A Tutorial on Solar PV

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Thanks to Wikipedia for much of the information and all of the figures
A fusion reactor

"The Sun as seen in January 1st 2015" by NASA/SDO (Wikipedia)
Solar path

Solar declination by Deditos - Own work. Licensed under CC BY-SA 4.0 via Wikimedia Commons.
Insolation

- 1367.7 W/m² in space
- 1000 W/m² at sea level on a clear day
- Typical level is 800-850 W/m²
In 1839, at age 19, experimenting in his father's laboratory, Edmond Becquerel created the world's first photovoltaic cell.

Albert Einstein explained the underlying mechanism of light instigated carrier excitation—the photoelectric effect—in 1905, for which he received the Nobel Prize in Physics.
Silicon PV cell

The first practical photovoltaic cell was publicly demonstrated on 25 April 1954 at Bell Laboratories. The inventors were Daryl Chapin, Calvin Fuller and Gerald Pearson.
Theory of operation
The Shockley-Queisser limit for the theoretical maximum efficiency of a solar cell. Semiconductors with band gap between 1 and 1.5 eV, or near-infrared light, have the greatest potential. Luckily, Silicon has this exact band gap.
Types

- Crystalline (160-240 micrometers thick)
  - mono – most expensive, most efficient
  - poly – most common
  - ribbon – low efficiency, easier to make

- Thin film (~10nm thick, vapor deposited)
  - between two pieces of glass
  - 2-3% less efficient than crystalline
  - CdTe is most common

- Multijunction, Perovskite, dye-sensitized, quantum dots
  - still in research stage
Solar arrays

From a solar cell to a PV System

- Solar Cell
- Solar Module
- Solar Panel
- PV-System
- Electricity Meter
- AC Isolator
- Fusebox
- Inverter
- Battery
- Charge Controller
- Generation Meter
- DC Isolator
- Cabling
- Mounting
- Tracking System
Precio de las células fotovoltaicas de silicio cristalino (en $/Wp)

Datos: Bloomberg New Energy Finance
Swanson's Law
Solar PV is growing as fast as cell phones


http://stats.areppim.com/stats/stats_mobile.htm

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Terms

- Amps: current
- Voltage: potential difference
- Watts: power = Amps X Volts (bandwidth)
- Watt-second = Joule: energy (bits)
IV curves

- Large resistance
- Small resistance
- Diode
- Battery
A PV cell acts as a **current source**, with voltage across load increasing linearly with the load resistance.
An MPPT tracker maintains the effective load resistance at the value that maximizes the power generated by the PV.
Practical considerations

- Shadowing
- Temperature (0.5% decline per degree over 25°C)
- Age (0.5% decline per year)
- Tilt angle (~10% if flat)
- Orientation (fixed vs. tracking)
- Wind load
Inverter

- DC -> AC
- A “smart inverter” will cut off the panel if Voltage exceeds a limit
- Can generate AC leading or lagging
  - VAR support
- A per-panel microinverter
  - adds cost
  - but prevents shading loss
  - and provides per panel MPPT
Grid intertie