20.16 kW
No. of inverters	1 inverter per group

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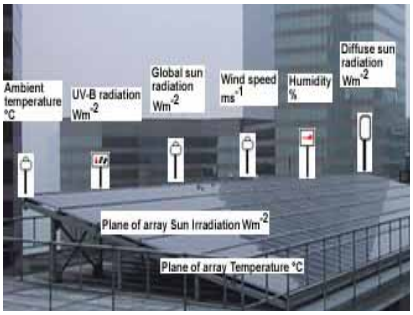
WanChai Tower: Roof
Polycrystalline 20 kWpeak



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Wan Chai Tower
Sun Shade BIPV System

Location	Middle section of the building
Orientation	Vertically facing south
Type of panels	Monocrystalline
No. of panels per string	21
No. of strings	8 strings per group, 2 groups
Total no. of panels	336
Total PV panel area	231.84 m^2
System rated power	20.16 kW
No. of inverters	1 inverter per group

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WanChai Tower: Sun Shading
BIPV system

Wan Chai Tower
Skylight BIPV System

Location	Ground floor lobby
Orientation	Vertically facing south
Type of panels	Monocrystalline
No. of panels per string	5
No. of strings	7 strings
Total no. of panels	35
Total PV panel area	95.98 m^2
System rated power	10.08 kW
No. of inverters	1 inverter per group

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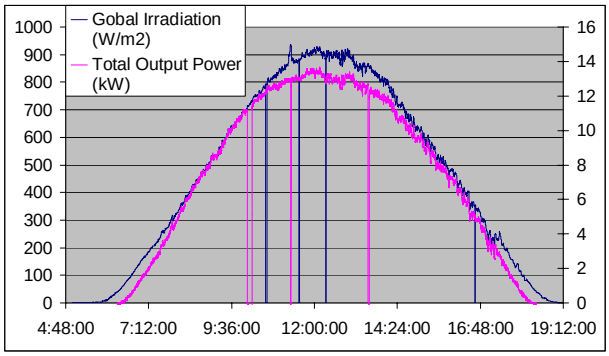
WanChai Tower: Skylight BIPV
system

Sunny Day (21/5)



Blue line: left-axis Pink line: right axis

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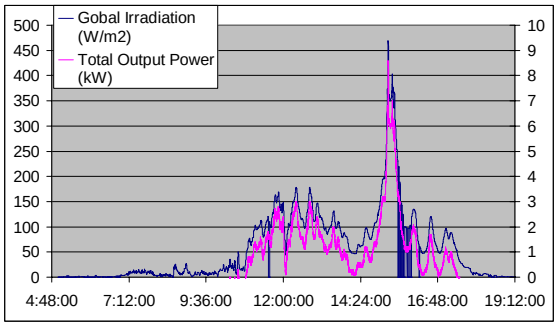
A heavy rainy day (5/5)



Blue line: left-axis Pink line: right axis

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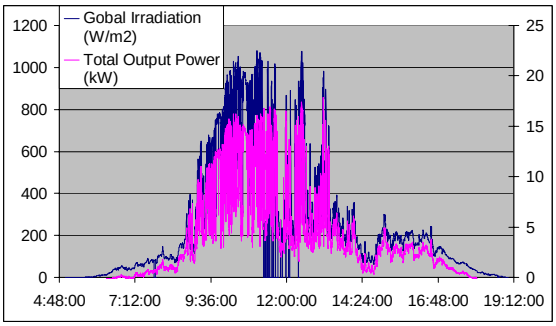
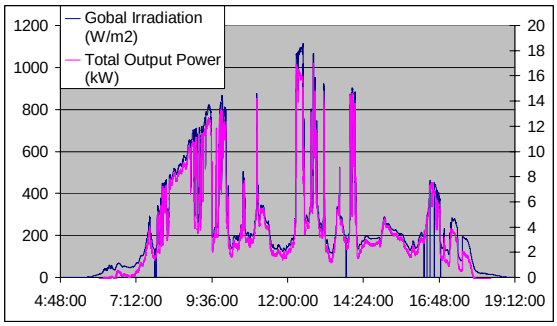
Typical cloudy day, with scattered "small clouds" (17/5)



Blue line: left-axis Pink line: right axis Mean amount of cloud on that day: 87%45
Total bright sunshine: 4.4 hr

Another typical cloudy day (24/5)



Blue line: left-axis Pink line: right axis Mean amount of cloud on that day: 81%46
Total bright sunshine: 5.1 hr

CCC Kei Wai School (Ma Wan) 3 BIPV Systems

- 1. 28.8kW CIS
- 2. 4.0kW p-Si
- 3. 7.2kW a-Si

Type:PV /grid-connected
PVtechnology:CIS / p-Si / a-Si
PVnos:720+52+63=835
kWp= 40kW
AEY = ~49000kWh
kWh/kWp:1225

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Science Park – 1 BIPV System

- The End For This Part
- Thanks for your attention

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Possible Talks from PolyU EE Dept:

- Electricity – generation, transmission & distribution
- Renewable Energies
- Energy Efficiency
- Intelligent Buildings
- Electric Vehicles
- LED Lighting and other new lighting systems
- Power electronics & drives
- Railway and its signaling systems
- Application of photonic devices in engineering
- Etc…..

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