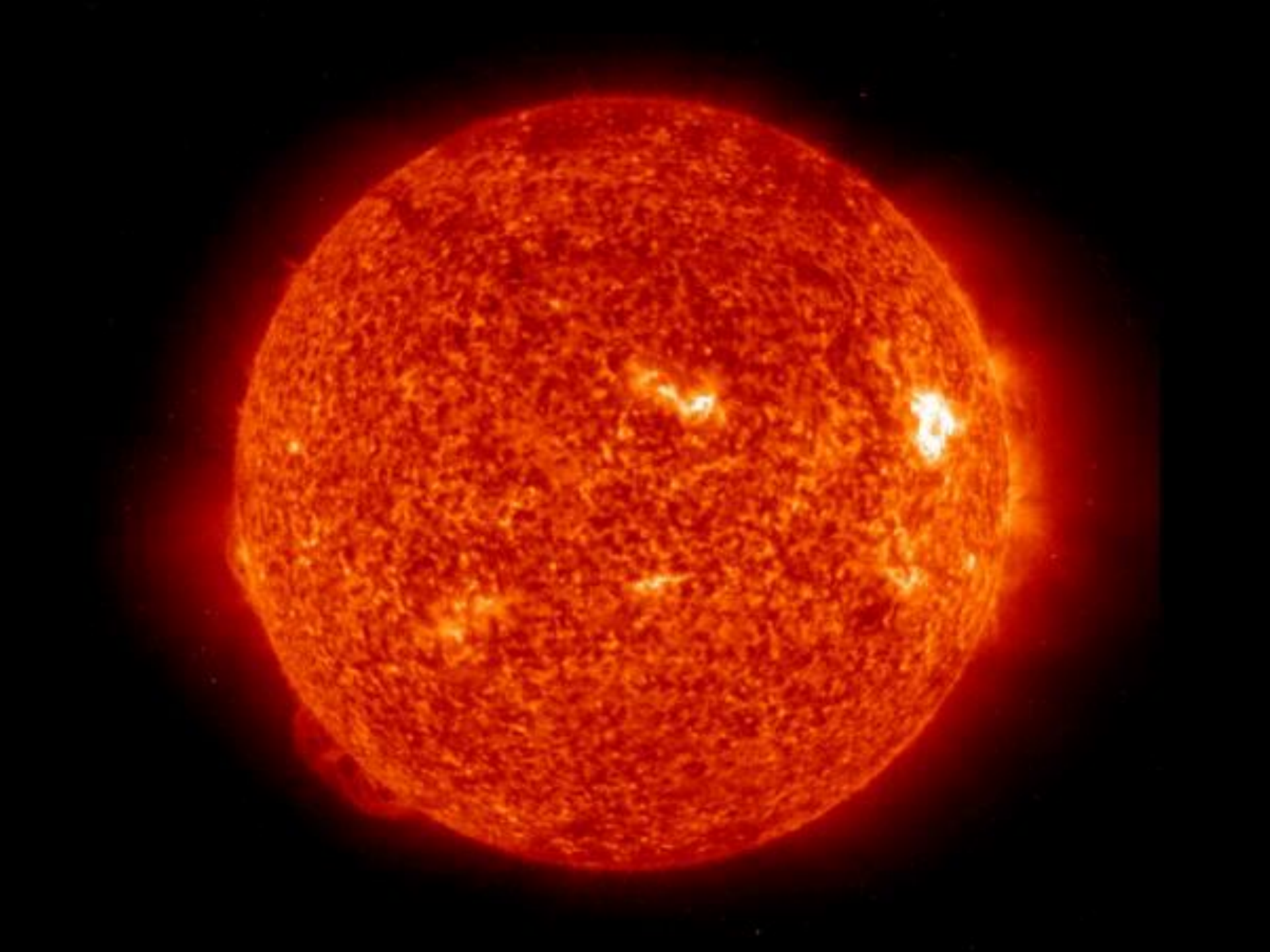
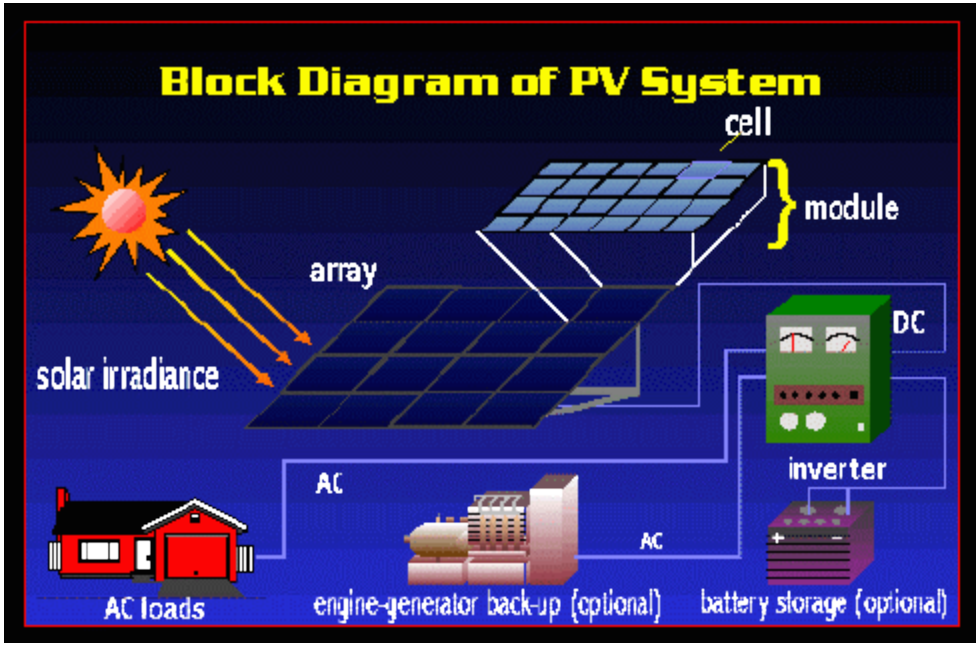
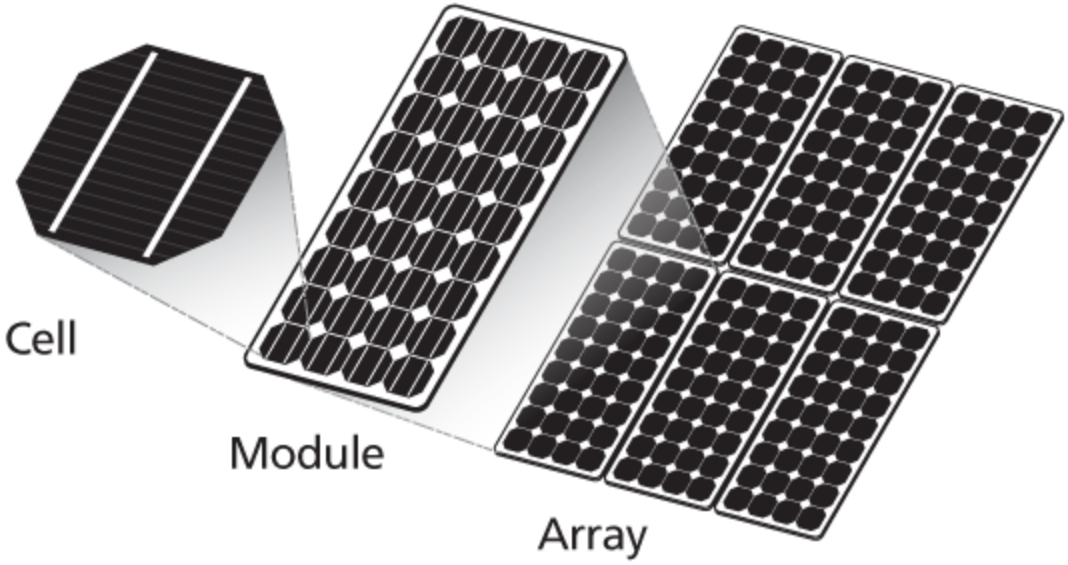
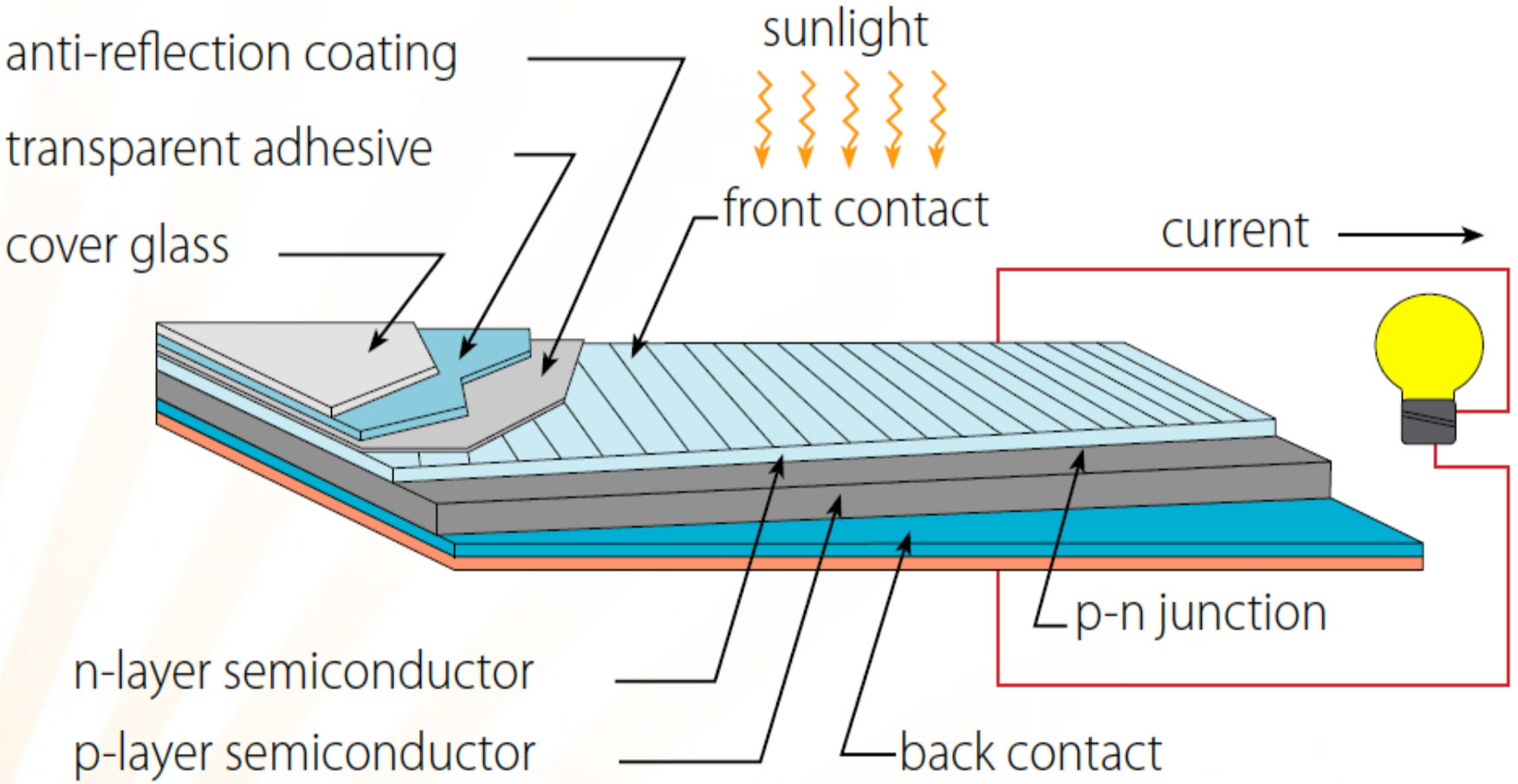
ELVISWEATHERCOCK




Block Diagram of PV System
cell
module
array
solar irradiance
DC
inverter
AC
AC
AC loads
engine-generator back-up (optional)
battery storage (optional)


Cell
Module
Array

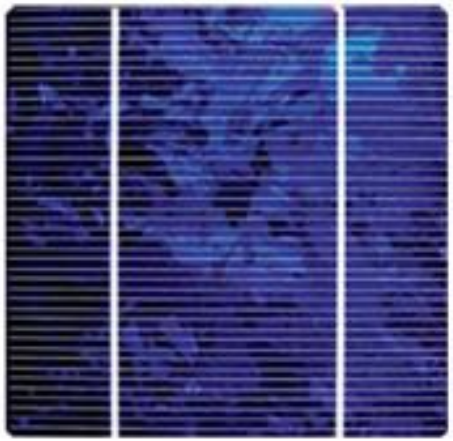

anti-reflection coating
transparent adhesive
cover glass
sunlight
front contact
current
p-n junction
n-layer semiconductor
p-layer semiconductor
back contact

A typical solar cell is a multi-layered unit consisting of a:

- Cover - a clear glass or plastic layer that provides outer protection from the elements. Transparent Adhesive - holds the glass to the rest of the solar cell.
- Anti-reflective Coating - this substance is designed to prevent the light that strikes the cell from bouncing off so that the maximum energy is absorbed into the cell.
- Front Contact - transmits the electric current.
- N-Type Semiconductor Layer - a thin layer of silicon which has been mixed (process if called doping) with phosphorous to make it a better conductor.
- P-Type Semiconductor Layer - This is a thin layer of silicon which has been mixed or doped with boron to make it a better conductor.
- Back Contact - transmits the electric current.

# Types of Solar Panels

Mono



Poly

Thin Film

# Difference

- Mono
  - More efficient
  - Better at lower temperatures and low light levels
  - From single wafer
- Poly
  - Less efficient
  - Better at higher temperature
  - Normally smaller
  - From molten silicon

# Module Types

- Traditional Silicon Wafer Modules
  - Monocrystalline
  - Polycrystalline
- Thin Film (Amorphous)
- Specialty

# Traditional Silicon Modules

**Mono**

**Poly**

# Thin Film (Amorphous)

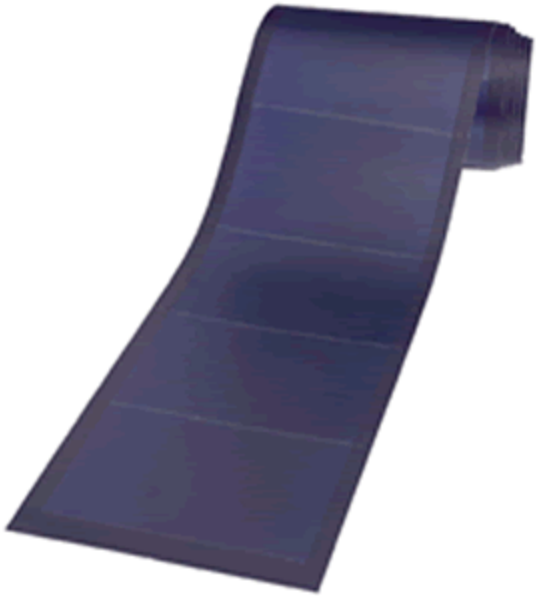
**CIGS**

# Specialty

**Transparent/Frameless**

# Specialty

**Flexible**



# Mounting Options

- Roof Mount
  - Flat (Rubber)
    - Ballast
    - Mechanically Attached
  - Slope (Standing Seam/Shingle)
    - Mechanically attached
    - Pentrating vs. Non-Penetrating
  - Structural/Wind Loading Considerations
  - Warranty Concerns

# Ballast Mount

# Mechanically Attached

# Standing Seam

# Shingle

# Mounting Options

- Ground
  - Ballast
  - Fixed Tilt
  - Top of Pole
  - Tracking
    - Single Axis
    - Dual Axis
  - Parking Canopy

# Ballast

# Fixed Tilt

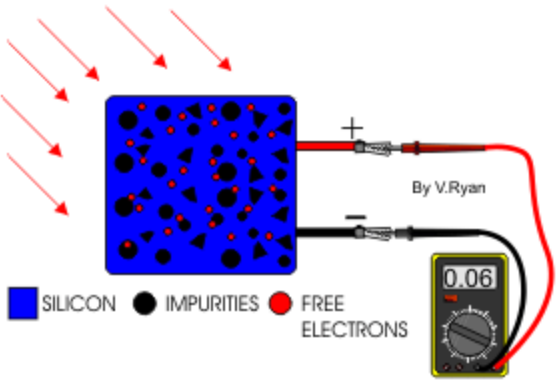
# Top of Pole

# Single Axis Tracking

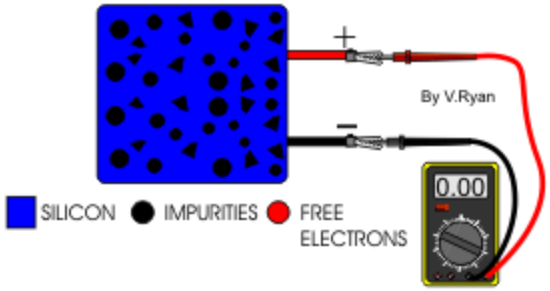
# Dual Axis Tracking

# Parking Canopy

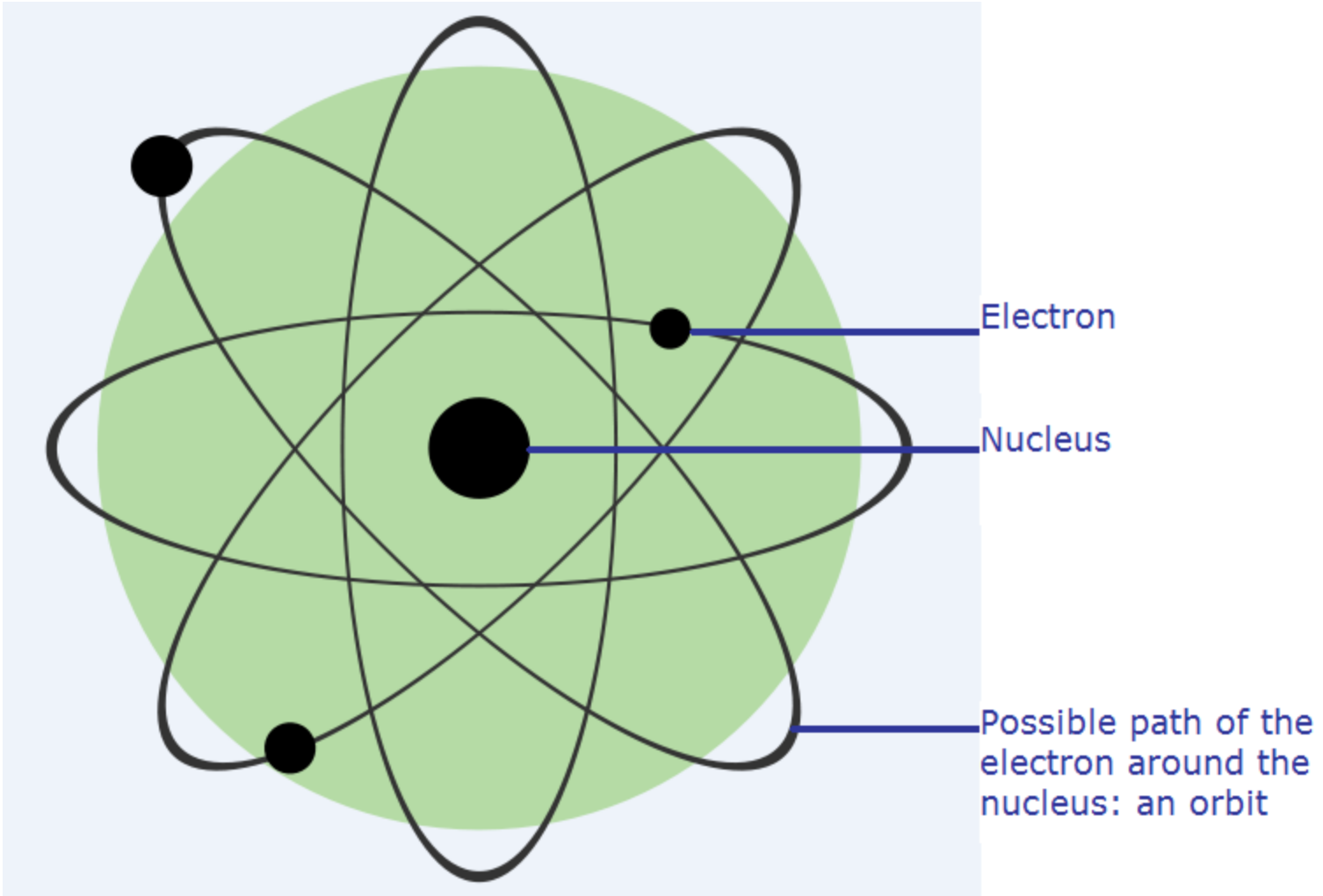
SUNLIGHT - ELECTRONS FREED



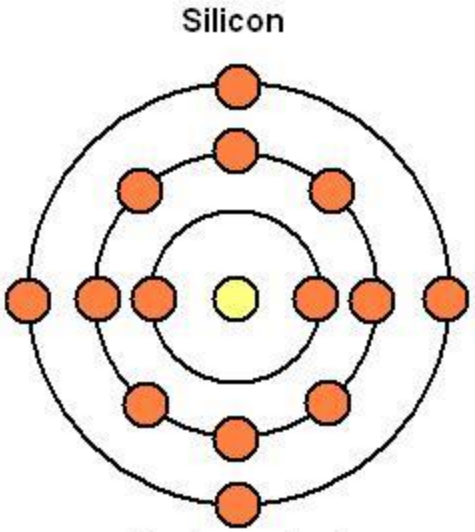

NO SUNLIGHT - NO ELECTRONS FREED

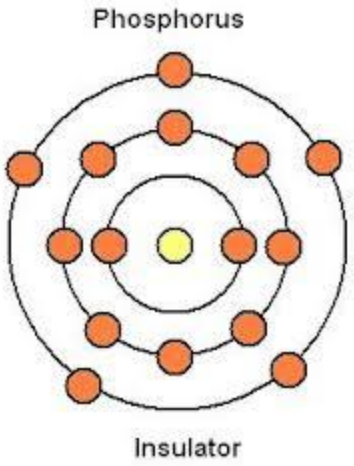


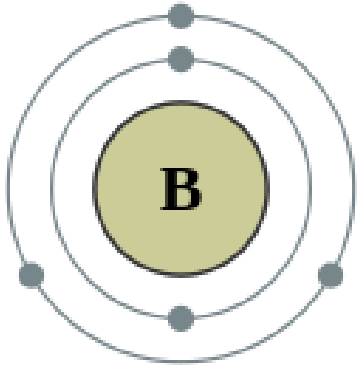
# Power from the Sun



# Making power



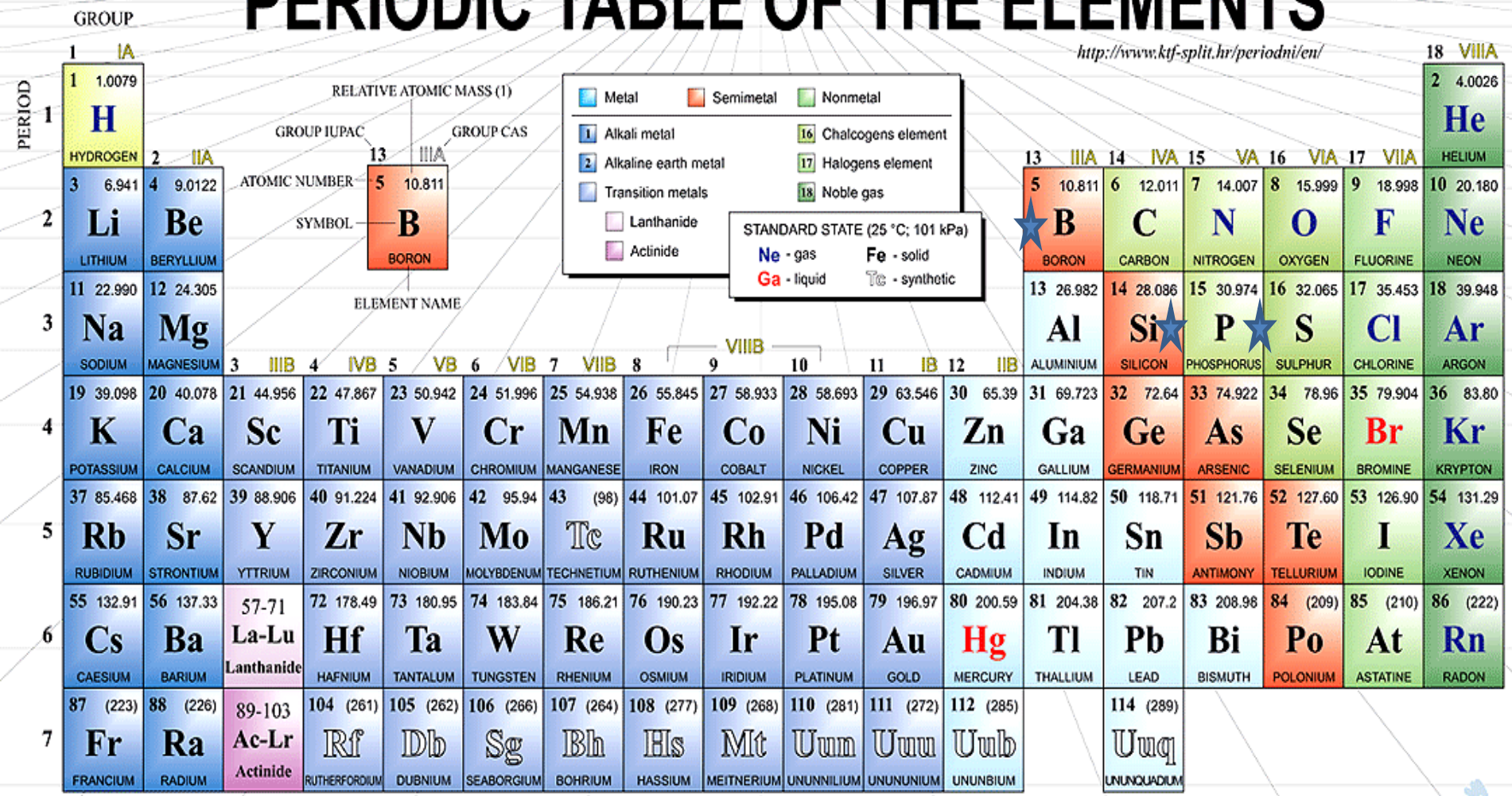




Boron

# PERIODIC TABLE OF THE ELEMENTS

http://www.ktf-split.hr/periodni/en/




LANTHANIDE

| 57 138.91 | 58 140.12 | 59 140.91 | 60 144.24 | 61 (145) | 62 150.36 | 63 151.96 | 64 157.25 | 65 158.93 | 66 162.50 | 67 164.93 | 68 167.26 | 69 168.93 | 70 173.04 | 71 174.97 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| La LANTHANUM | Ce CERIUM | Pr PRASEODYMIUM | Nd NEODYMIUM | Pm PROMETHIUM | Sm SAMARIUM | Eu EUROPIUM | Gd GADOLINIUM | Tb TERBIUM | Dy DYSPROSIUM | Ho HOLMIUM | Er ERBIUM | Tm THULIUM | Yb YTTERBIUM | Lu LUTETIUM |

ACTINIDE

| 89 (227) | 90 232.04 | 91 231.04 | 92 238.03 | 93 (237) | 94 (244) | 95 (243) | 96 (247) | 97 (247) | 98 (251) | 99 (252) | 100 (257) | 101 (258) | 102 (259) | 103 (262) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ac ACTINIUM | Th THORIUM | Pa PROTACTINIUM | U URANIUM | Np NEPTUNIUM | Pu PLUTONIUM | Am AMERICIUM | Cm CURIUM | Bk BERKELIUM | Cf CALIFORNIUM | Es EINSTEINIUM | Fm FERMIUM | Md MENDELEVIUM | No NOBELIUM | Lr LAWRENCIUM |

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(1) Pure Appl. Chem., 73, No. 4, 667-683 (2001)

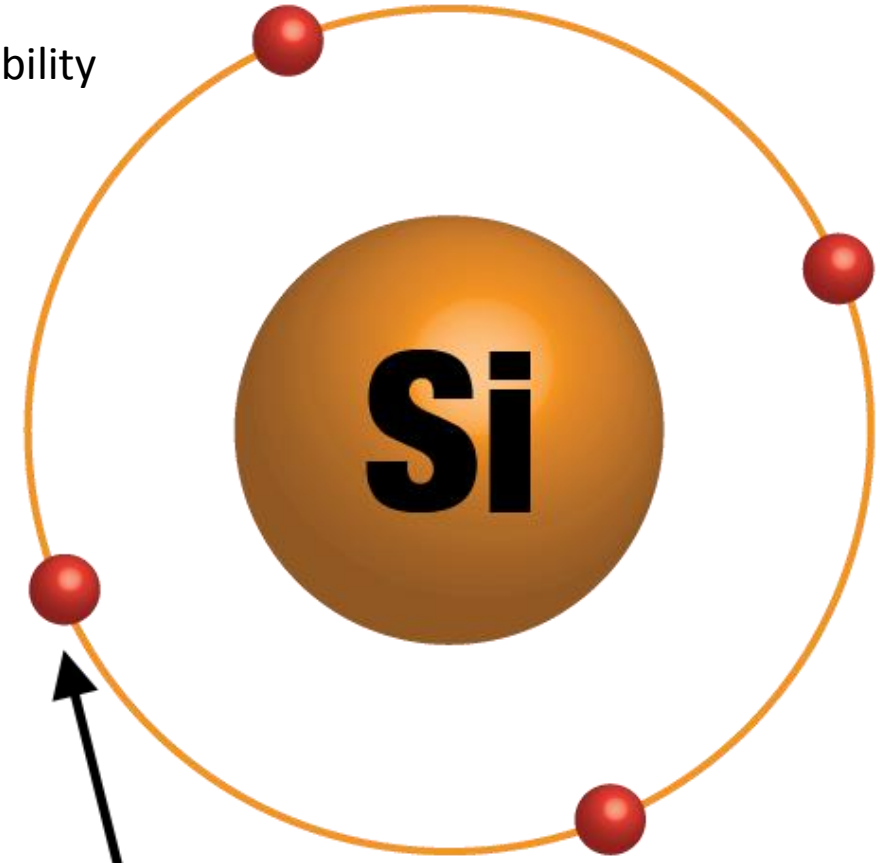
Relative atomic mass is shown with five significant figures. For elements have no stable nuclides, the value enclosed in brackets indicates the mass number of the longest-lived isotope of the element.

However three such elements (Th, Pa, and U) do have a characteristic terrestrial isotopic composition, and for these an atomic weight is tabulated.

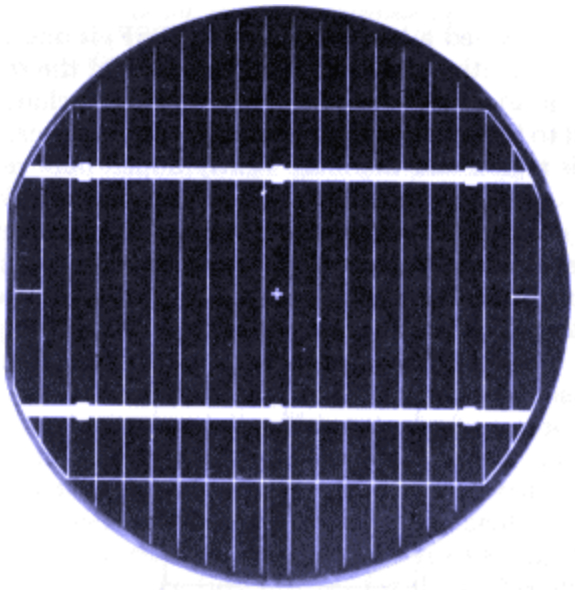
Editor: Aditya Vardhan (adivar@nettlinx.com)

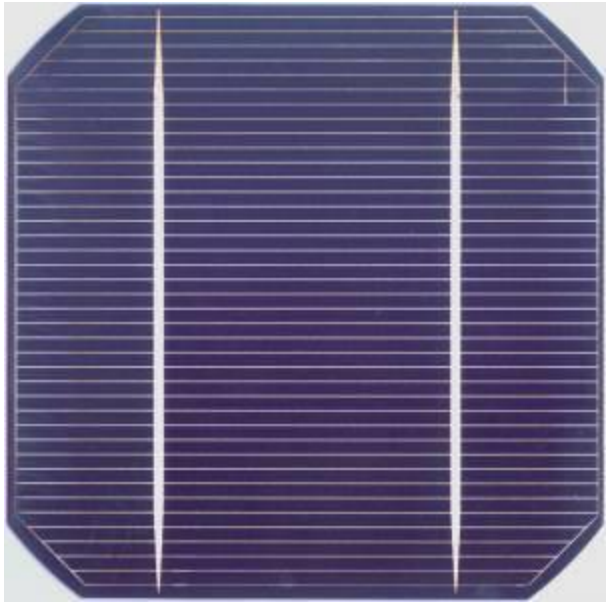
# Silicon Atom

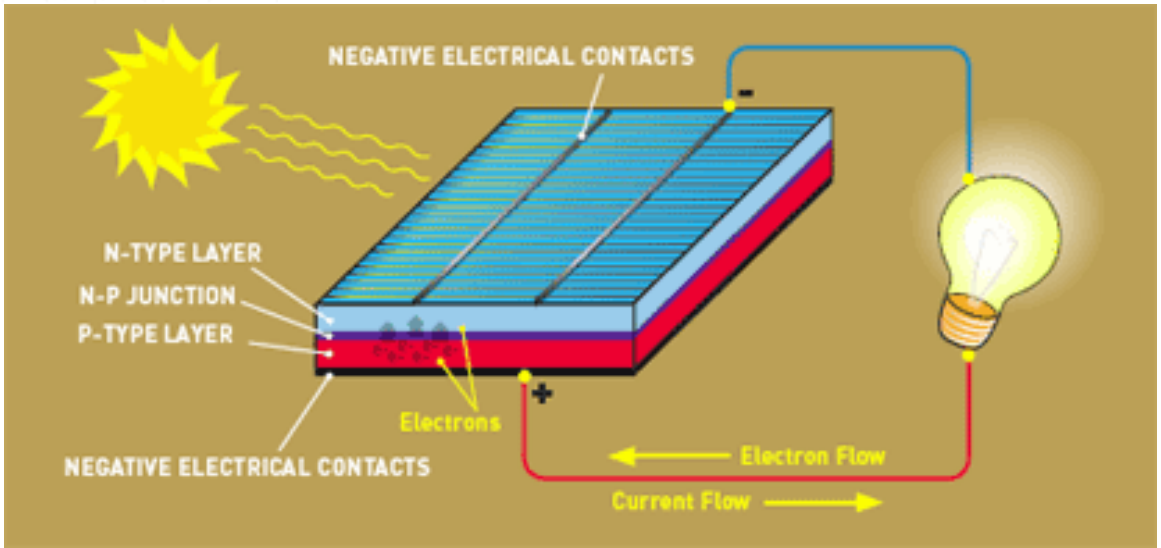
Requires 8 electrons for stability

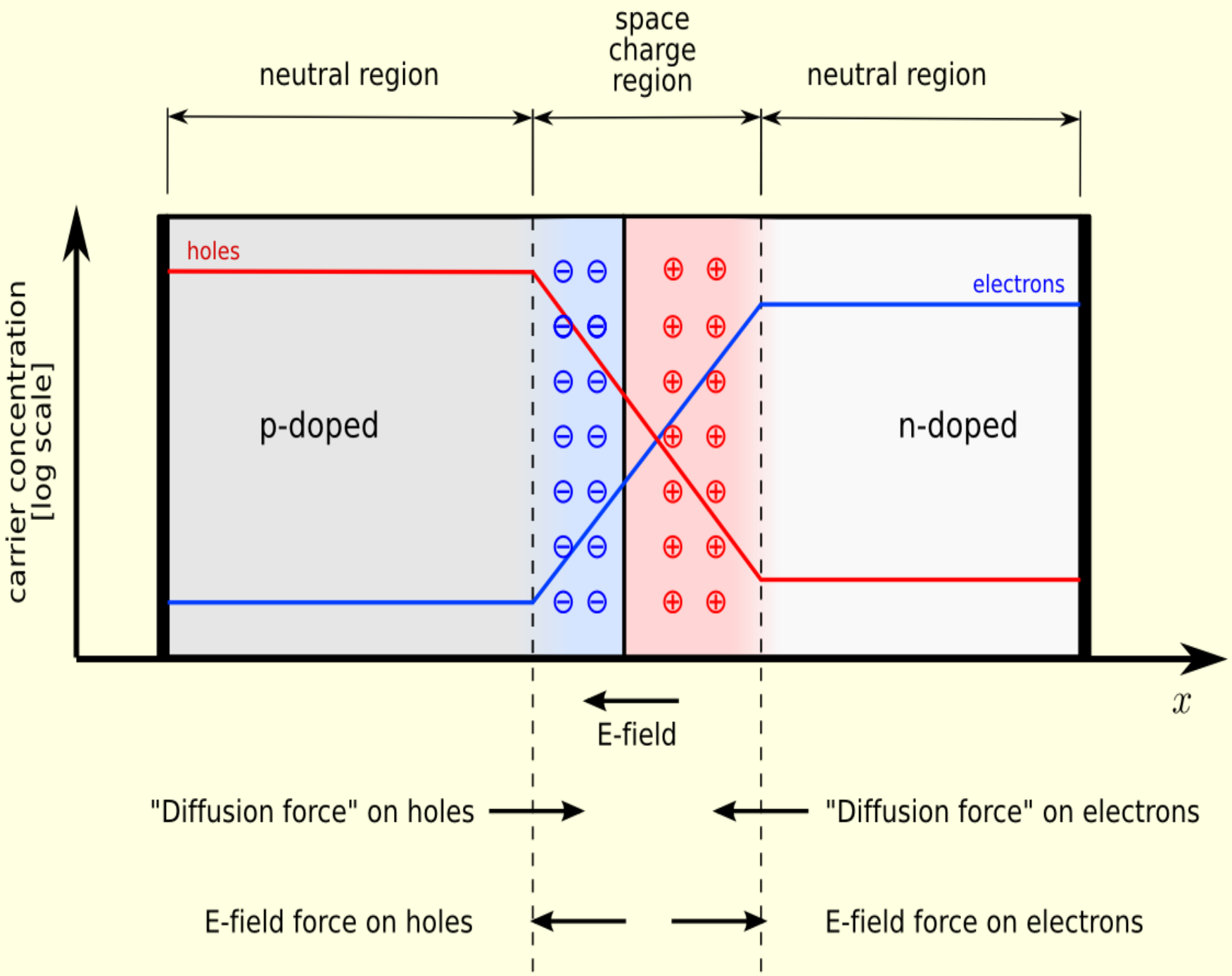


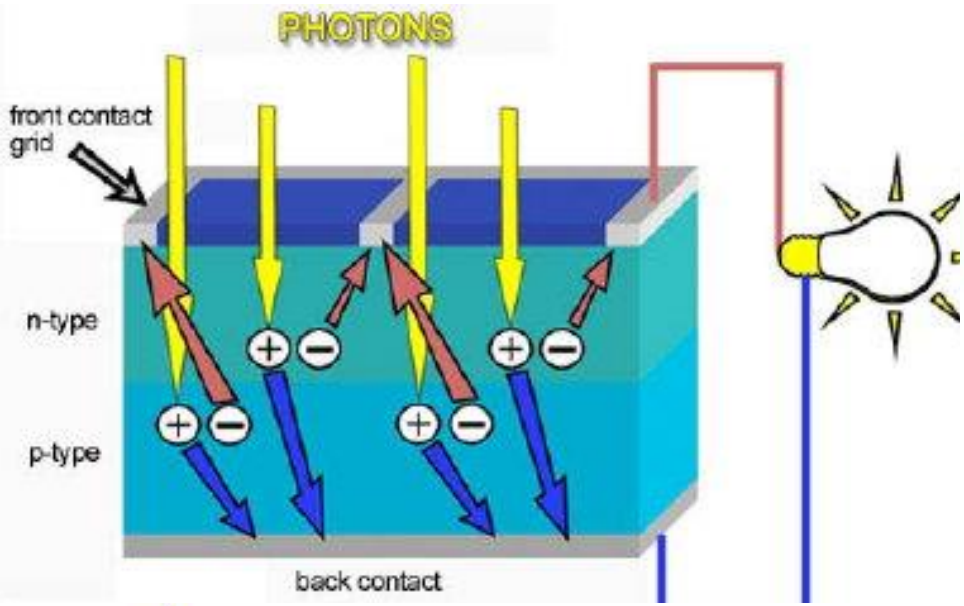

4 outer shell electrons

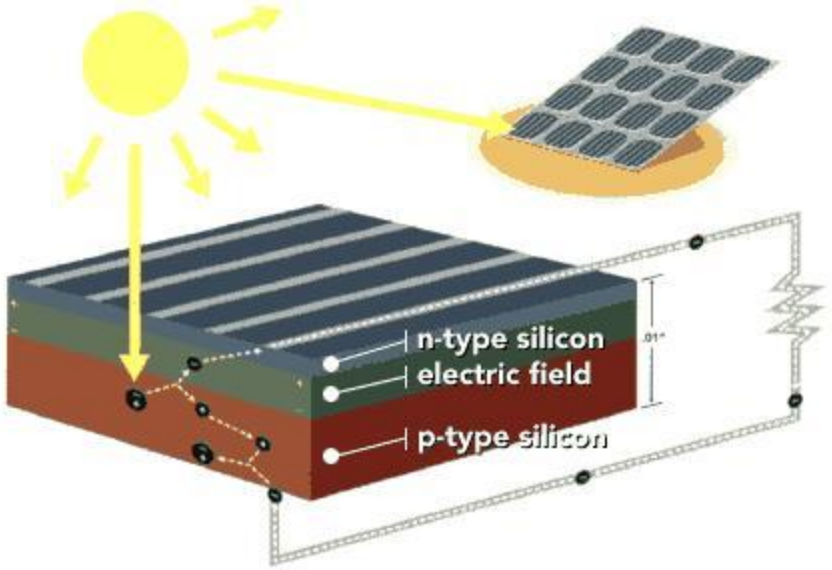


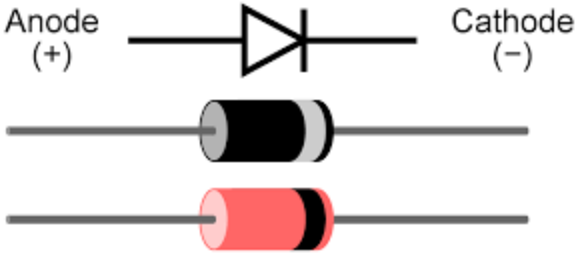


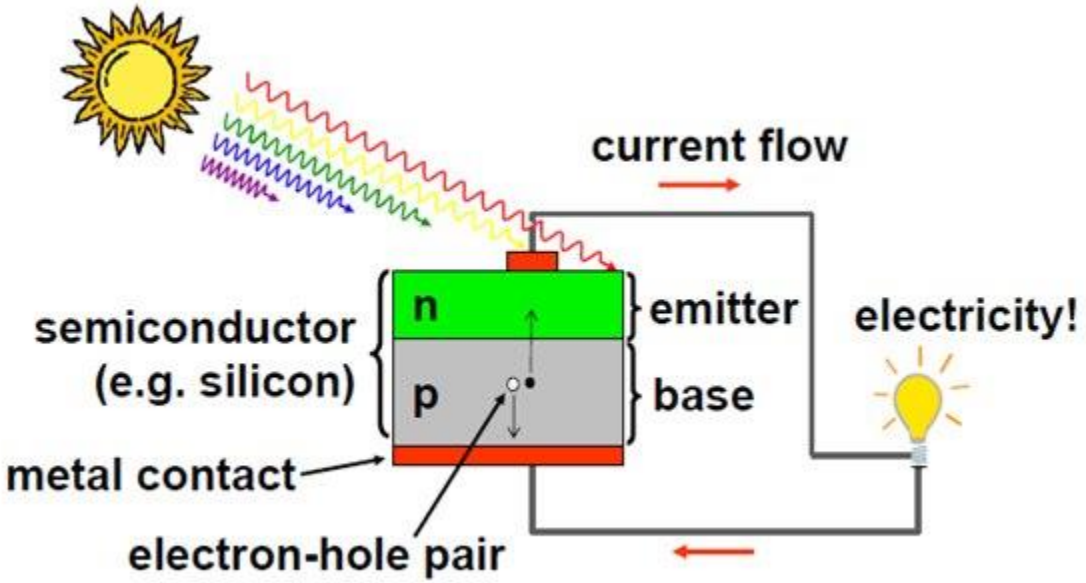

NEGATIVE ELECTRICAL CONTACTS
N-TYPE LAYER
N-P JUNCTION
P-TYPE LAYER
Electrons
NEGATIVE ELECTRICAL CONTACTS
Electron Flow
Current Flow

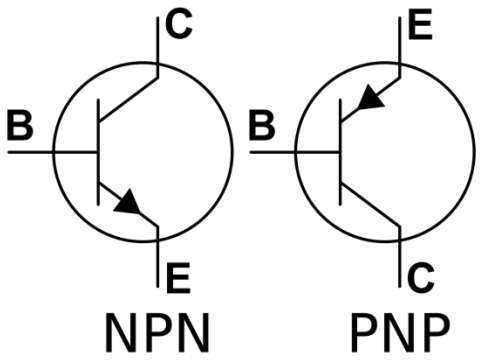

neutral region
space charge region
neutral region
holes
electrons
p-doped
n-doped
carrier concentration [log scale]
$x$
E-field
"Diffusion force" on holes
"Diffusion force" on electrons
E-field force on holes
E-field force on electrons

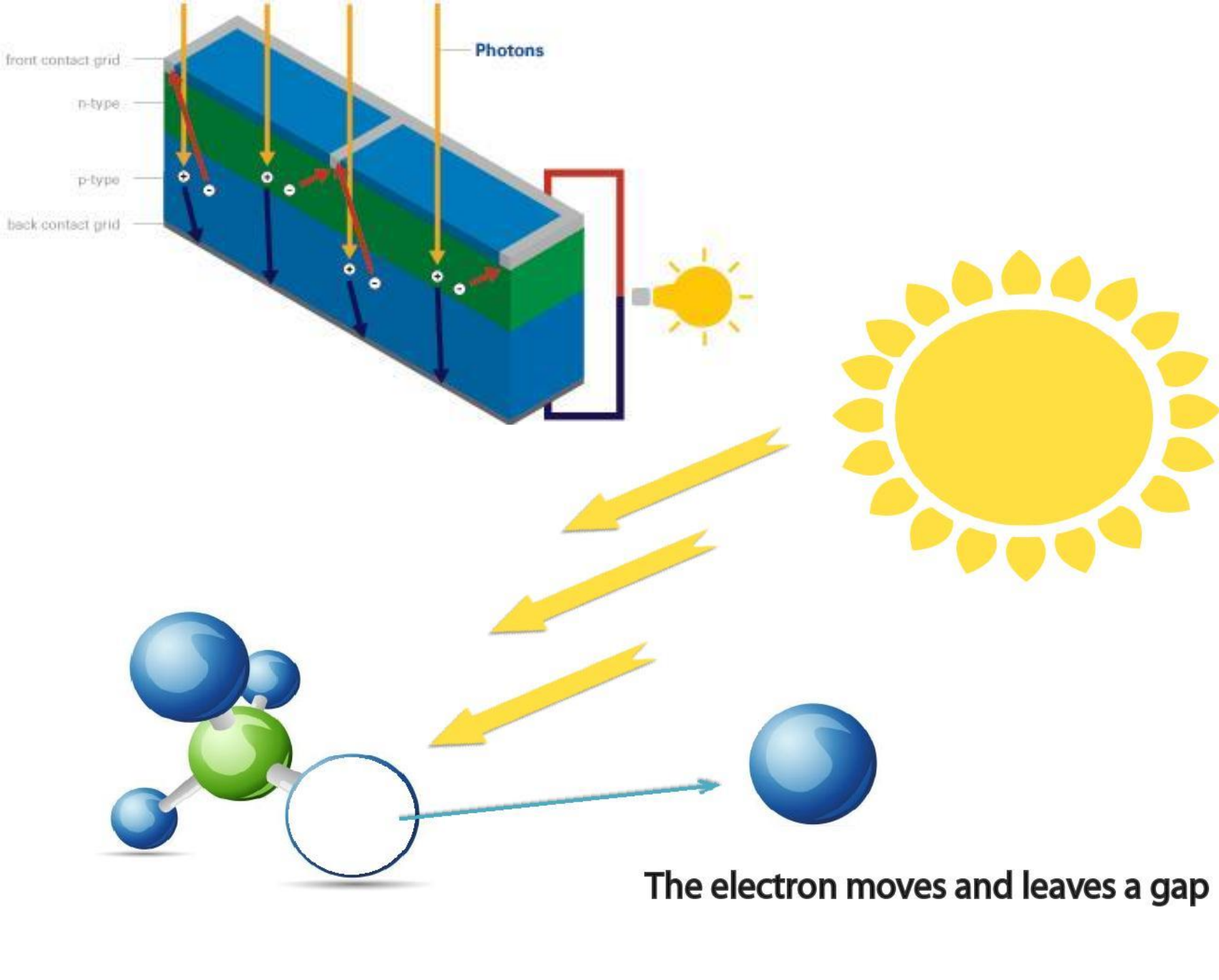

PHOTONS
front contact grid
n-type
p-type
back contact

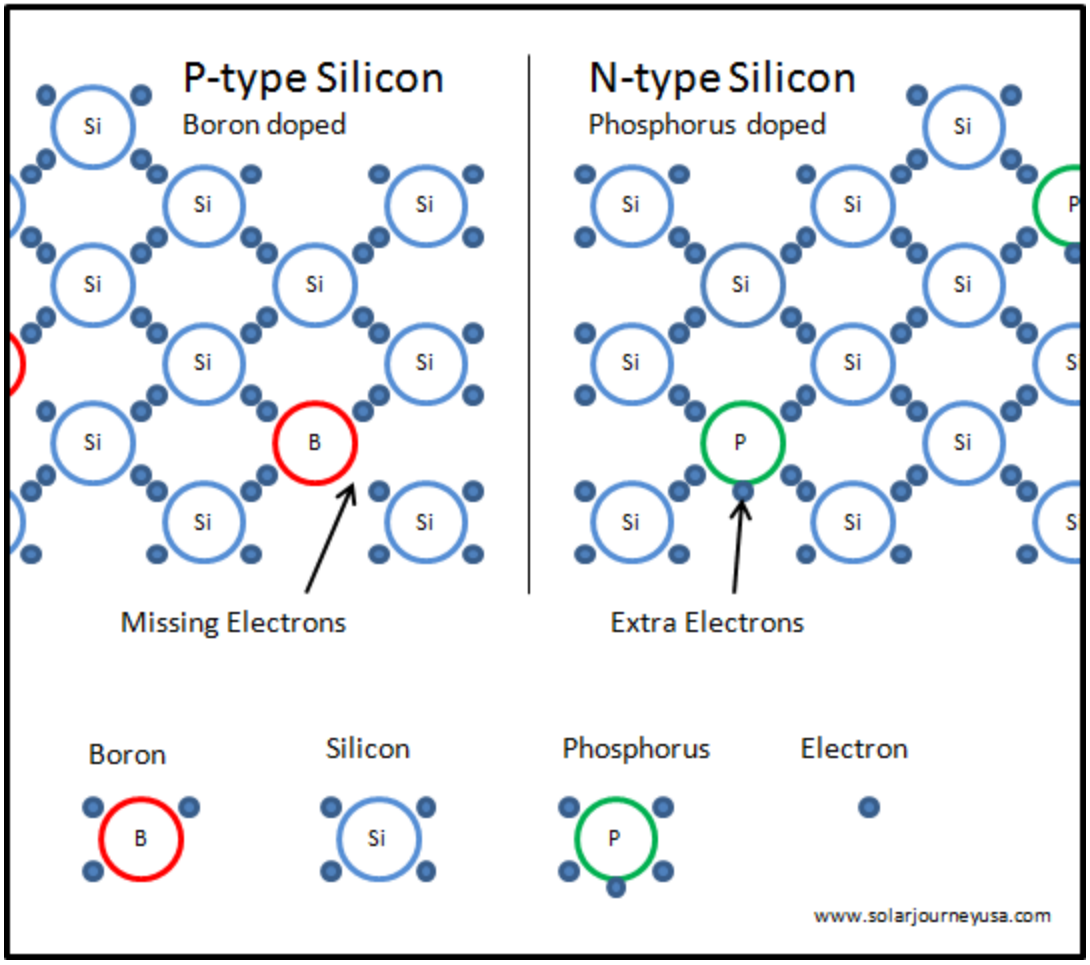

n-type silicon
electric field
p-type silicon


Anode
(+)
Cathode
(−)


current flow
semiconductor
(e.g. silicon)
n
p
emitter
base
electricity!
metal contact
electron-hole pair


C
B
E
NPN
E
B
C
PNP

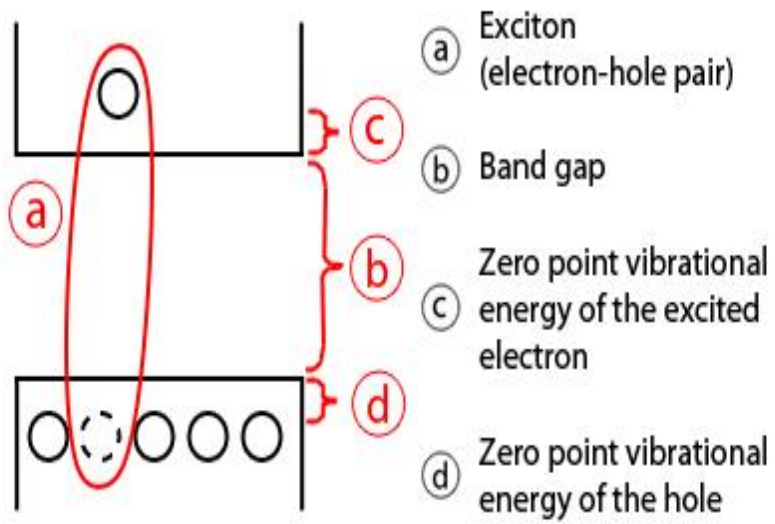

front contact grid
n-type
p-type
back contact grid
Photons
The electron moves and leaves a gap


P-type Silicon
Boron doped
Si
B
Missing Electrons
N-type Silicon
Phosphorus doped
P
Extra Electrons
Boron
Silicon
Phosphorus
Electron
www.solarjourneyusa.com

# Band Gap

- The Measured energy across the junction or depleted region (the P and N junction) has a between .3 -.7 volts across the P and N junctions dependent on materials used.
- In order for electrons to  cross this band gap the applied voltage must be higher than the band gap voltage
- In PV panels this required energy comes from photons from the sun.

# Band Gap

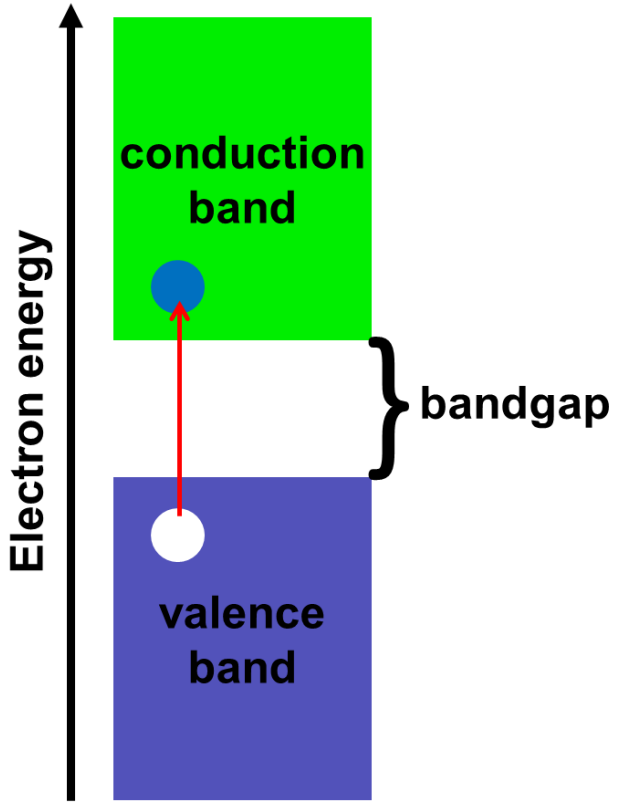



(a) Exciton (electron-hole pair)

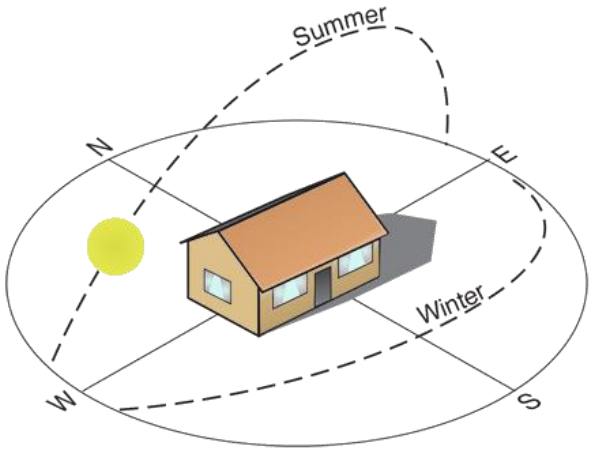
(b) Band gap

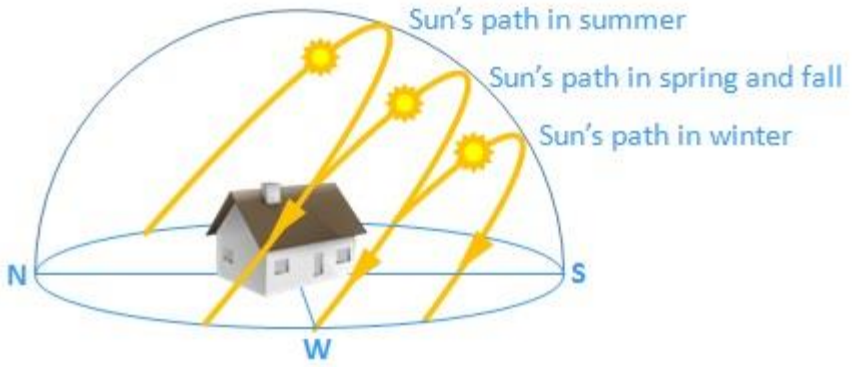
(c) Zero point vibrational energy of the excited electron

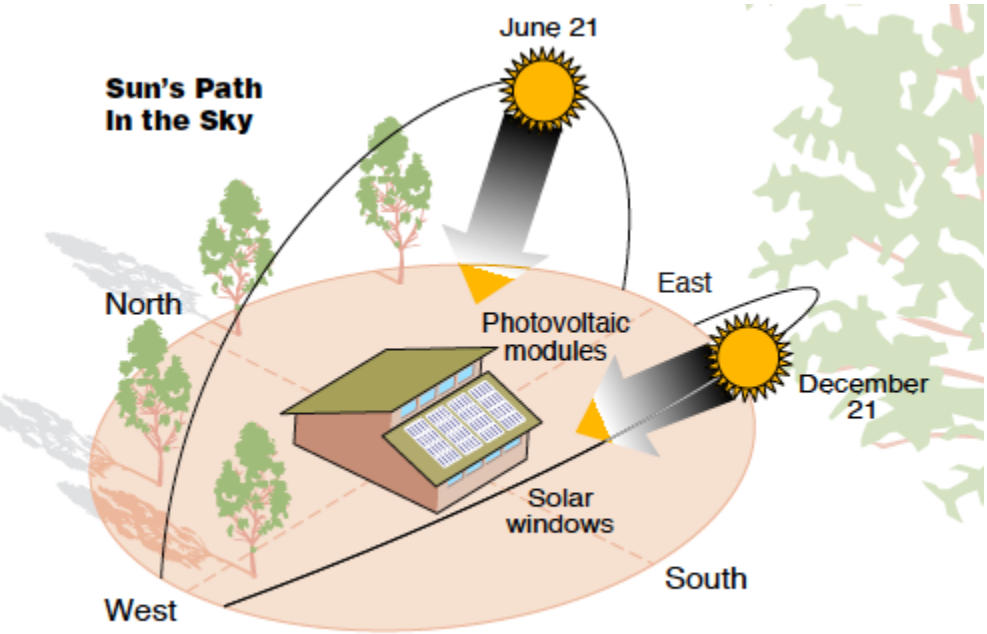
(d) Zero point vibrational energy of the hole

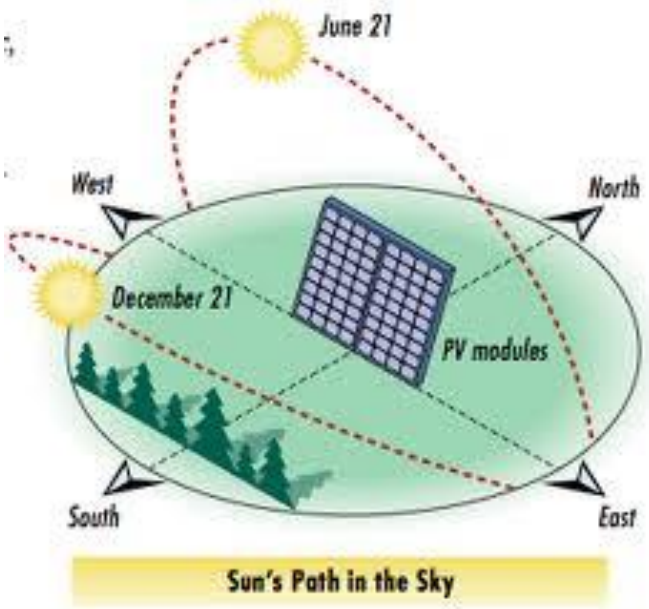


# Summer & Winter Sunpaths

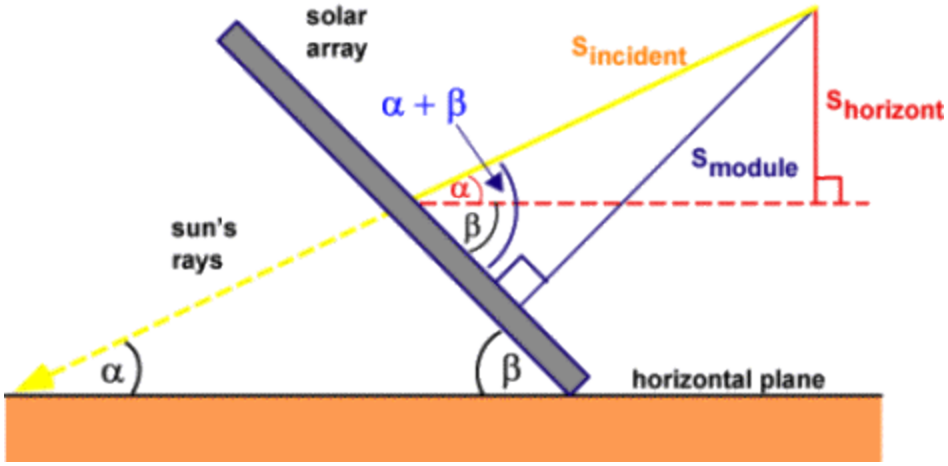


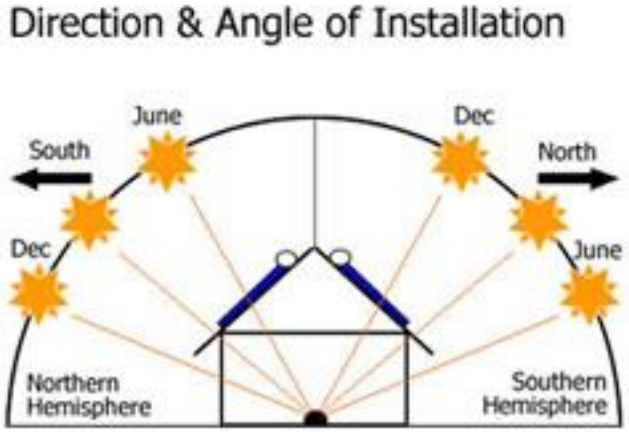



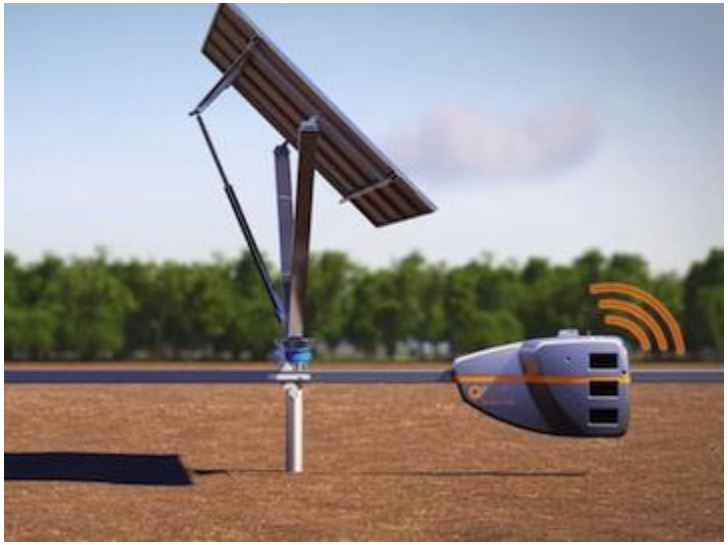



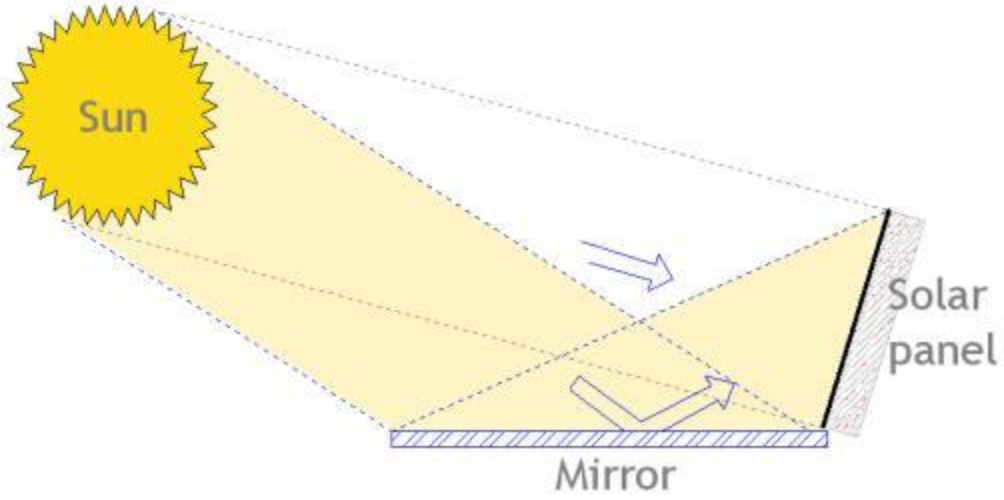
# Angle of Solar Array



# Auto Alignment





# Rediscovering the Future

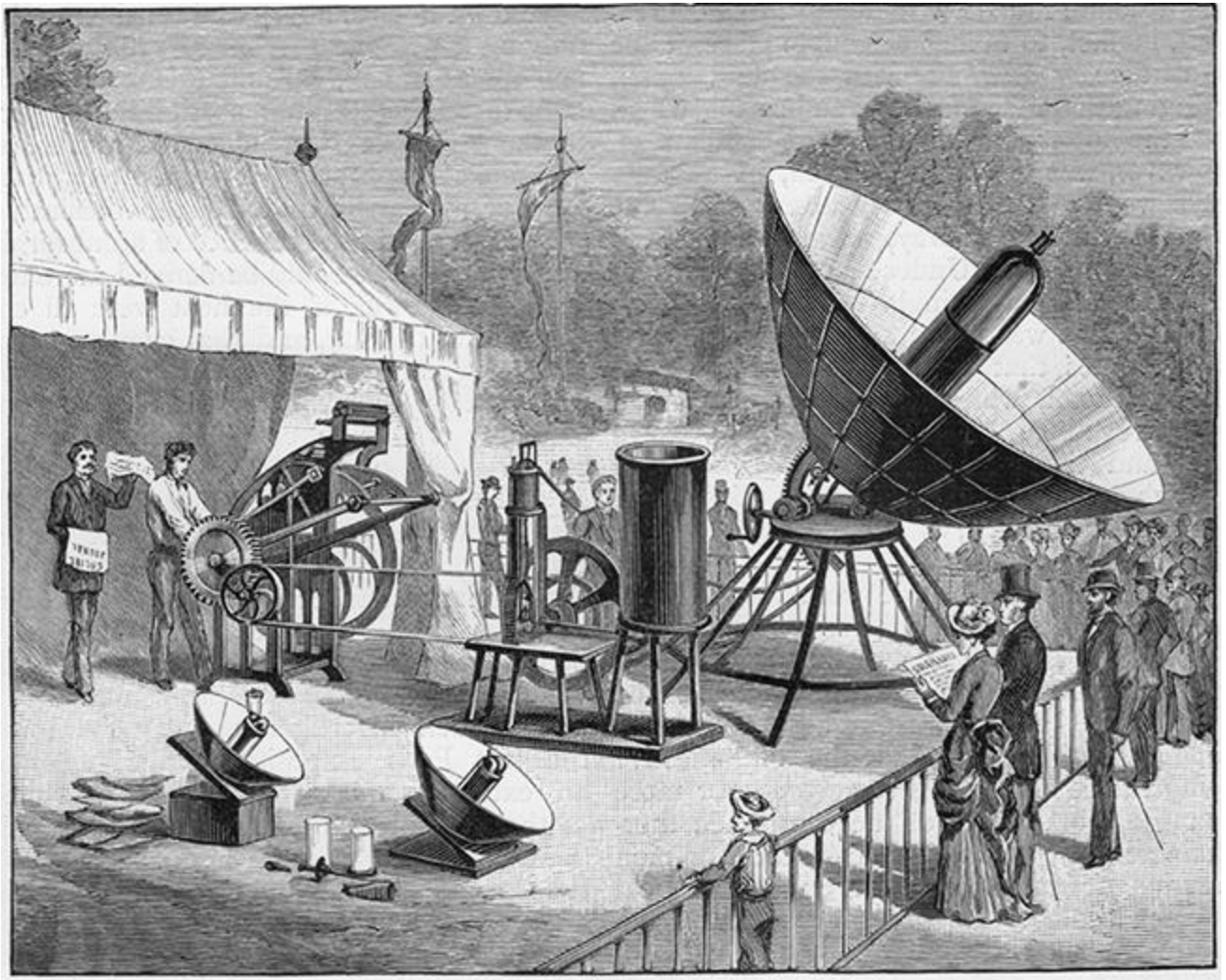
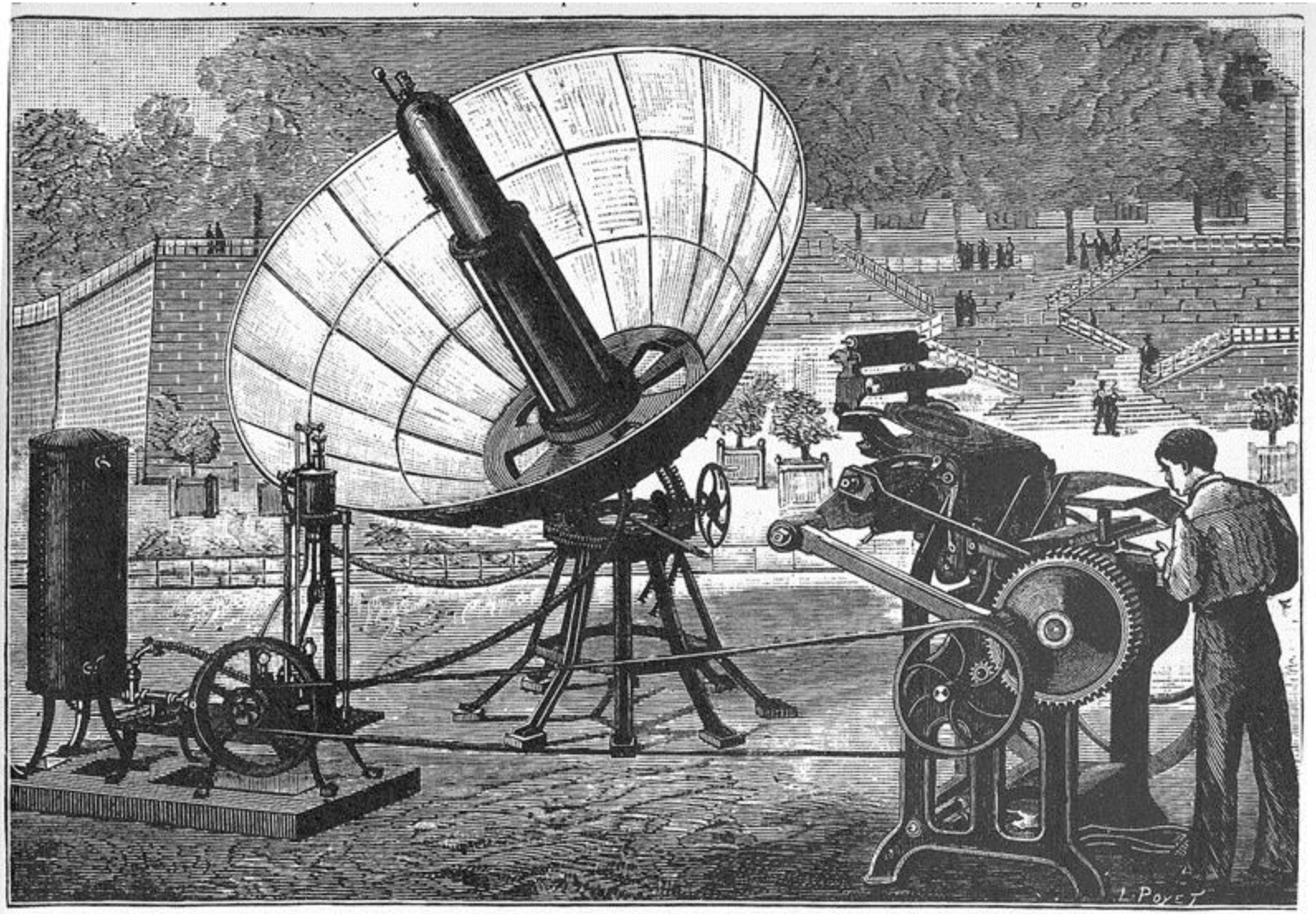
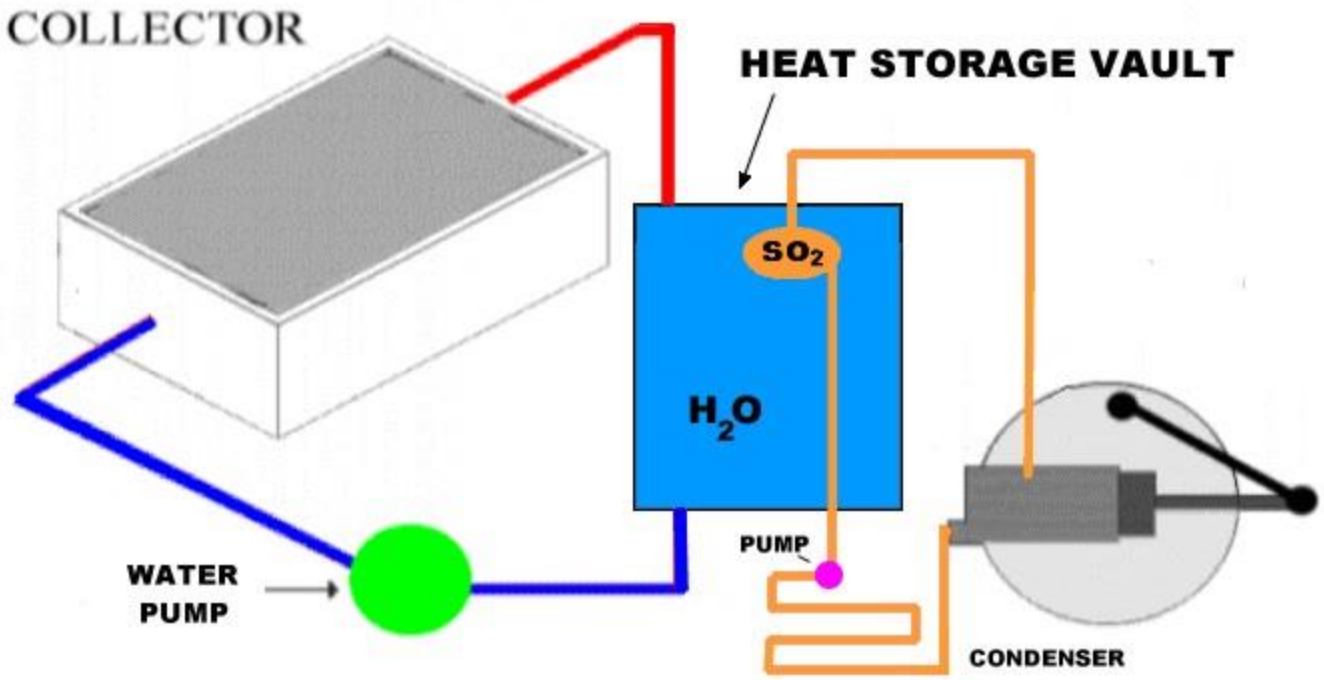


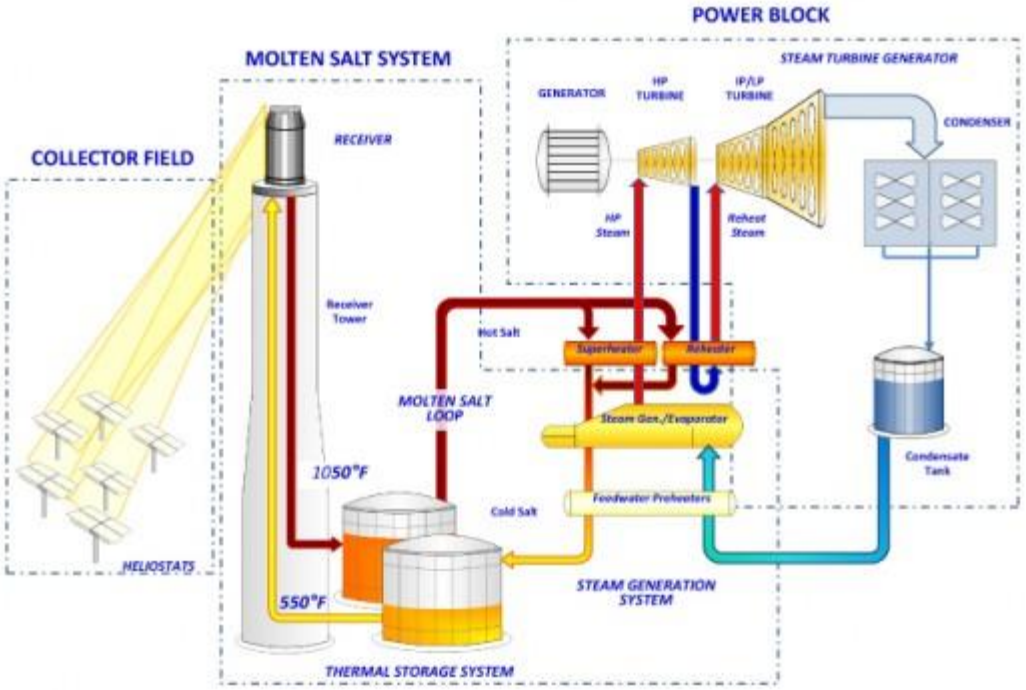
FIG. 11.— MOUCHOT'S SOLAR ENGINE. (FROM A FRENCH PRINT.)

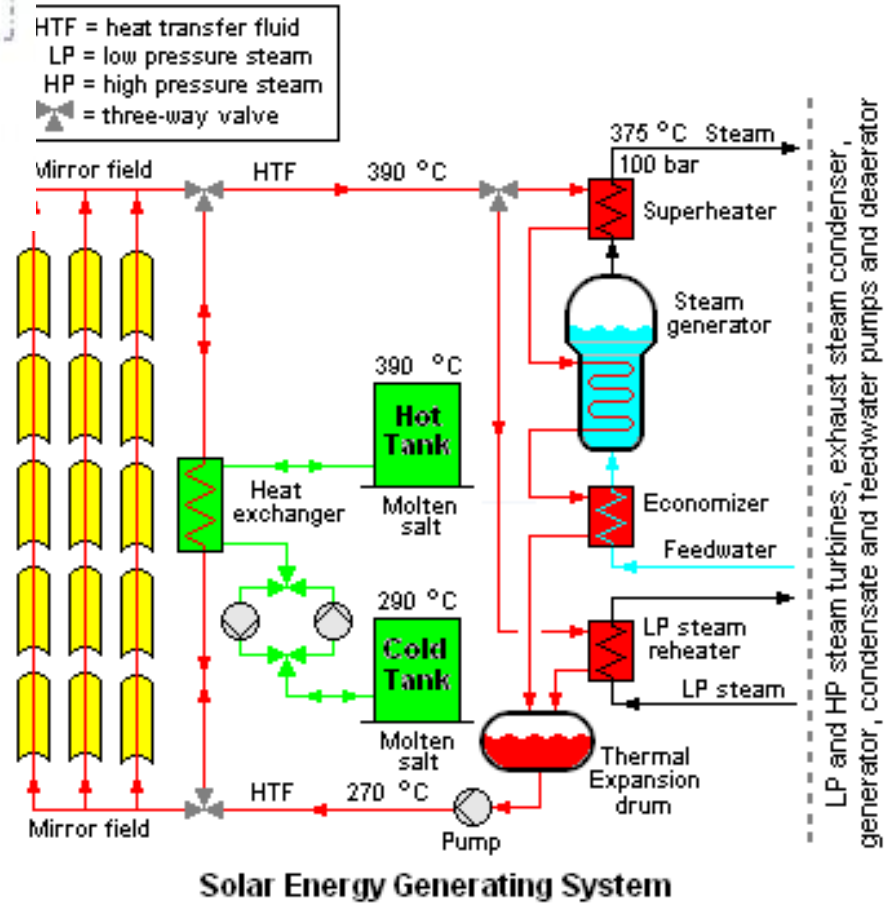



*Printing press driven by solar energy [1882]*

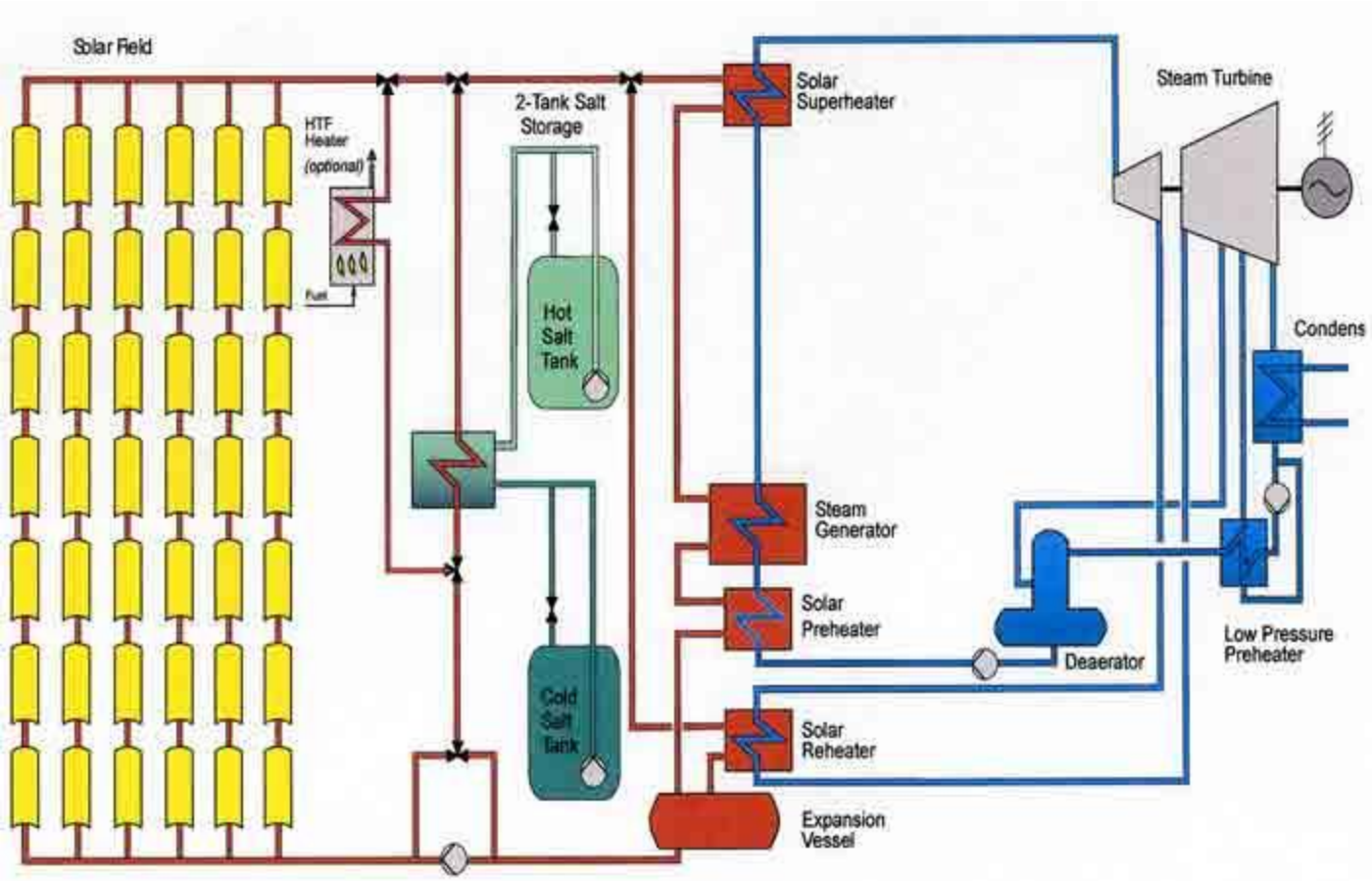
# Day & Night Generator 1904





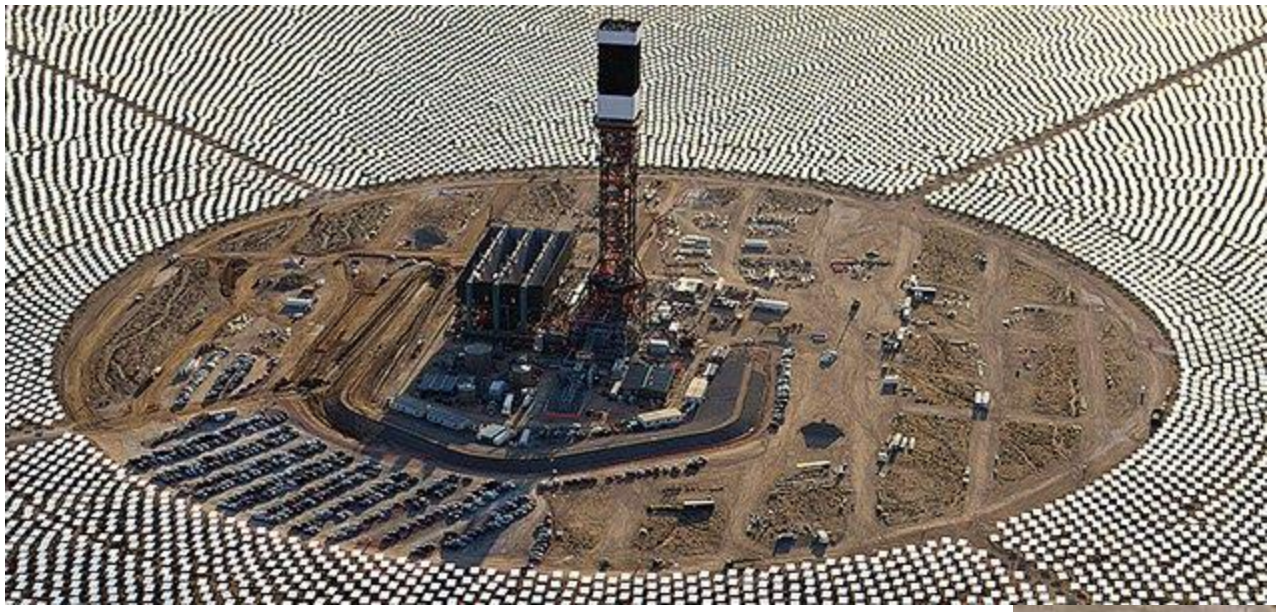




**Solar Energy Generating System**




Plant Schematic Diagram (with Thermal Storage)

# Mojave Desert CA.

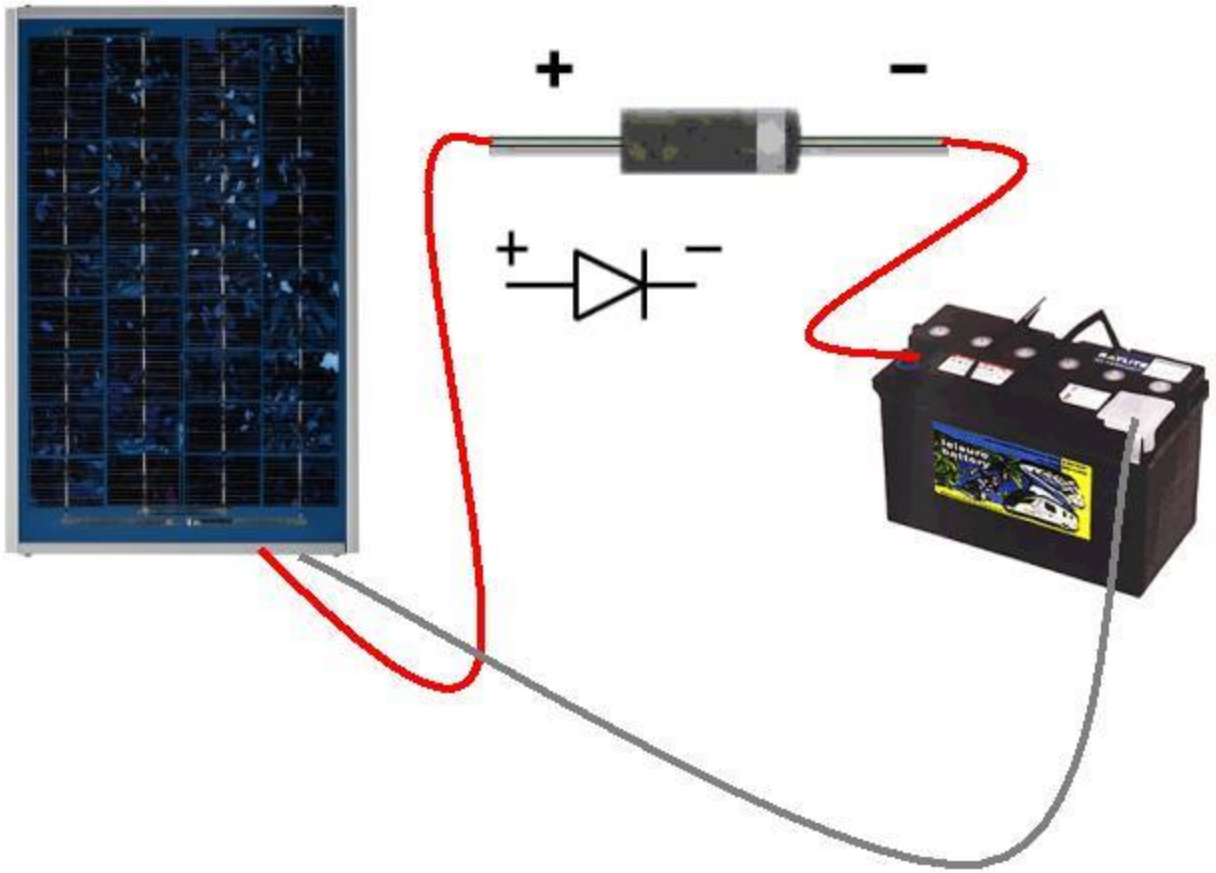


Power for 160,000 homes

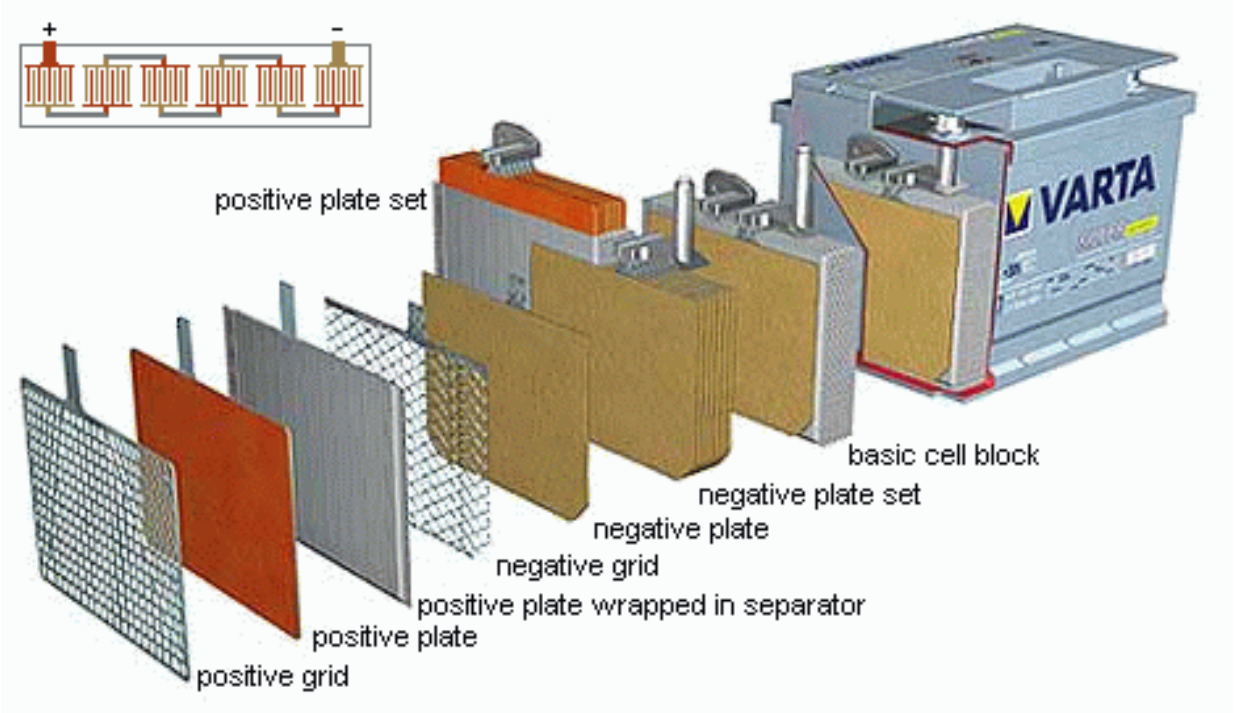
# Problems with solar electricity

- Solar panels use expensive semiconductor material to generate electricity directly from sunlight. Semiconductor factories need 'clean' manufacturing environments and are expensive to build & maintain.
- The efficiency of solar cells is only about 22%. The rest of the sunlight that strikes the panel is wasted as heat. More efficient photovoltaic cells have been discovered (up to 43% efficient these are still in their experimental phase and are expensive to manufacture).
- Solar electricity is expensive
- Dependent on availability of the sun

# Solar power with Battery's



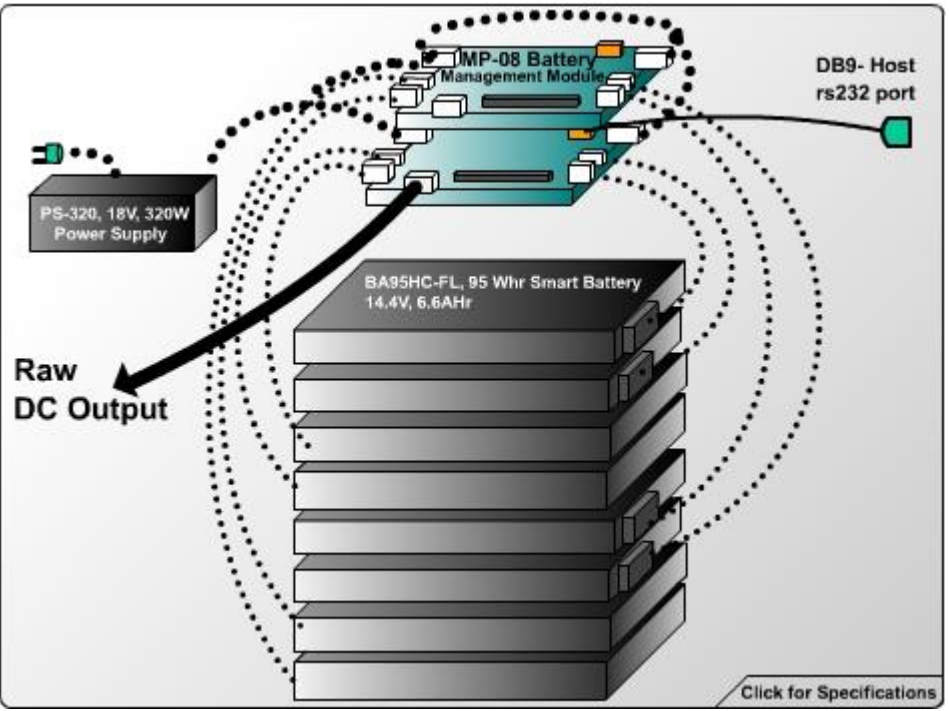
# Battery’s


+
-
positive plate set
basic cell block
negative plate set
negative plate
negative grid
positive plate wrapped in separator
positive plate
positive grid
VARTA

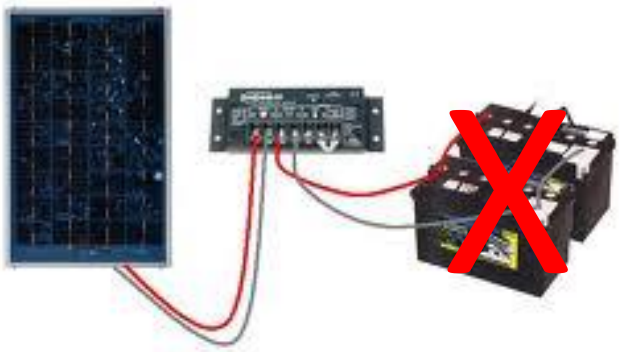
# Deep Cycle Battery

- Deep cycle battery can be deeply discharged over and over again which would often ruin a car battery very quickly.
- Deep cycle battery's use thicker plates.
- Can not provide as high a surge current as a standard car battery.

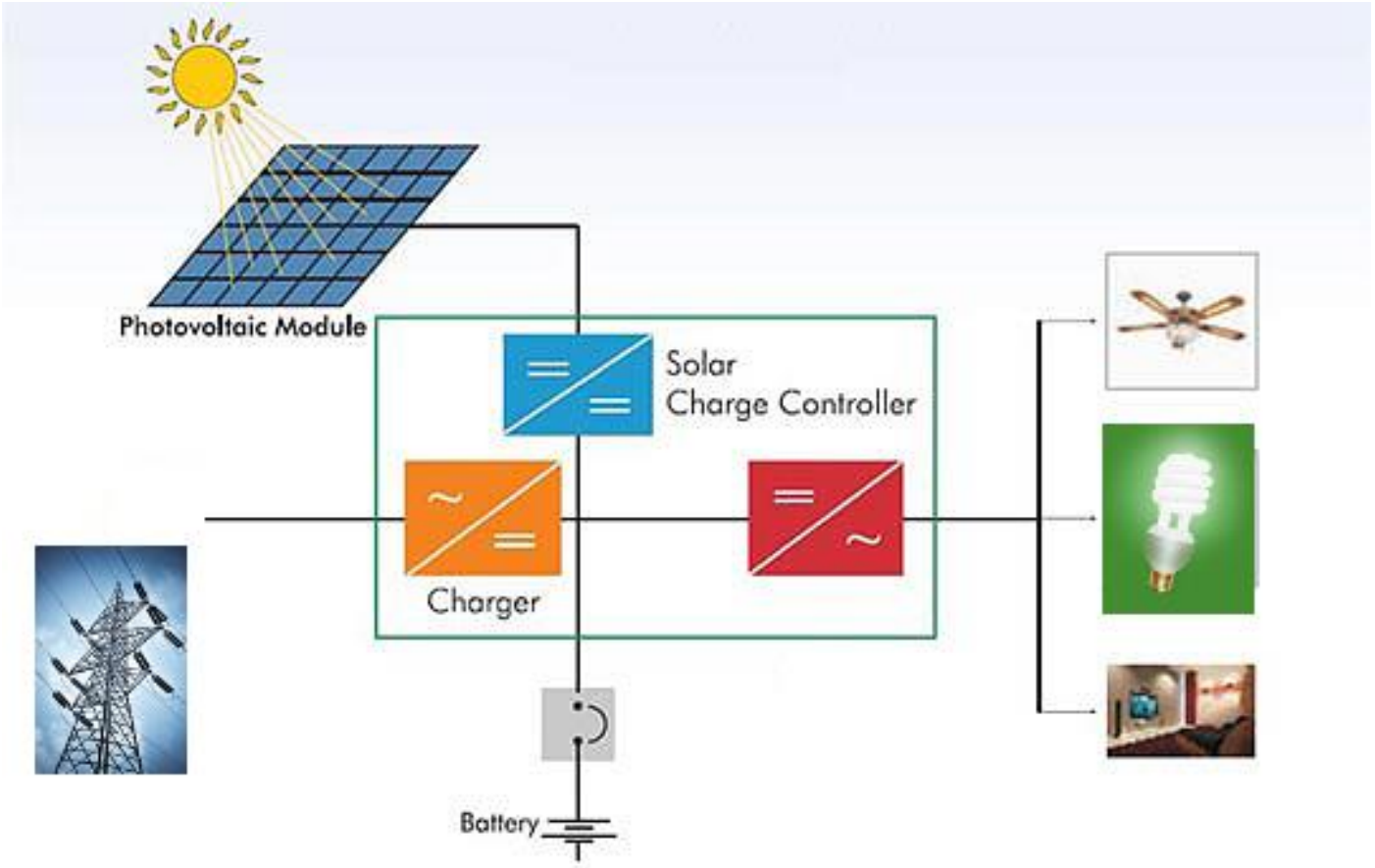
SMARTBATTERY®
LITHIUM ION TECHNOLOGY

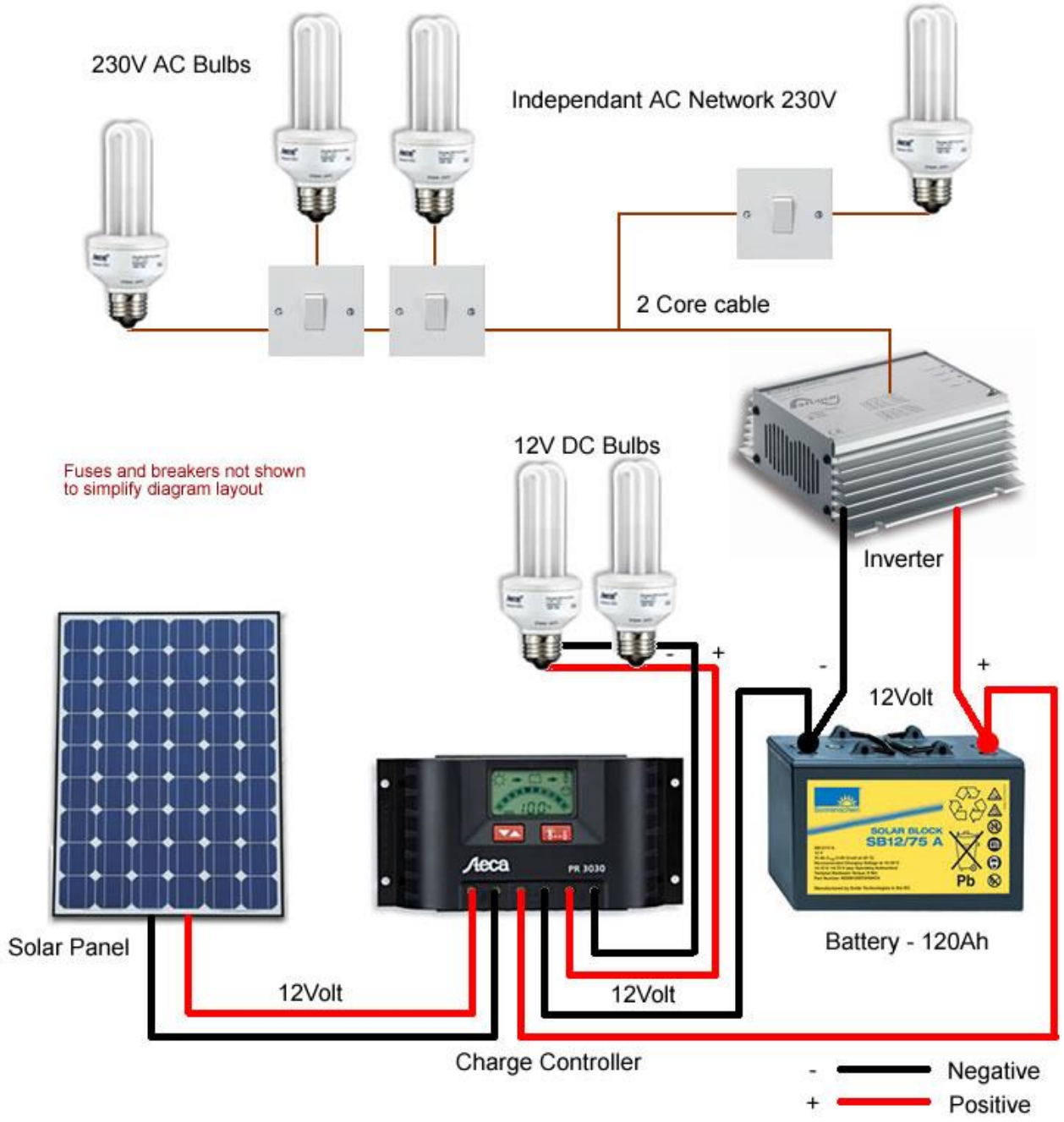


# The Battery Problem

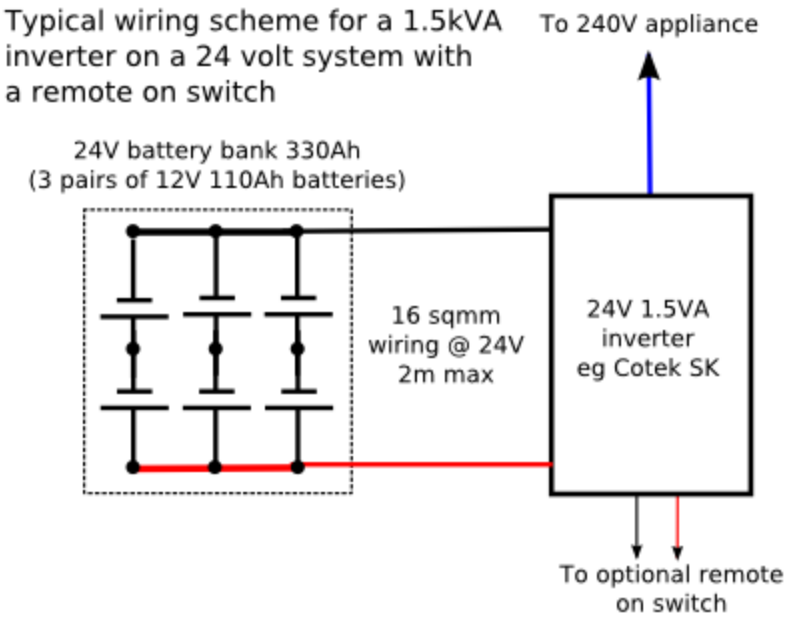


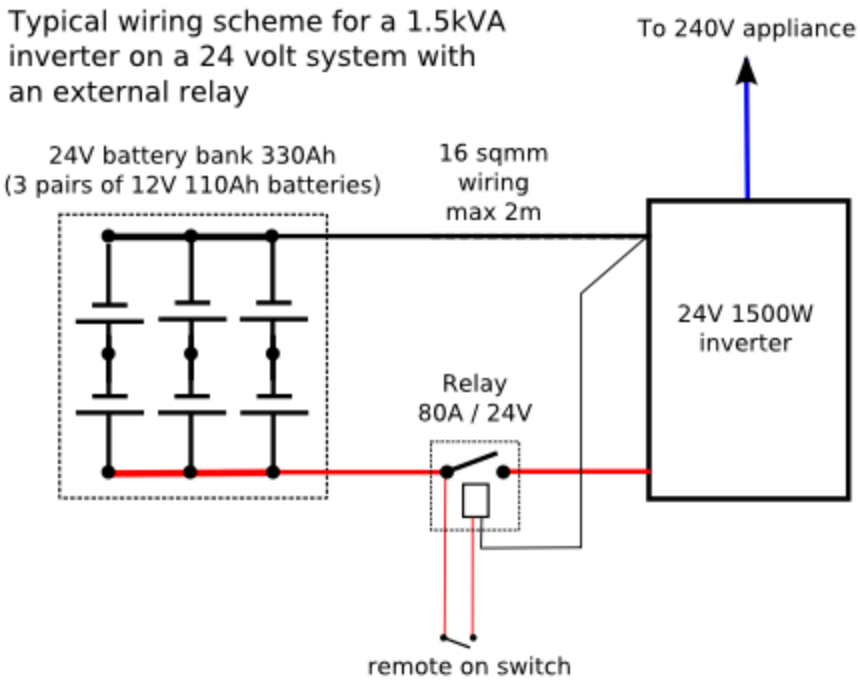
# Capacitor Battery


Photovoltaic Module
Solar
Charge Controller
Charger
Battery

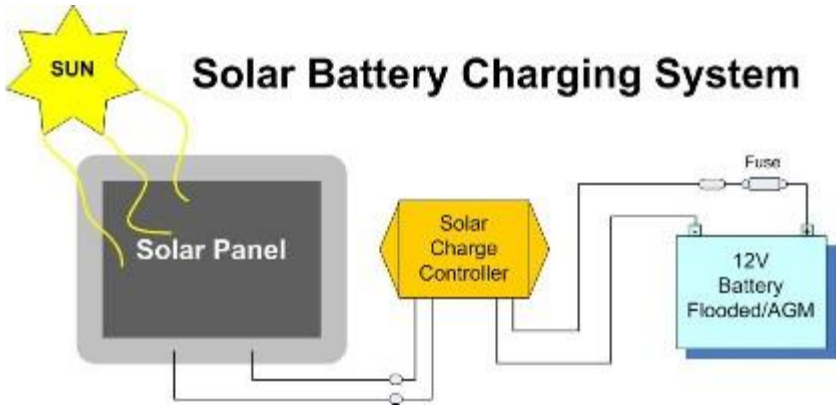

230V AC Bulbs
Independant AC Network 230V
2 Core cable
Fuses and breakers not shown
to simplify diagram layout
12V DC Bulbs
Inverter
12Volt
Solar Panel
Battery - 120Ah
12Volt
12Volt
Charge Controller
Negative
Positive

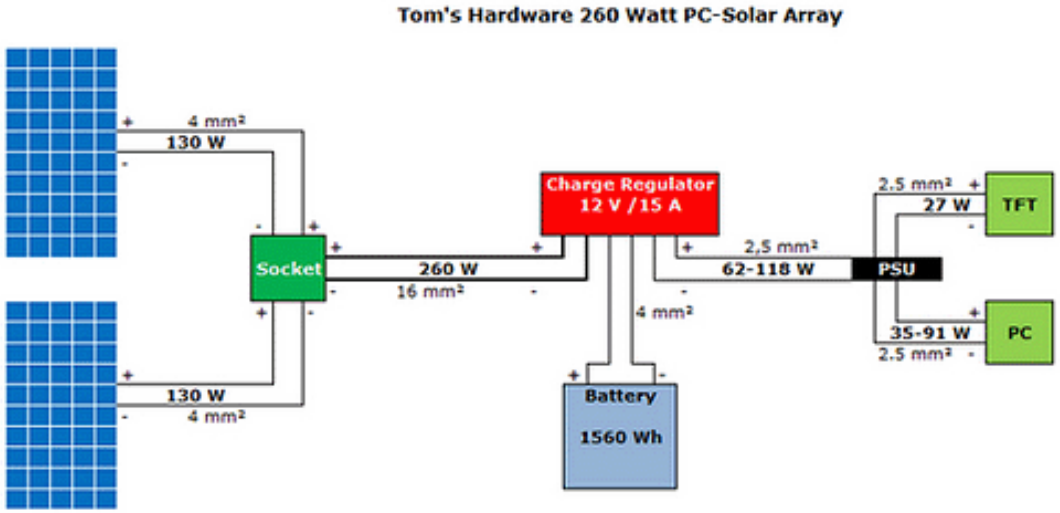
# Inverter


Typical wiring scheme for a 1.5kVA inverter on a 24 volt system with a remote on switch
To 240V appliance
24V battery bank 330Ah
(3 pairs of 12V 110Ah batteries)
16 sqmm
wiring @ 24V
2m max
24V 1.5VA
inverter
eg Cotek SK
To optional remote
on switch

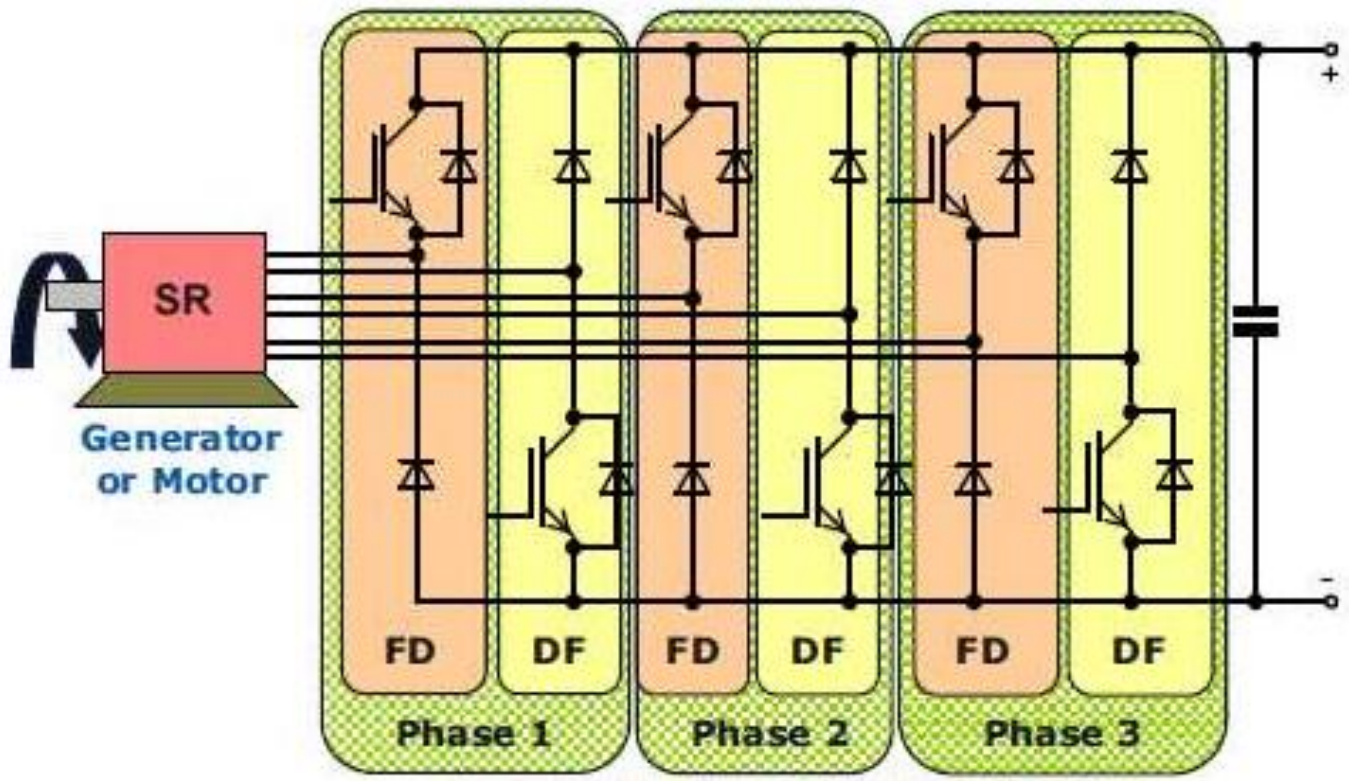

Typical wiring scheme for a 1.5kVA inverter on a 24 volt system with an external relay
To 240V appliance
24V battery bank 330Ah
(3 pairs of 12V 110Ah batteries)
16 sqmm
wiring
max 2m
24V 1500W
inverter
Relay
80A / 24V
remote on switch

# Battery Charger

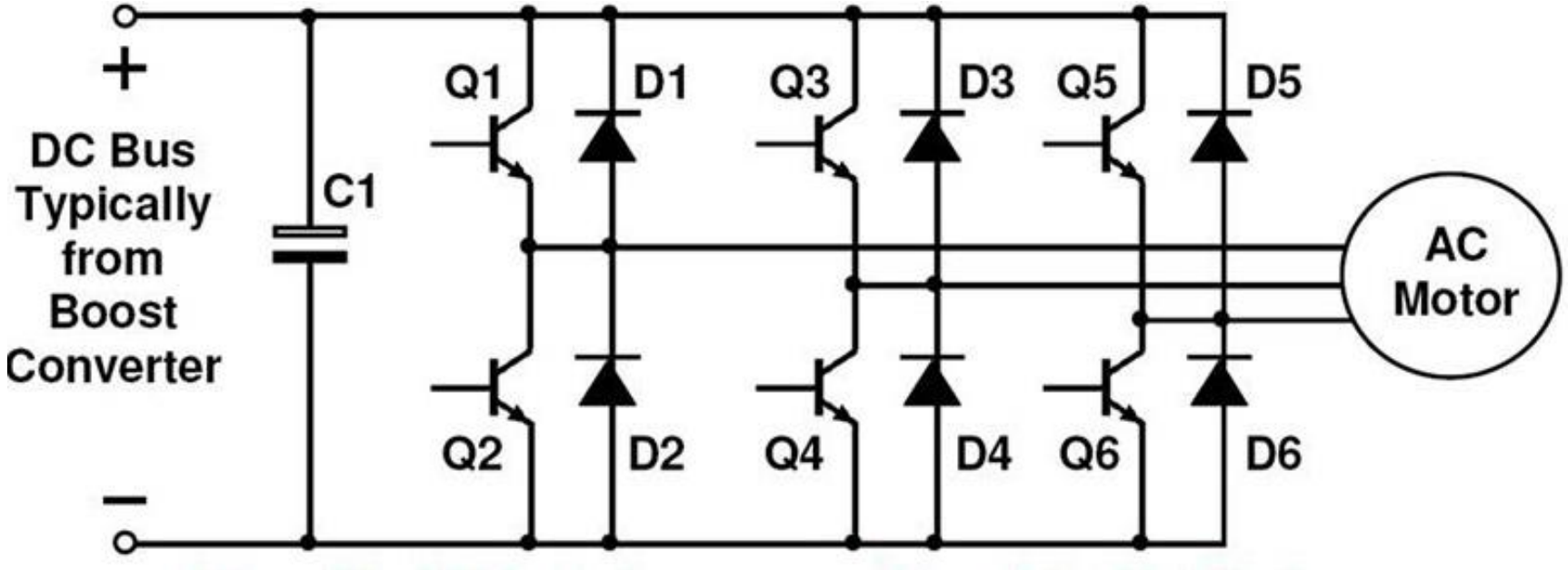


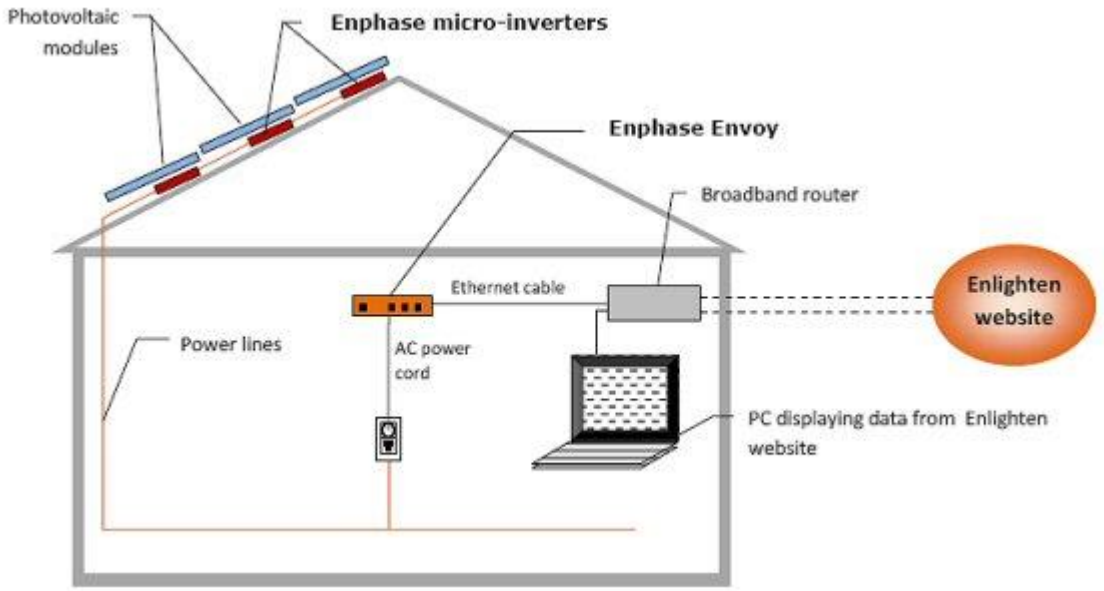
# Inverter 2



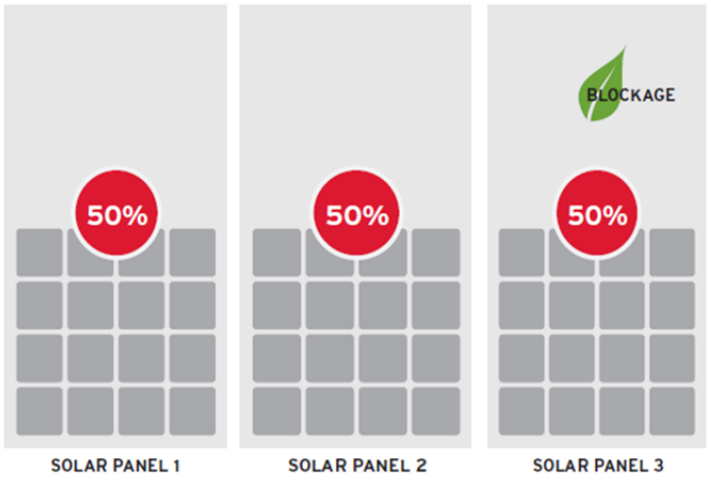
# Inverter 3


+
DC Bus
Typically
from
Boost
Converter
–
C1
Q1
D1
Q3
D3
Q5
D5
Q2
D2
Q4
D4
Q6
D6
AC
Motor

Enecsys micro-inverter
installed on the rack at the back
of each solar module
DC input to micro-inverter
AC output

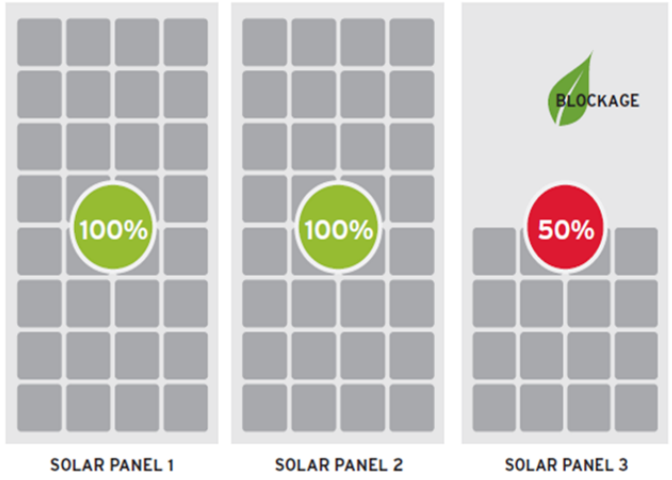



## Conventional Inverters




VS

## Micro Inverter



# The Future