Module 9.4
Photovoltaics

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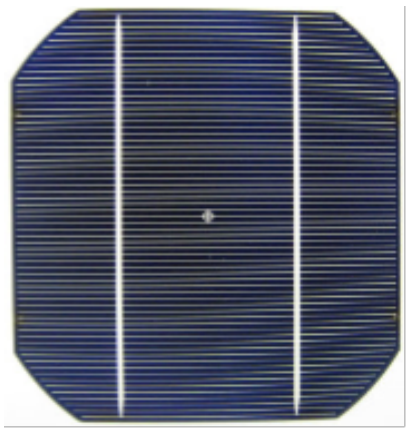
Module 9.4 Photovoltaics

- On completion of this module learners will be able to:
  - Describe the operating principle of a PV array
  - Quantify the output from a PV array

General principles:

- Solar Photovoltaic (PV) cell converts sunlight to electricity
- A number of cells electrically connected is called a module
- A number of modules electrically connected is called an array
- PV array produces direct current (DC) electricity
- This is converted to Alternating Current (AC) for use in the home or export to the electricity grid
- Ideal installation is at a tilt of 35-40 degrees and south facing

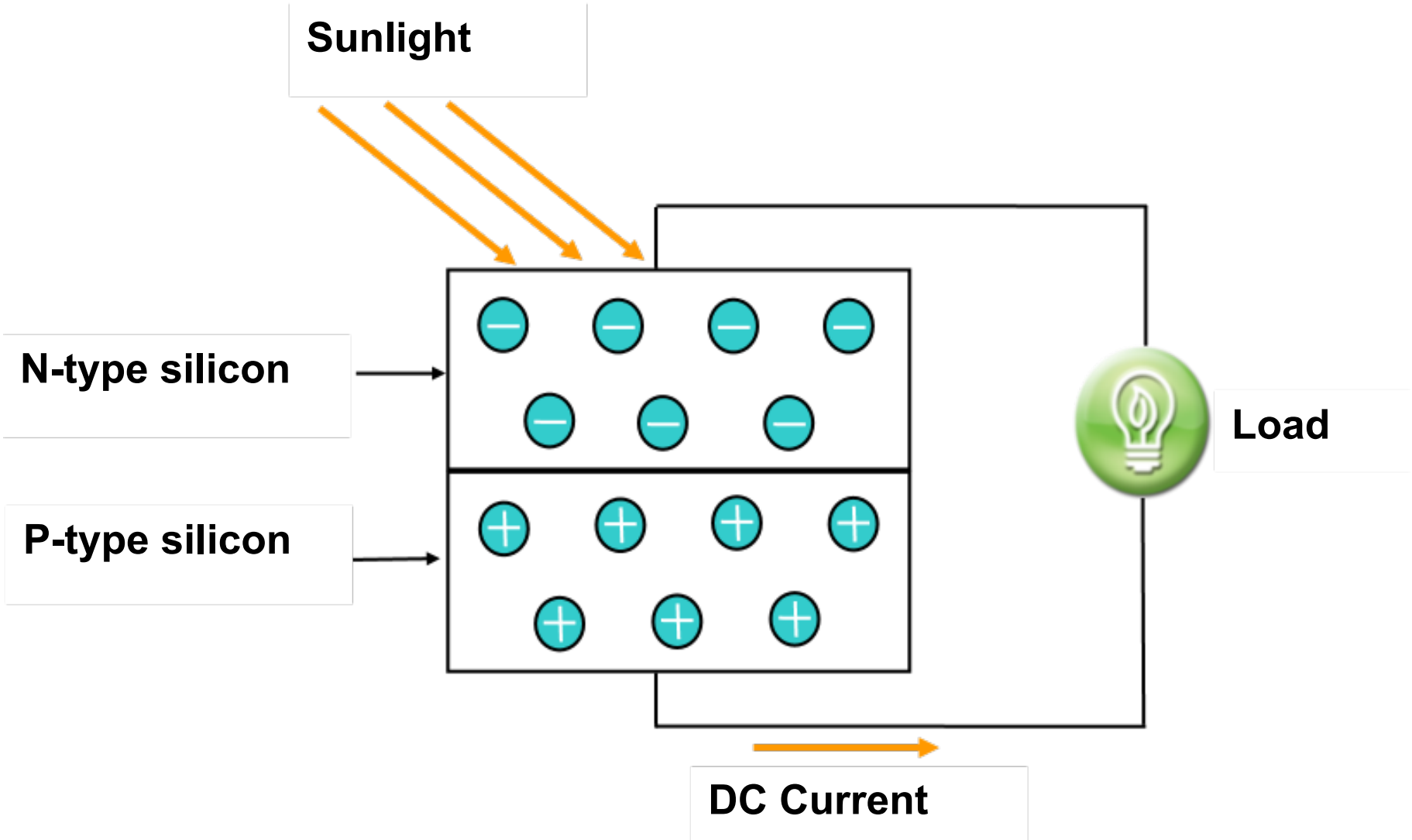


PV Cell → PV Module → PV array

Operation of a PV Cell

- Junction between two layers of dissimilar semi-conducting materials primarily silicon
- The first layer is “doped” with small amounts of boron – “p” layer positively charged due to shortage of electrons
- The second layer is “doped” with small amounts of phosphorous – “n” layer negatively charged due to excess of electrons

- Light provides sufficient energy to allow electrons to pass across the p-n junction between the two layers creating a potential difference or voltage
- If the cell is connected to a circuit then DC electrical current is produced.
- Cells linked together form a module
- Modules linked together form an array



PV Cell

There are 3 common types of silicon PV cells. These are listed below with typical efficiencies

Type	Efficiency %
Monocrystalline	15
Polycrystalline	12
Thin film	7

Output of a PV Array

- The output of an array can be quantified by its Peak Power
- Peak Power (kWp) of the PV module power corresponds to the rate of electricity generation in bright sunlight, formally defined as the output of the module under radiation of 1 kW/m² at 25° C
- A 1 kWp array would produce in Ireland and the UK about 700 to 800 kWh per annum

Output from a PV Array

- The electricity produced (E) by a PV module can be calculated from the product of its peak power (kWp) and the annual solar radiation (S) in kWh/m^2 for a given location
- E = kWp x S (kWh/annum)
- The peak power will be available on the module data sheet
- Annual solar radiation is available from meteorological offices

Annual Solar Radiation kWh/m^2 Ireland					
	Orientation				
Tilt	South	SE/SW	E/W	NE/NW	North
30	1074	1021	886	736	676
45	1072	1005	837	644	556
60	1027	956	778	574	463
vertical	822	773	628	461	380

SHARP

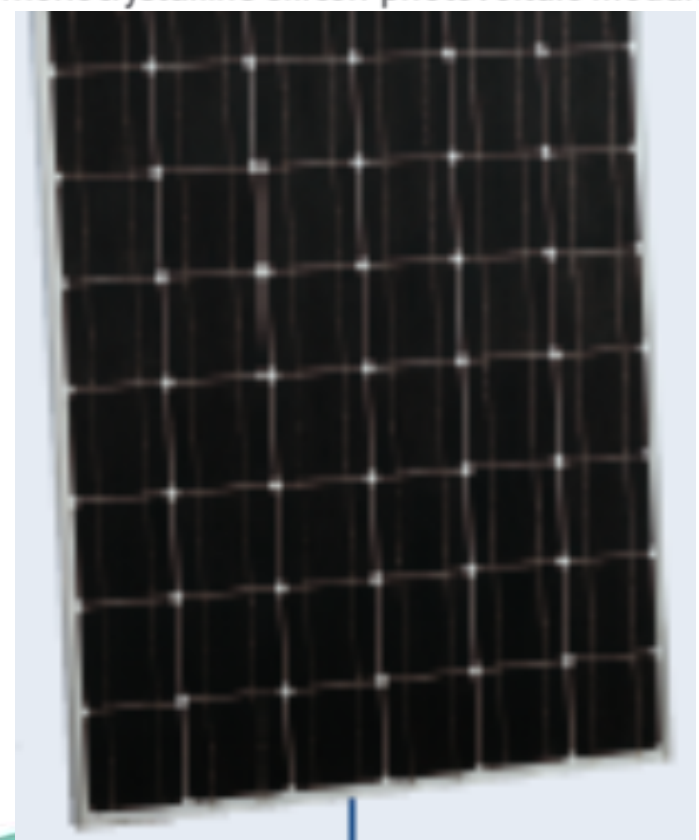
Example of manufacturer's data

NU Series (48 cells)

185 W | 180 W

175 W | 170 W

Monocrystalline silicon photovoltaic modules



Mechanical data

Cell	Monocrystalline (156.5 mm)^2 Sharp silicon solar cells
Quantity and wiring of cells	48 in series
Dimensions	1,318 x 994 x 46 mm (1.31 m^2)
Weight	16 kg
Connection type	Cable with plug connector (MC-3)

Electrical data

Made in EU		**NU-185 (E1)**
Made in Japan		**NU-S5 (E3E)**
Maximum power	P_{max}	185 W_p
Module efficiency	η_m	14.1

0.185 kWp per module

For example:

A 1kWp system installed in Ireland , south facing at 45 degree tilt

Electricity produced in kWh/annum is

E = kWp x S

= 1 * 1072

= 1072 kWh/annum

Allowing for approximately 80% efficiency in the system this gives 860 kWh per annum

How many modules and how much space will they take up?

- At 0.187 kWp 6 modules will deliver 1.1 kWp
- Each module is 1.318m high by 0.996m wide.
- An array of 3 modules wide by 2 modules high requires a roof space of approximately 3m wide by 2.64m high excluding any mounting frame

Connection options:

There are two main connection options

- Grid-connected
  - Supply excess power back into the grid
  - Draw power from the grid when demand in the home exceeds PV output
- Stand alone
  - Produce electricity independently of the electricity grid
  - Requires battery storage so that energy produced in the day can be used at evening/night

Suggested reading:

- Tipperary Institute, 2007. *ELREN Renewable Energy Training Manual* [online at www.elren.net], published by Carlow LEADER and Tipperary Institute, Ireland.

- Training for Renovated Energy Efficient Social housing,TREES, Section 1 Techniques 1.5 Photovoltaic systems, www.-cep.ensmp.fr/trees