Basic technical information on solar PV
1. How does solar PV work?
2. Main components of a PV system
3. Solar PV mounting options
4. Solar thermal systems
5. Emerging technologies
How does solar PV work?
Video: Basics of solar PV technology
How does solar PV work?

- Sunlight
- Front electrode (−)
- Antireflection coating
- Back electrode (+)
- Current
What’s a watt?

1 Light Bulb = 100 Watts (W)

10 Light Bulbs = 1,000 Watts (W) or 1 Kilowatt (kW)
What’s a kilowatt hour?

1 Kilowatt \times 1 Hour = 1 Kilowatt-hour (kWh)
Energy vs. power

\[ \text{Power} = \text{Kilowatt (kW)} \]

\[ \text{Energy} = \text{Kilowatt-hour (kWh)} \]
Direct Current vs. Alternating Current

Direct Current (DC) = Produced by solar panels

Alternating Current (AC) = ‘usable’ energy in your home or business
What are the main components of a PV system?
Main components of solar PV

From a solar cell to a PV system

Solar Cell

Solar Panel

PV-System

- Solar Array
- DC Isolator
- Cabling
- Mounting
- Tracking System
- Generation Meter
- Charge Controller
- Battery
- Inverter
- Fusebox
- AC Isolator
- Electricity Meter

Solar Module

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U.S. Department of Energy
PV cell technology

Crystalline silicon

Thin film
Main components of solar PV: cell

Photo credit: International Energy Agency
Main components of solar PV: cell
Main components of solar PV: module/panel

Multiple PV cells make up a PV module

Photo credit: CSE
The visible assembly of multiple modules and support structure is the array.
Main components of solar PV: inverter

Two types of inverters:
- String Inverters
- Micro Inverters
Inverters change **DC** electricity from panels to **AC** electricity for use in your building.

There are basically two types of inverters:

- **String inverters**
- **Micro-inverters**
String inverters

One individual inverter per array
String inverters

One individual inverter **per array**

**Benefits**
- Longer track record
- Established reliability
- High efficiency
- Lower cost*

**Disadvantages**
- Shading can affect power output dramatically
- Does not allow for easy system size increases
One individual inverter per module
Micro inverters

One individual inverter **per module**

**Benefits**
- Makes the array more tolerant to shading
- Allows flexibility in design and for future additions
- Built-in rapid shut-down compliance

**Disadvantages**
- Shorter track record
DC Power Optimizers

Attaches to or is integrated in the junction box of a PV module

Photo credit: SolarEdge
What are the available solar PV mounting options?

- Flush mounted
- Tilted rack mounted
- Pole mounted
- Ballasted

Photo credit: NREL
Flush mounted
Tilted rack mounted

• Solar cells perform best when their surface is perpendicular to the sun's rays

• Many PV systems are installed on tilted rack mounted systems, which can help to optimize PV module output
Ground and pole mounted

Example of PV array being used as a shade structure

Photo credit: NREL
Solar thermal systems are a different type of system used to collect and utilize the sun's energy.

**How is solar thermal different from solar PV?**

- **Solar PV** converts photons to electricity.
- **Solar thermal systems** use solar thermal energy to heat water or to heat another medium to store the energy.
Solar thermal systems

Two categories that solar thermal systems fall into:

• Glazed
• Unglazed
Unglazed solar thermal

**Unglazed collectors** are flat plates generally used to heat swimming pools.

Photo credit: Alternative Energy Tutorials
Unglazed solar thermal systems are fairly easily discernable from solar photovoltaic systems because of the observable piping systems which carry the heated water.
Solar thermal system types

System Types

Open Loop:
Direct heating with Low-Temperature Unglazed Polymer Collectors

Closed Loop:
Indirect heating with a heat exchanger using Medium-Temperature or Evacuated-Tube Collectors

Photo credit: Aquatherm/Slideshare
Glazed collectors are also usually flat plates but are used for heating water or air.

Photo credit: NREL
Glazed solar thermal collectors

Flat plate collectors

Photo credit: NREL
The list of top 10 emerging technologies of 2016 includes two solar technologies:

- Next generation batteries
- Perovskite solar cells
Emerging Technology: Alternative Energy Storage (AES)

Photo credit: CSE
Emerging Technology: Ready-to-install storage systems

Tesla’s Powerwall
Emerging Technology: Ready-to-install storage systems

Example: Y.Cubes
Panasonic and Denver International Airport plan to install 1.86 MW solar system and Y.Cubes

Rendering of planned Y.Cube placement in front of Panasonic HQ

Photo credit: Younicos
Emerging Technology: Colored Solar PV

Photo credit: CSEM
Emerging Technology: White PV Modules
Emerging Technology: Tesla Roof Tiles

Anatomy of the Solar Roof

- **High efficiency solar cell**
  Produces energy even during high temperature days.

- **Color louver film**
  Allows cells to blend into the roof while exposing them to the sun above.

- **Tempered glass**
  Extremely durable and impact resistant.

Photo credit: Tesla
Emerging Technology: Spray on / Paint-on PV

Perovskite cells

Photo credit: NREL
Emerging Technology: Peel-and-stick modules

Photo credit: Miasole

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Quiz and discussion
Which of the following PV systems is considered building integrated?

a) Flush mounted PV system
b) Tilted rack roof mounted PV system

c) Photovoltaics shingles

d) Ballasted PV system
Which of the following PV systems is not a roof mounted PV system?

a) Titled rack mounted PV system
b) Ballasted PV system
c) Integrated PV system
d) Pole mounted PV system
e) None of the above
Which of the following roof mounted systems does not penetrate the roofing material?

a) Flush mounted PV system
b) Building integrated PV system
c) Ballasted PV system
d) Class A PV system
e) Class C PV system