Department of Mechanical Engineering,
Pulchowk campus, Institute of Engineering,
Tribhuvan University

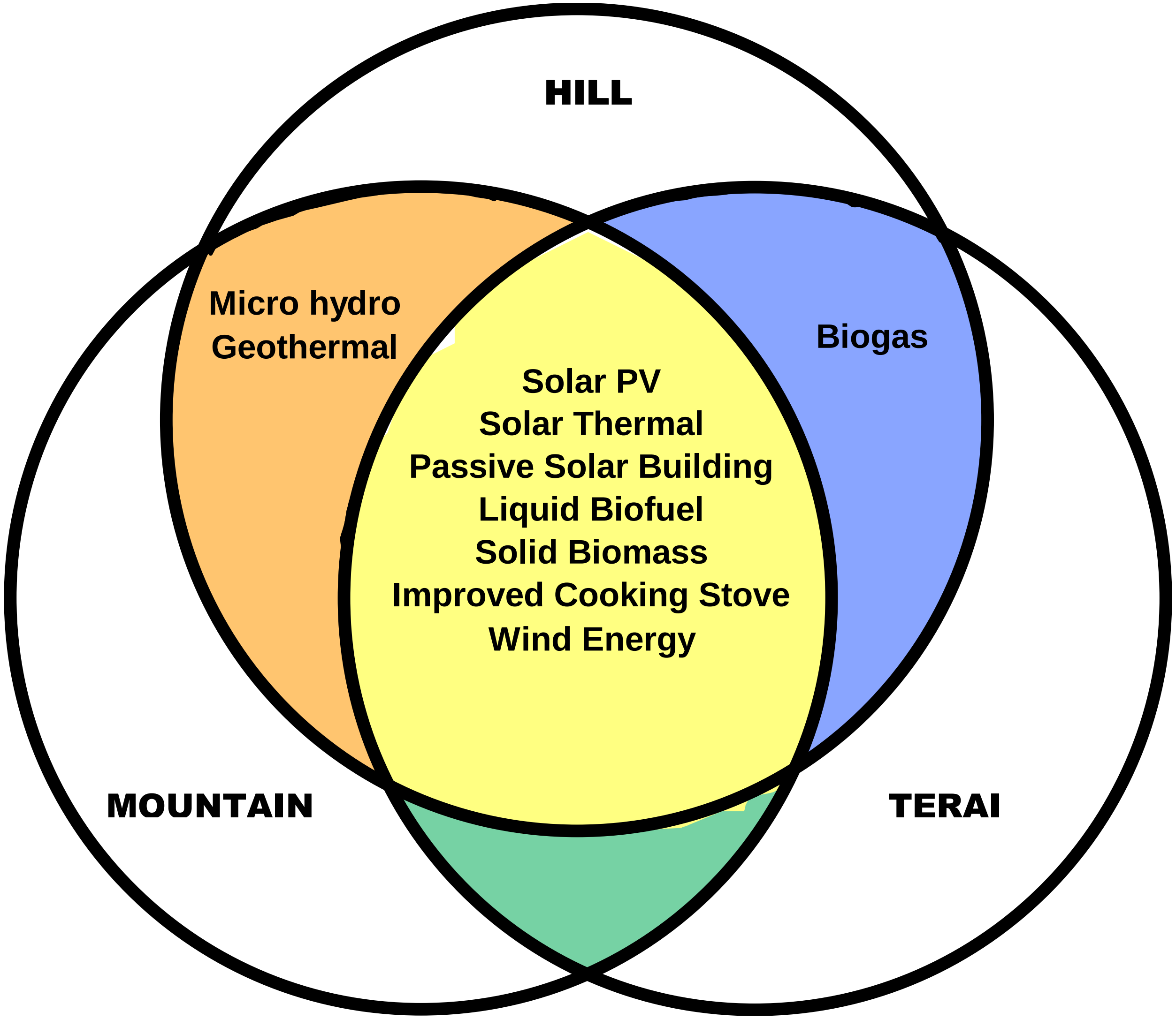
Sustainable Energy Technologies
(Session 5)

Solar Photovoltaic (PV) Technologies

Dr. Shree Raj Shakya
2016

Flash Back

Suitability of RETs by region



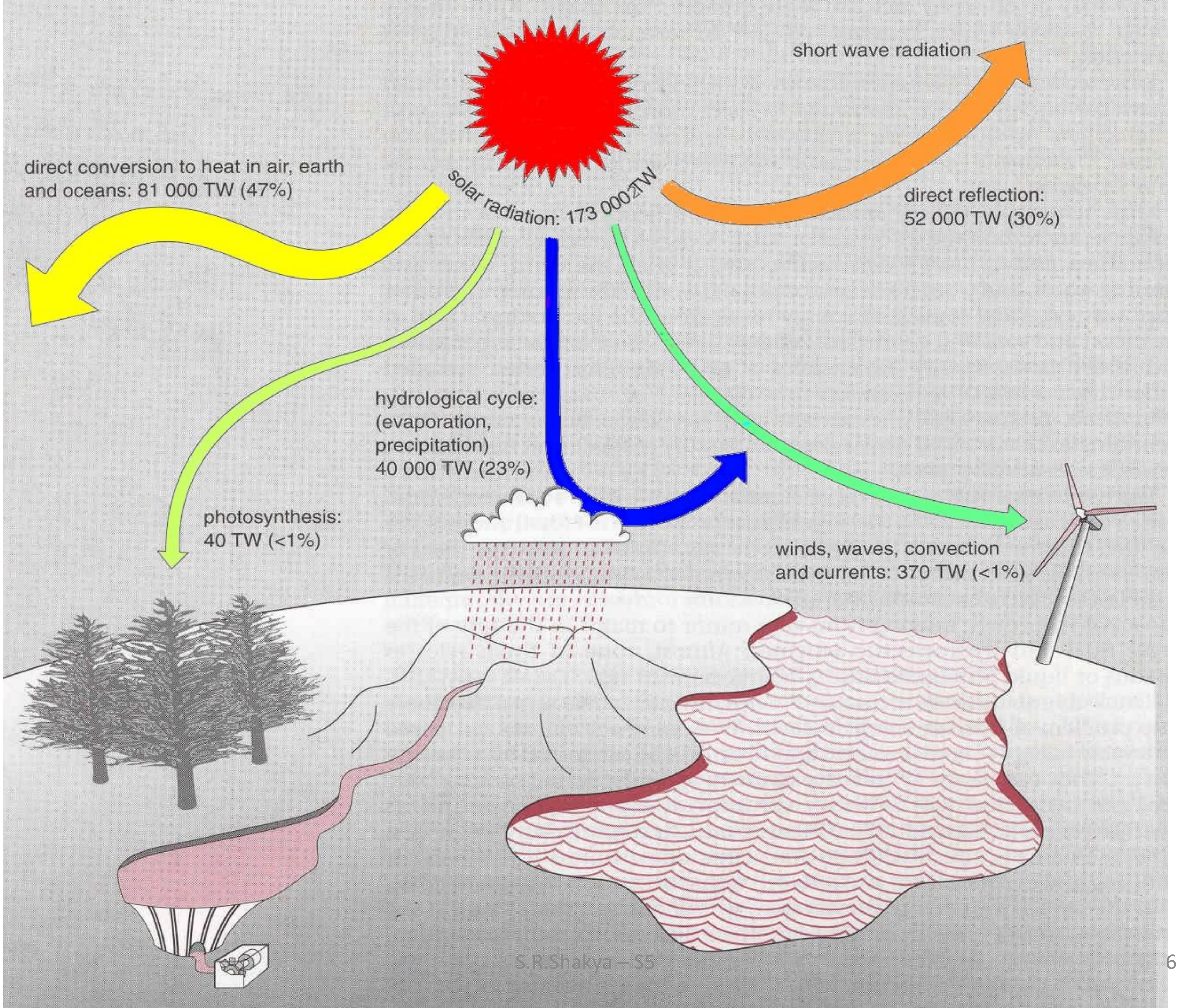
Solar Energy

- Thermal
- Photovoltaic

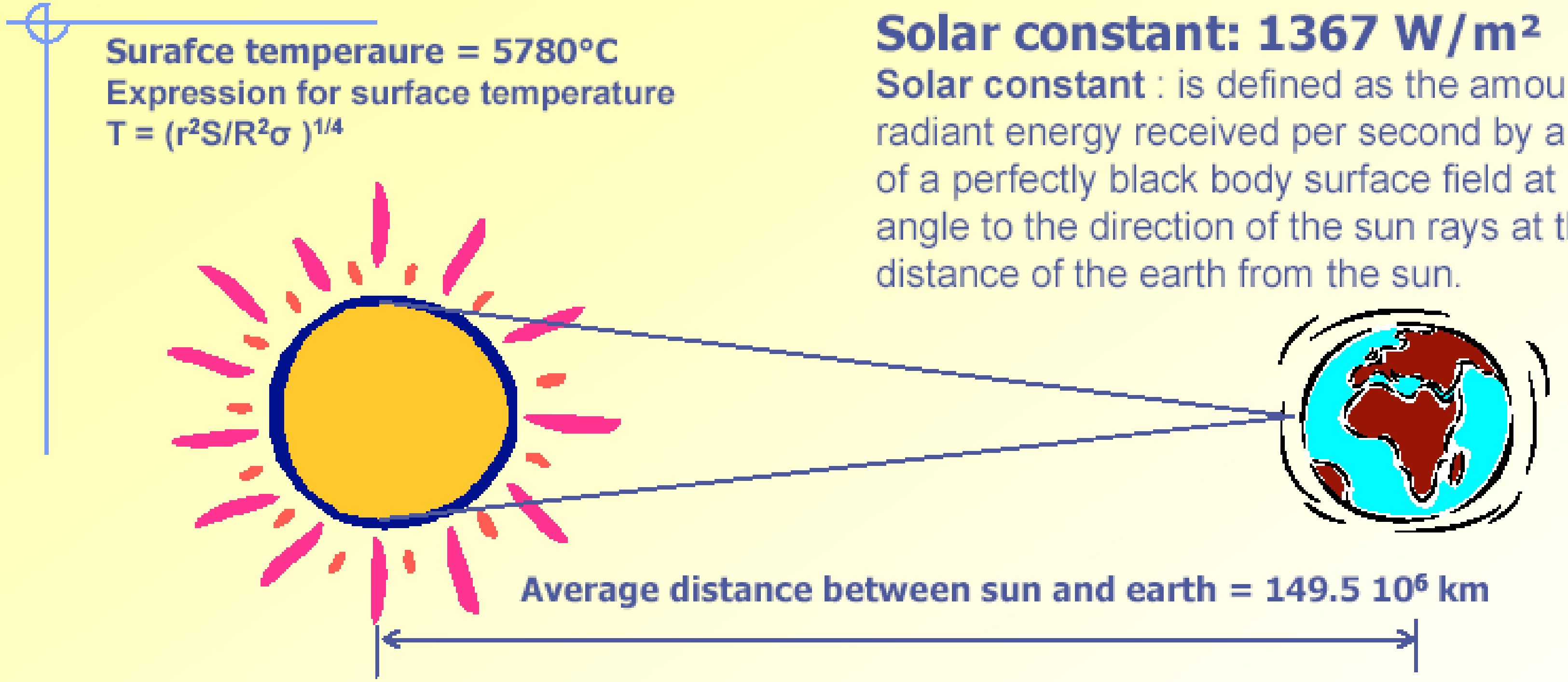
The SUN

Source of all Energy

Produces Energy from H_2


short wave radiation
direct conversion to heat in air, earth and oceans: 81 000 TW (47%)
solar radiation: 173 000 TW
direct reflection: 52 000 TW (30%)
hydrological cycle: (evaporation, precipitation) 40 000 TW (23%)
photosynthesis: 40 TW (<1%)
winds, waves, convection and currents: 370 TW (<1%)

Solar radiation: Some data

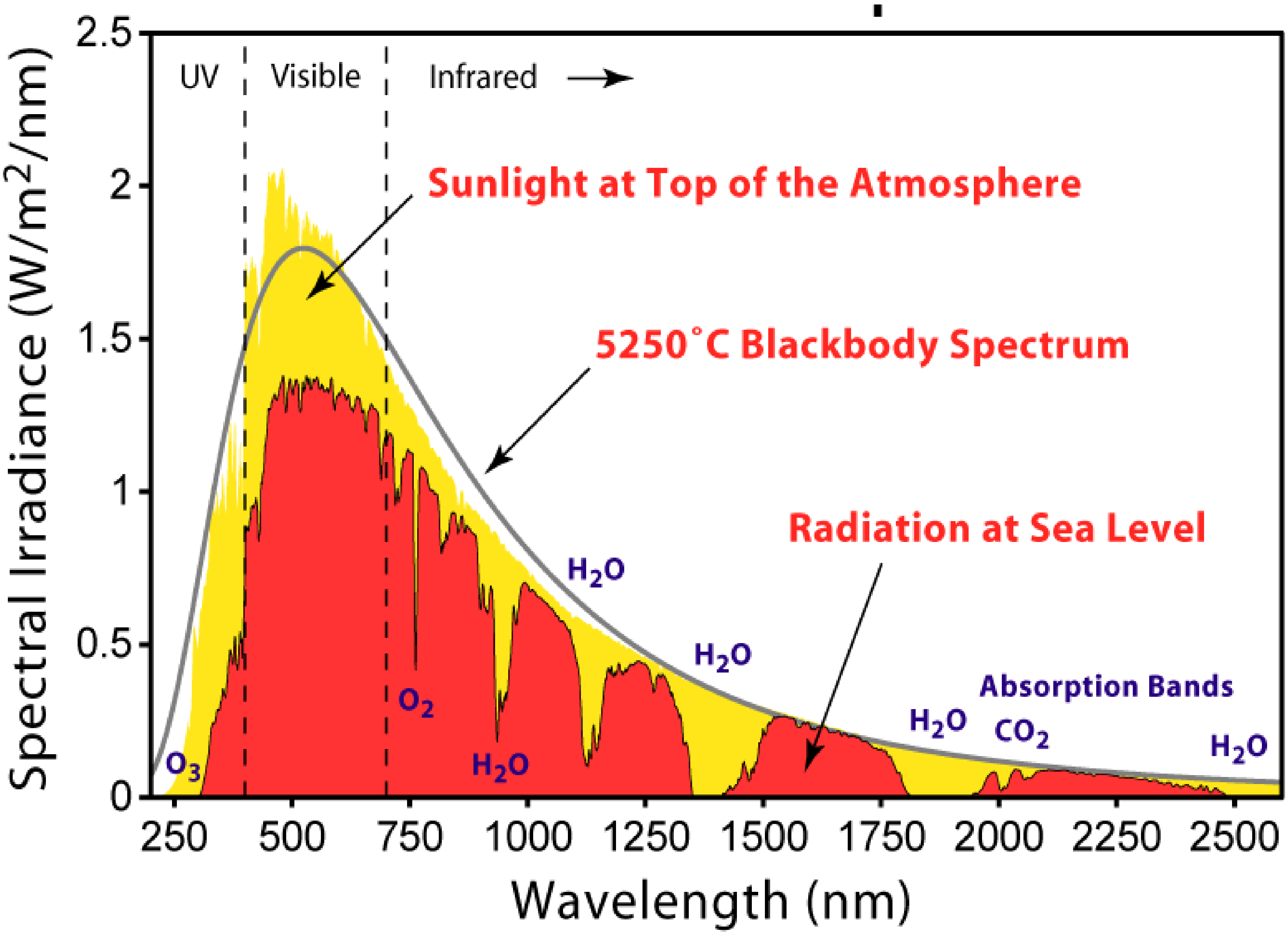


Solar constant: 1367 W/m²

Solar constant : is defined as the amount of radiant energy received per second by a unit area of a perfectly black body surface field at right angle to the direction of the sun rays at the mean distance of the earth from the sun.

Solar radiation on the surface comprises of :

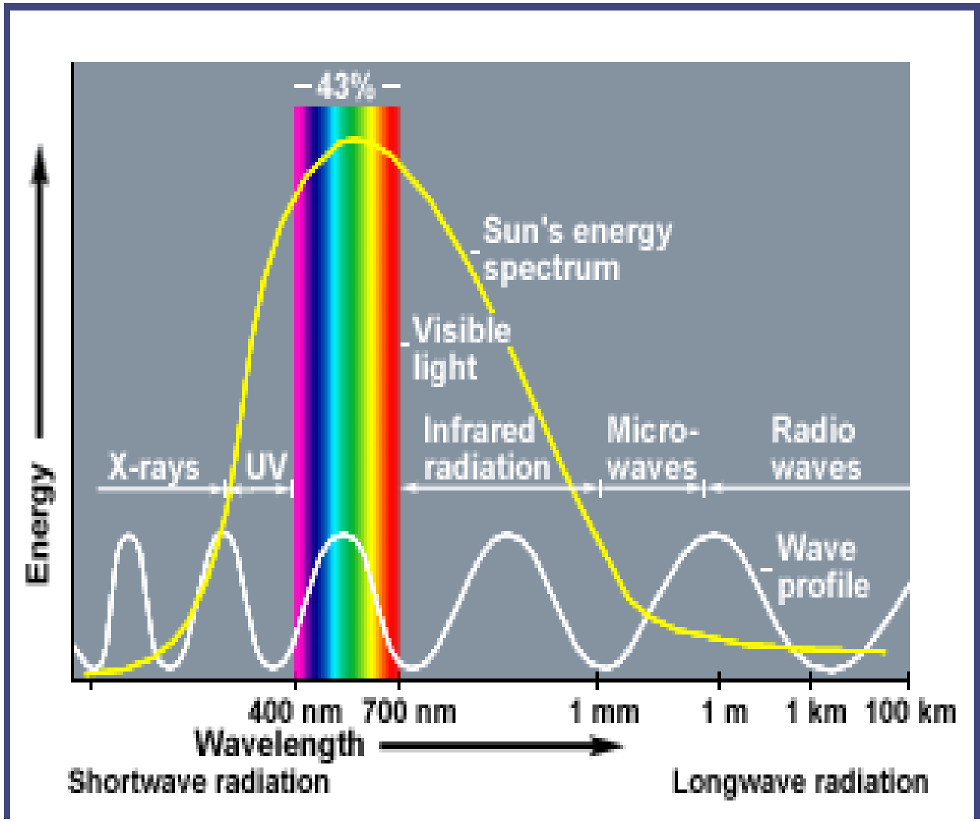
- **Direct radiation:** The solar radiation that reaches the surface of the earth without being diffused is called direct beam solar radiation.
- **Diffused radiation**: As sunlight passes through the atmosphere, some of it is absorbed, scattered, and reflected by air molecules, water vapour, clouds, dust, and pollutants from power plants, forest fires, and volcanoes. This is called diffuse solar radiation.
- **Global solar radiation:** The sum of the diffuse and direct solar radiation is called global solar radiation.



Solar Radiation Spectrum

What is Solar Energy?

- **Originates with the thermonuclear fusion reactions occurring in the sun.**
- **Represents the entire electromagnetic spectrum (visible light, infrared, ultraviolet, x-rays, and radio waves).**
- **The sun is, in effect, a continuous fusion reactor with its constituent gases as the 'containing vessel'**



retained by gravitational forces. The fusion reaction in which hydrogen (i.e. four protons) combines to form helium (i.e. one helium nucleus) accompanied by a 0.7 percent loss of mass and converted to energy is the source of energy in the SUN.

$4H^1 \rightarrow He^4 + 2\beta^+ + 2\nu + 25 \text{ MeV}$

$E = mc^2$

Solar Energy Potential in Nepal

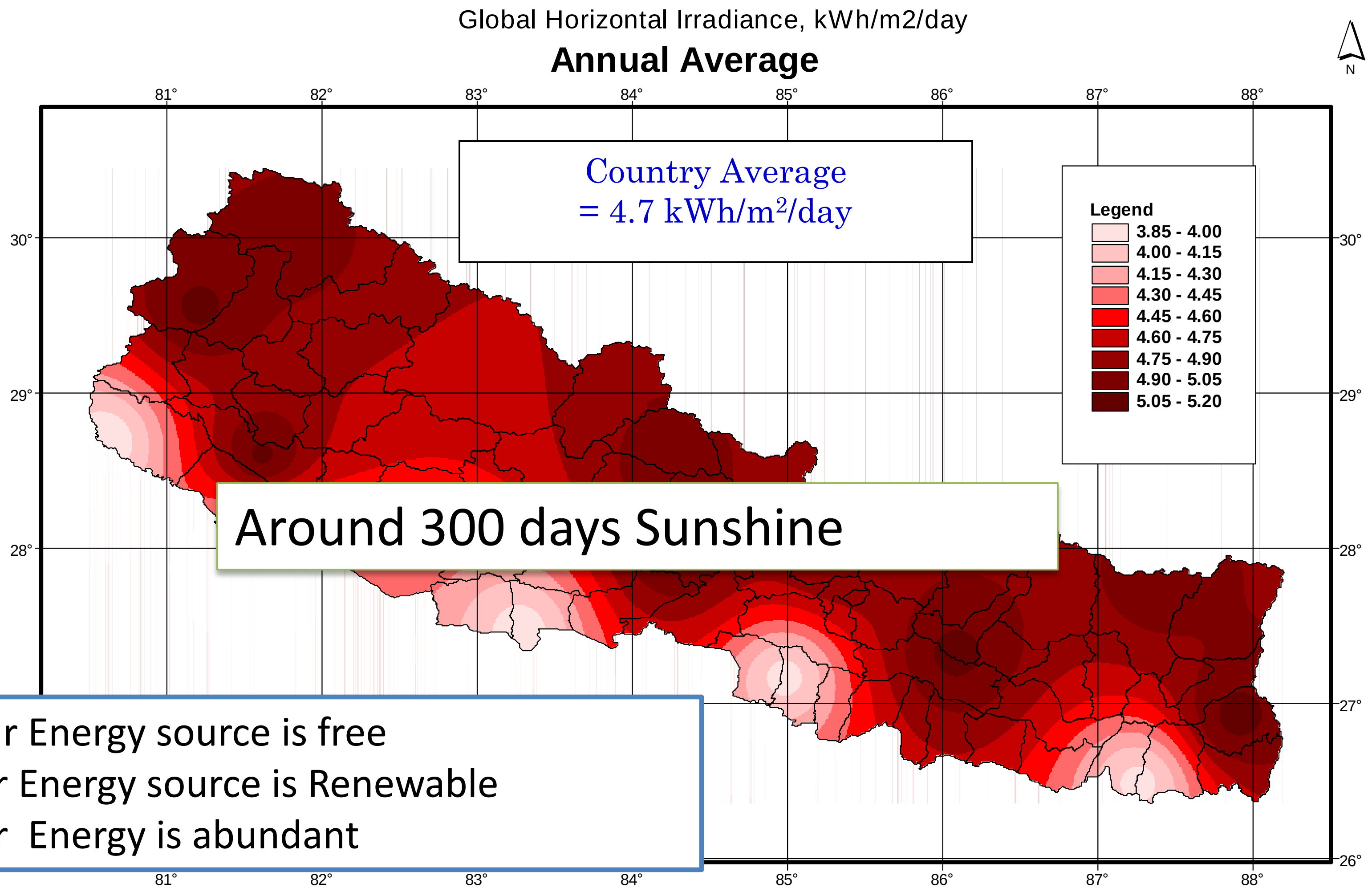


Figure 1

Country Average
= 4.7 kWh/m²/day

Around 300 days Sunshine

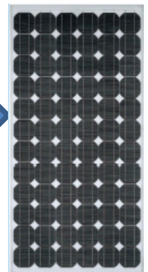
Solar Energy source is free
Solar Energy source is Renewable
Solar Energy is abundant

10% tapping- 34587535000 KWh/day

Solar Energy Technologies

Solar Photovoltaic Technology

Solar Light Energy



- Solar Home System
- Solar Tuki
- Institutional solar PV system
- Solar Water pumping system
- Building integrated solar PV Systems
- Electrical vehicle charging station

Solar Thermal Technology

Solar Heat Energy

- Solar Dryer
- Solar Cooker
- Solar Water Heater
- Solar room heating system
- Solar Refrigeration

Two Main Categories:

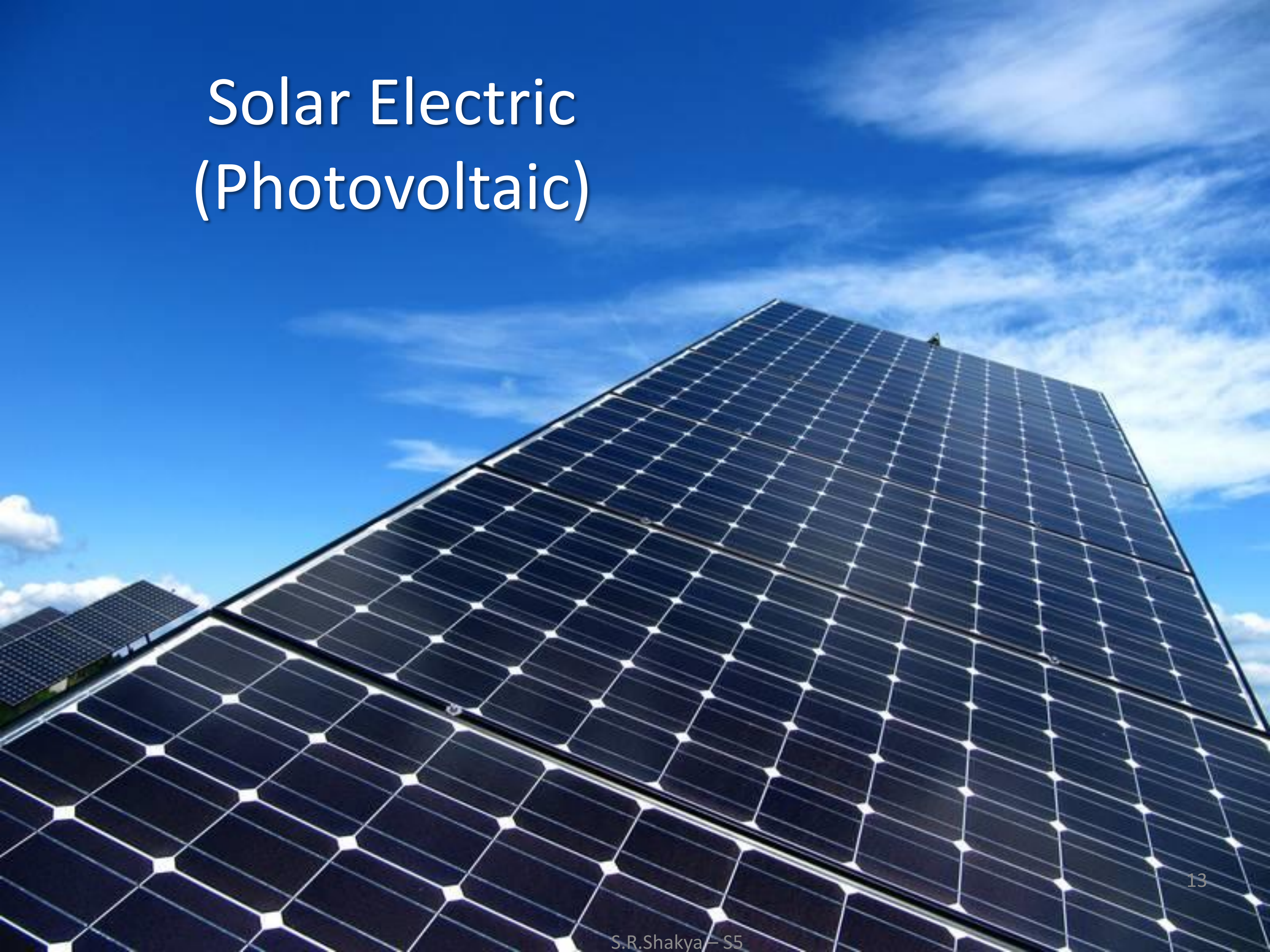
Solar Thermal

Water heating and cooking

Solar Photovoltaic (PV)

Electricity production

Solar Electric (Photovoltaic)

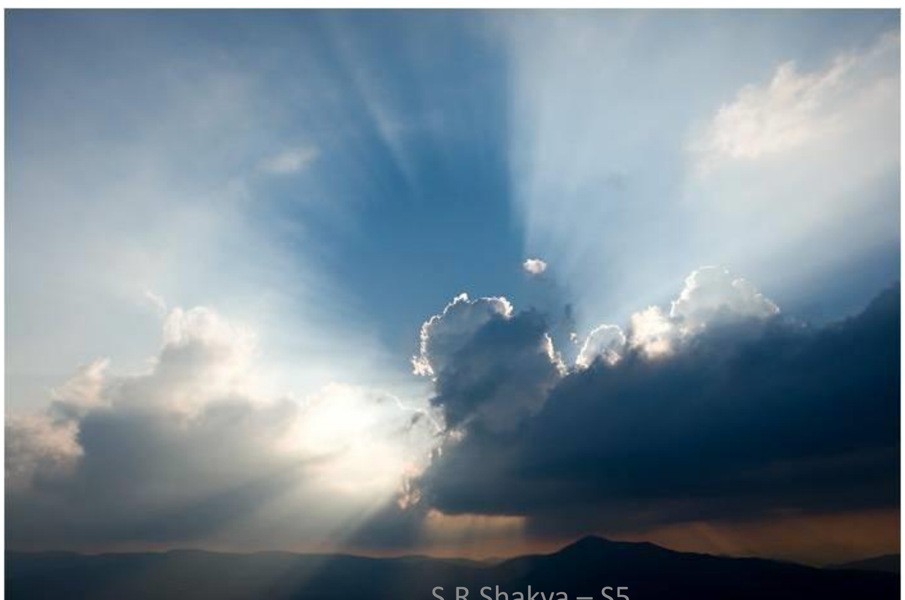


Solar Electric Systems

- **Photovoltaic (PV) systems convert light energy directly into electricity.**
- **Commonly known as “solar cells.”**
- **The simplest systems power the small calculators we use every day. More complicated systems will provide a large portion of the electricity in the near future.**
- PV represents one of the most promising means of maintaining our energy intensive standard of living while not contributing to global warming and pollution.

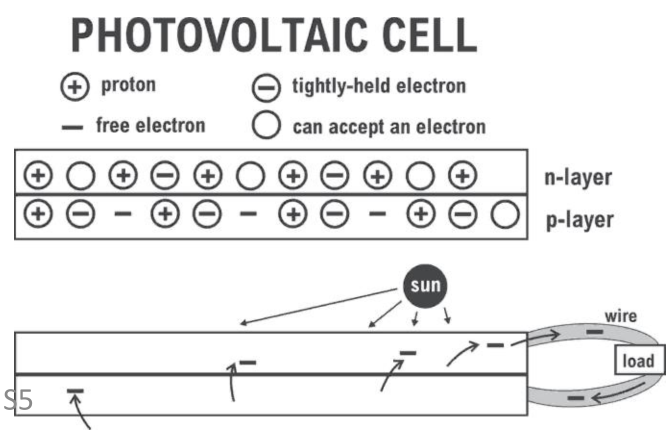
How Does it Work?

- Sunlight is composed of **photons**, or bundles of radiant energy. When photons strike a PV cell, they may be reflected or absorbed (transmitted through the cell). Only the absorbed photons generate electricity. When the photons are absorbed, the energy of the photons is transferred to electrons in the atoms of the solar cell.

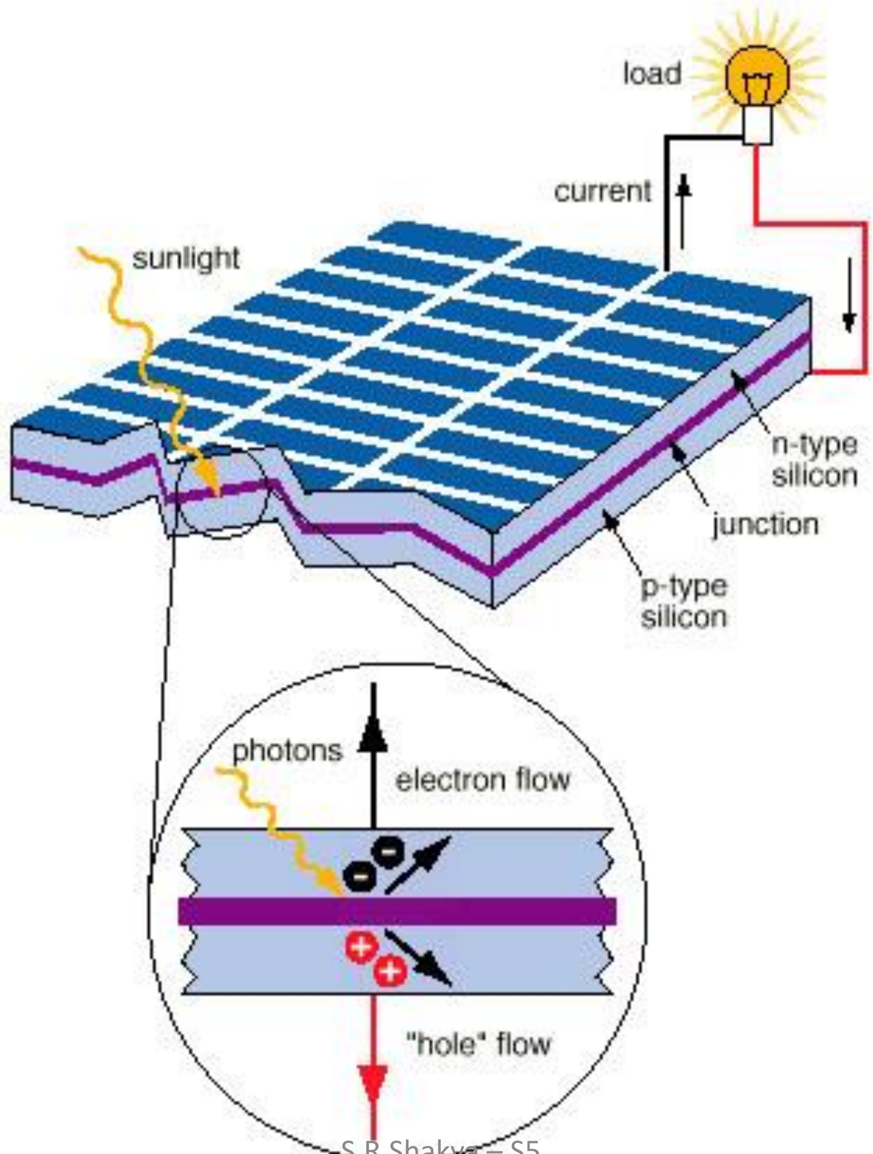


How Does it Work?

- Solar cells are usually made of two thin pieces of silicon, the substance that makes up sand and the second most common substance on earth.
- One piece of silicon has a small amount of boron added to it, which gives it a tendency to attract electrons. It is called the p-layer because of its positive tendency.
- The other piece of silicon has a small amount of phosphorous added to it, giving it an excess of free electrons. This is called the n-layer because it has a tendency to give up negatively charged electrons.



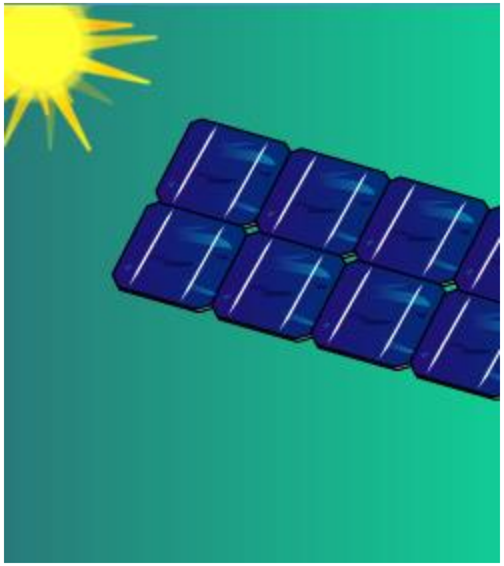
How Does it Work?

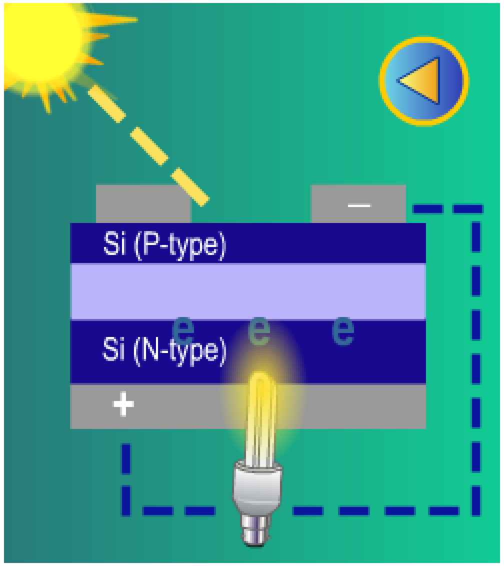


Helpful PV Animations

http://www1.eere.energy.gov/solar/animations.html

http://www.managenergy.net/kidscorner/animations/solar_an.html



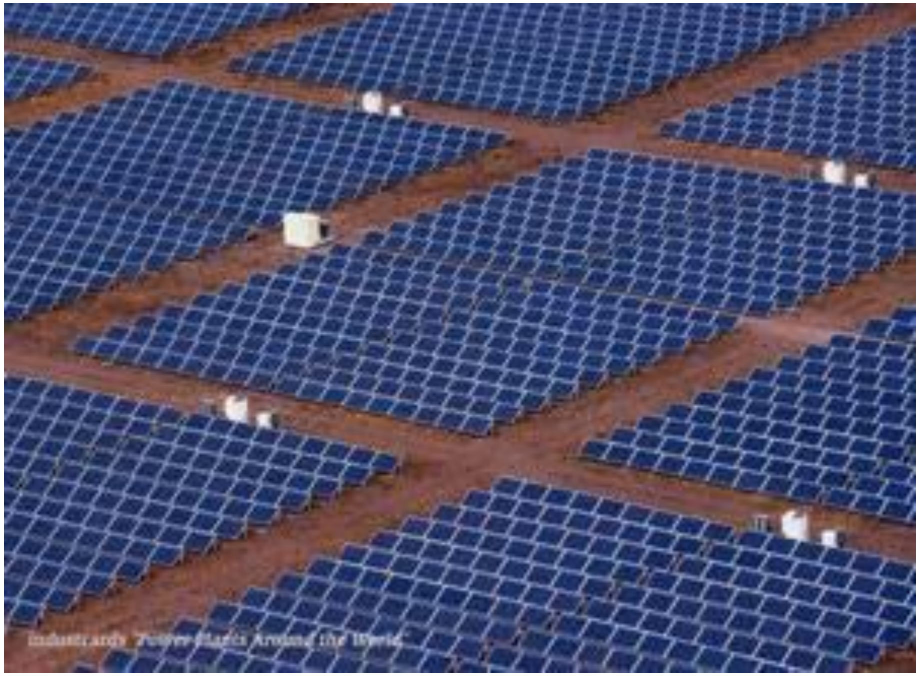


Best Place For Solar Panels?

- South Facing roof, adequate space
- No shading (time of year, future tree growth)
- Roof structure, condition

‘Solar roofs’

Large Scale PV Power Plants



Prescott Airport
Location: AZ
Operator: Arizona Public Service
Configuration: 1,450 kWp

SGS Solar
Location: AZ
Operator: Tucson Electric Power Co
Configuration: 3,200 kWp

Centralized Wind-Solar Hybrid System

- **In hybrid energy systems more than a single source of energy supplies the electricity.**
- **Wind and Solar compliment one another**

Solar Concentrators

- These 20-kW Solar Systems dishes dwarf visitors in Alice Springs, Australia.
- The concentrators use an array of mirrors to focus sunlight onto high-efficiency solar cells.
- Four supports hold the cells in front of the mirrors
- The supports also supply cooling water and electrical connections

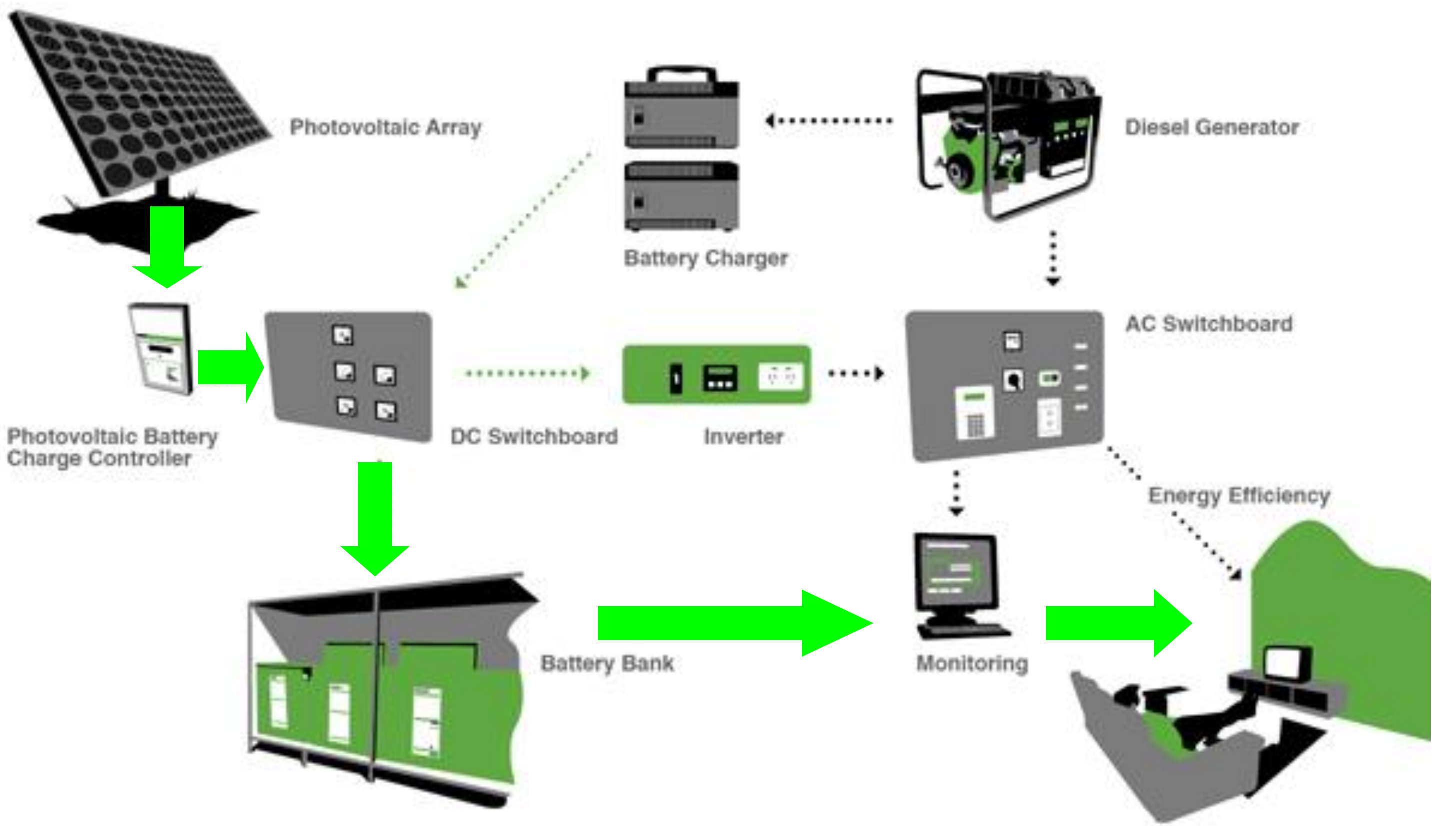
How Does the Color/Wavelength of Light Affect PV Efficiency?

- Test 5-8 colors using different backgrounds on PowerPoint Slides
  - Purple
  - Blue
  - Green
  - Yellow
  - Orange
  - Red
  - White

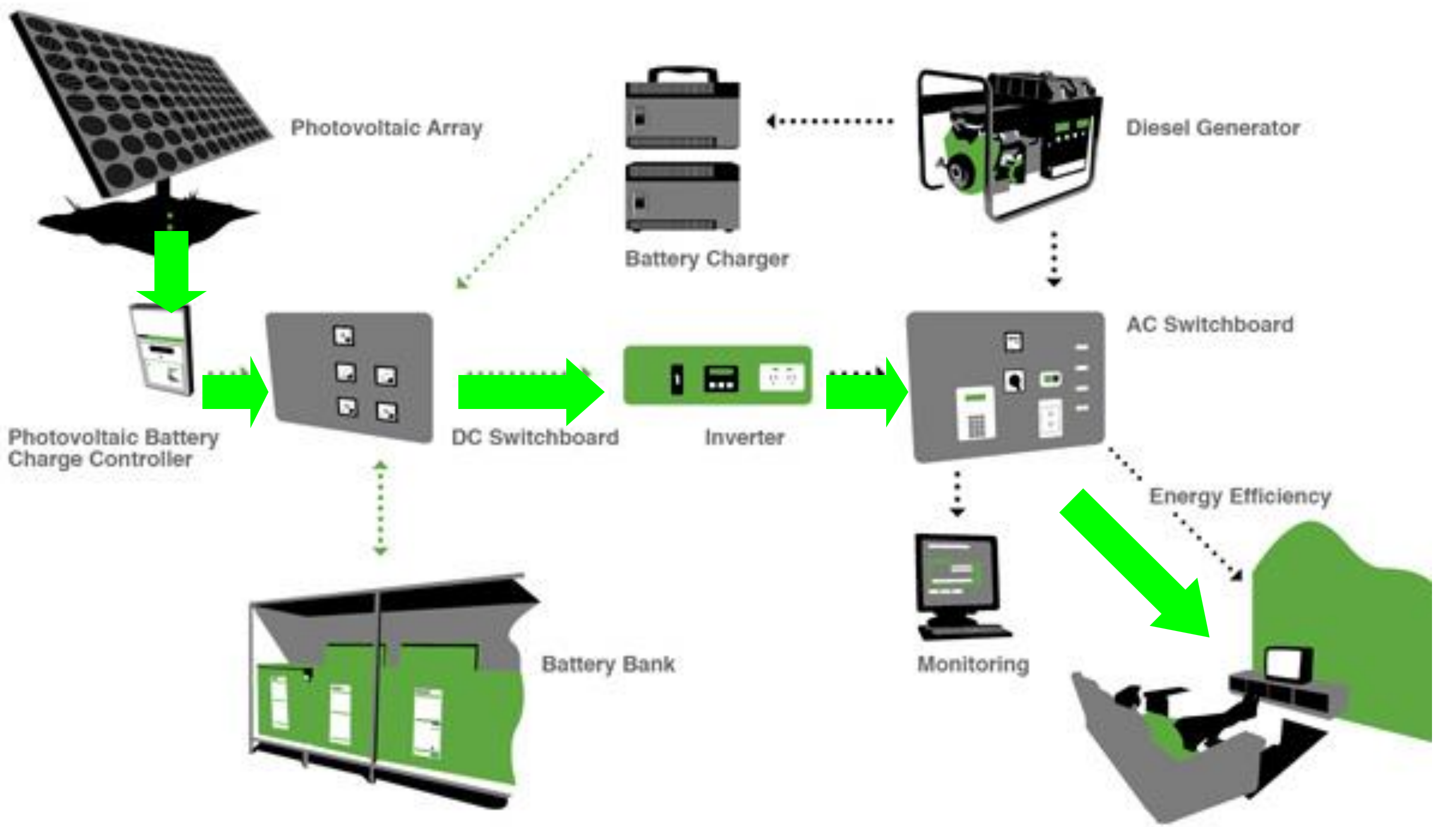
Photovoltaic (PV) Terminology

- Cell < Module < Panel < Array
- Battery – stores DC energy
- Controller – senses battery voltage and regulates charging
- Inverter – converts direct current (DC) energy to alternating current (AC) energy
- Loads – anything that consumes energy

Systems with DC Loads



Systems with AC loads

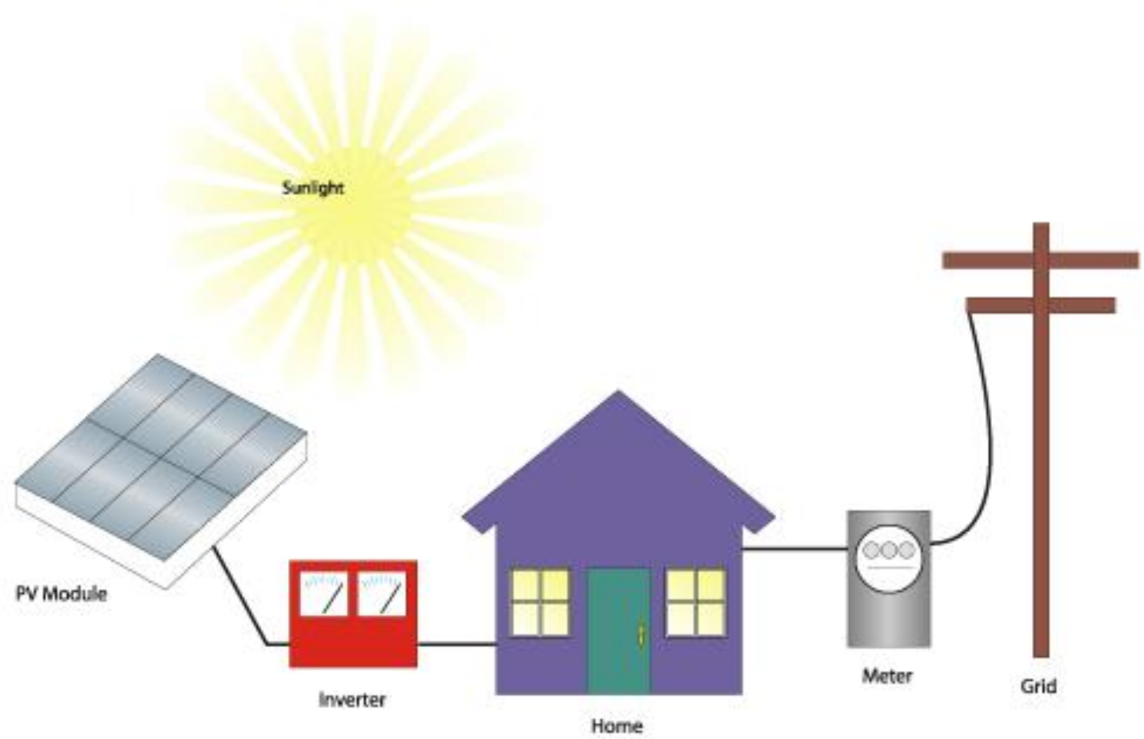


AC System Options

- Combined AC and DC loads
- Hybrid system with back up generator
- Grid tied utility interactive system without batteries
- Grid tied interactive with battery backup

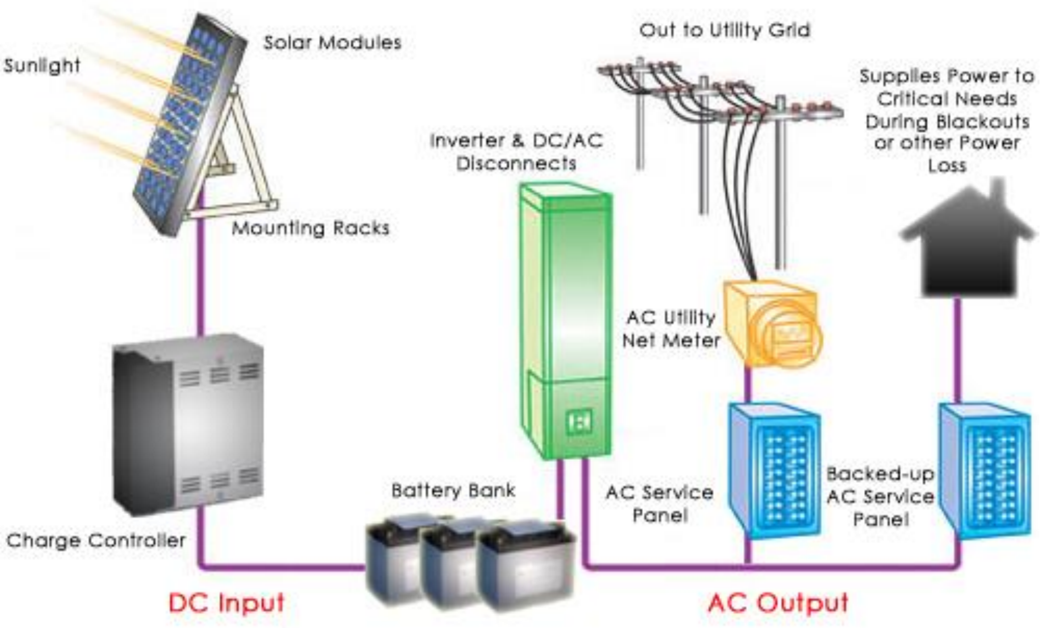
Grid-Tied System
(Without Batteries)

- Complexity
  - Low: Easy to install (less components)
- Grid Interaction
  - Grid can supplement power
  - No power when grid goes down

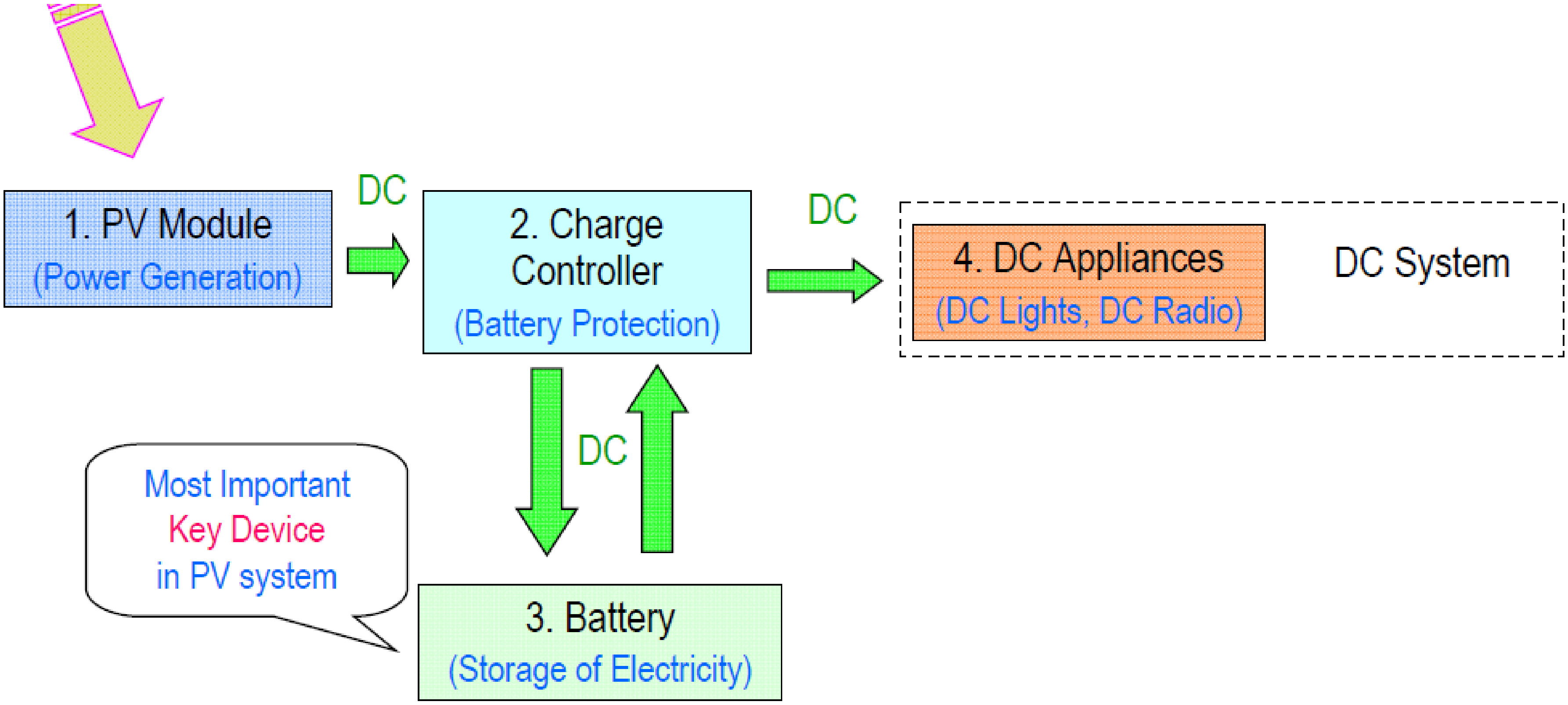


Grid-Tied System
(With Batteries)

- Complexity
  - High: Due to the addition of batteries
- Grid Interaction
  - Grid still supplements power
  - When grid goes down batteries supply power to loads (aka battery backup)



Solar Home System



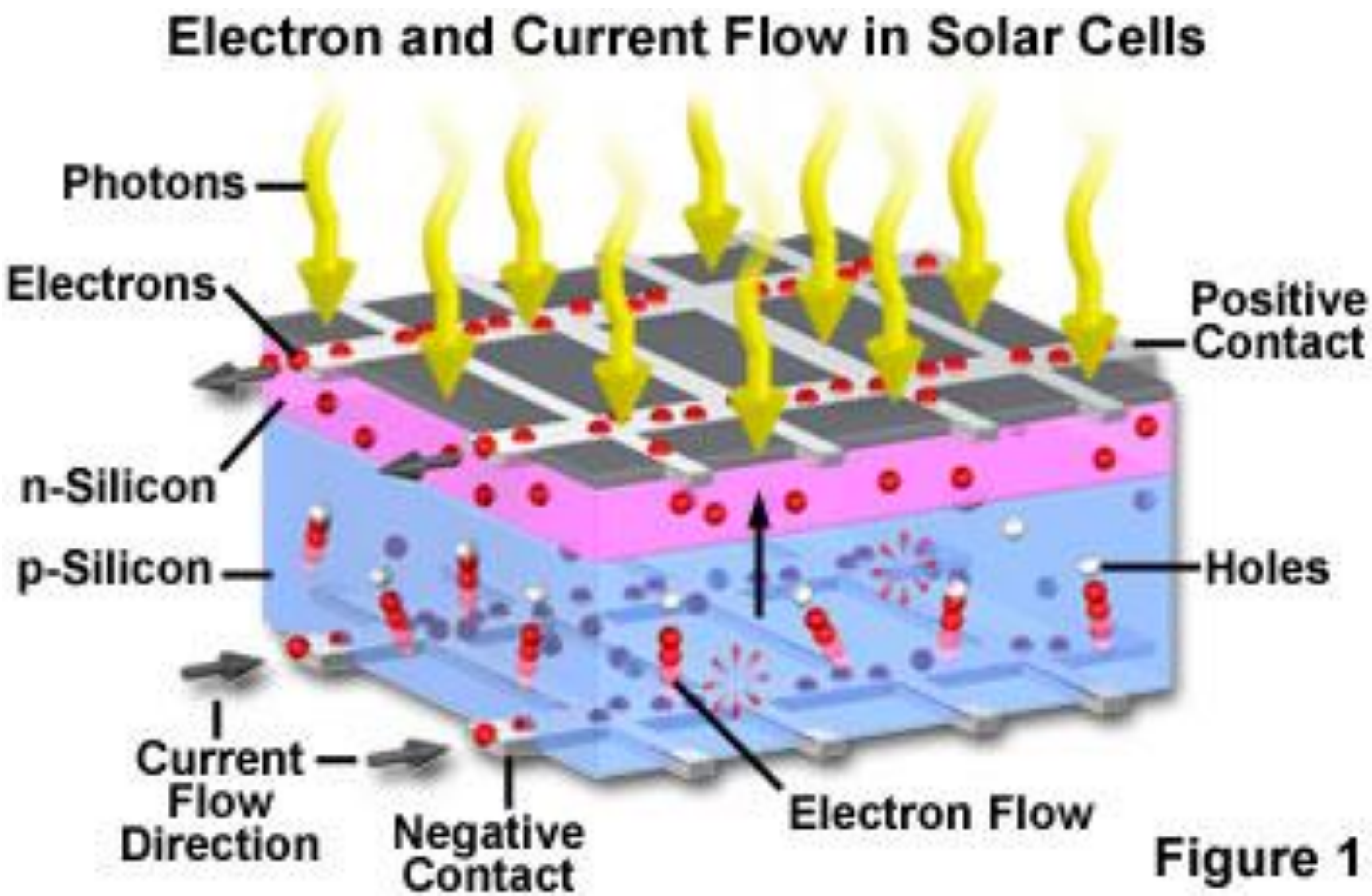
Source: JICA (2009)

PV Modules

Solar Cells and the PV Effect

- Usually produced with Semi-conductor grade silicon
- Doping agents create positive and negative regions
- P/N junction results in 0.5 volts per cell
- Sunlight knocks available electrons loose
- Wire grid provides a path to direct current

Inside a PV Cell



Available Cell Technologies

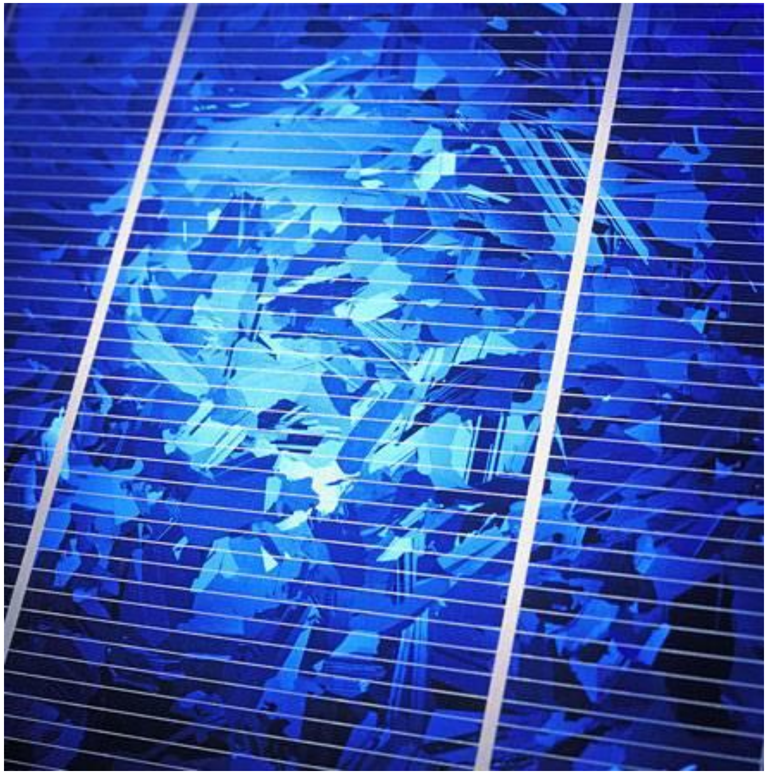
- Single-crystal or Mono-crystalline Silicon
- Polycrystalline or Multi-crystalline Silicon
- Thin film
  - Ex. Amorphous silicon or Cadmium Telluride

Monocrystalline Silicon Modules

- Most efficient commercially available module (11% - 14%)
- Most expensive to produce
- Circular (square-round) cell creates wasted space on module

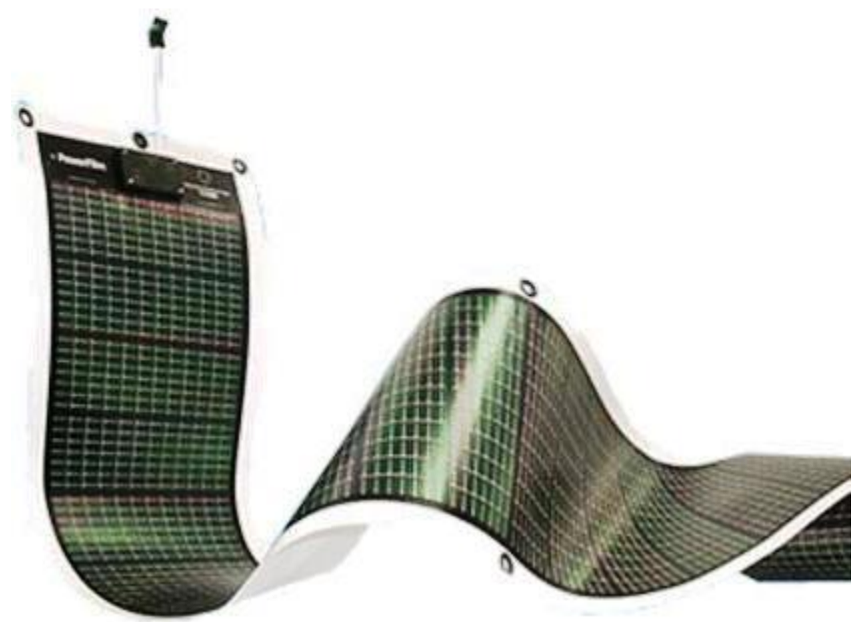
Polycrystalline Silicon Modules

- Less expensive to make than single crystalline modules
- Cells slightly less efficient than a single crystalline (10% - 12%)
- Square shape cells fit into module efficiently using the entire space



Amorphous Thin Film

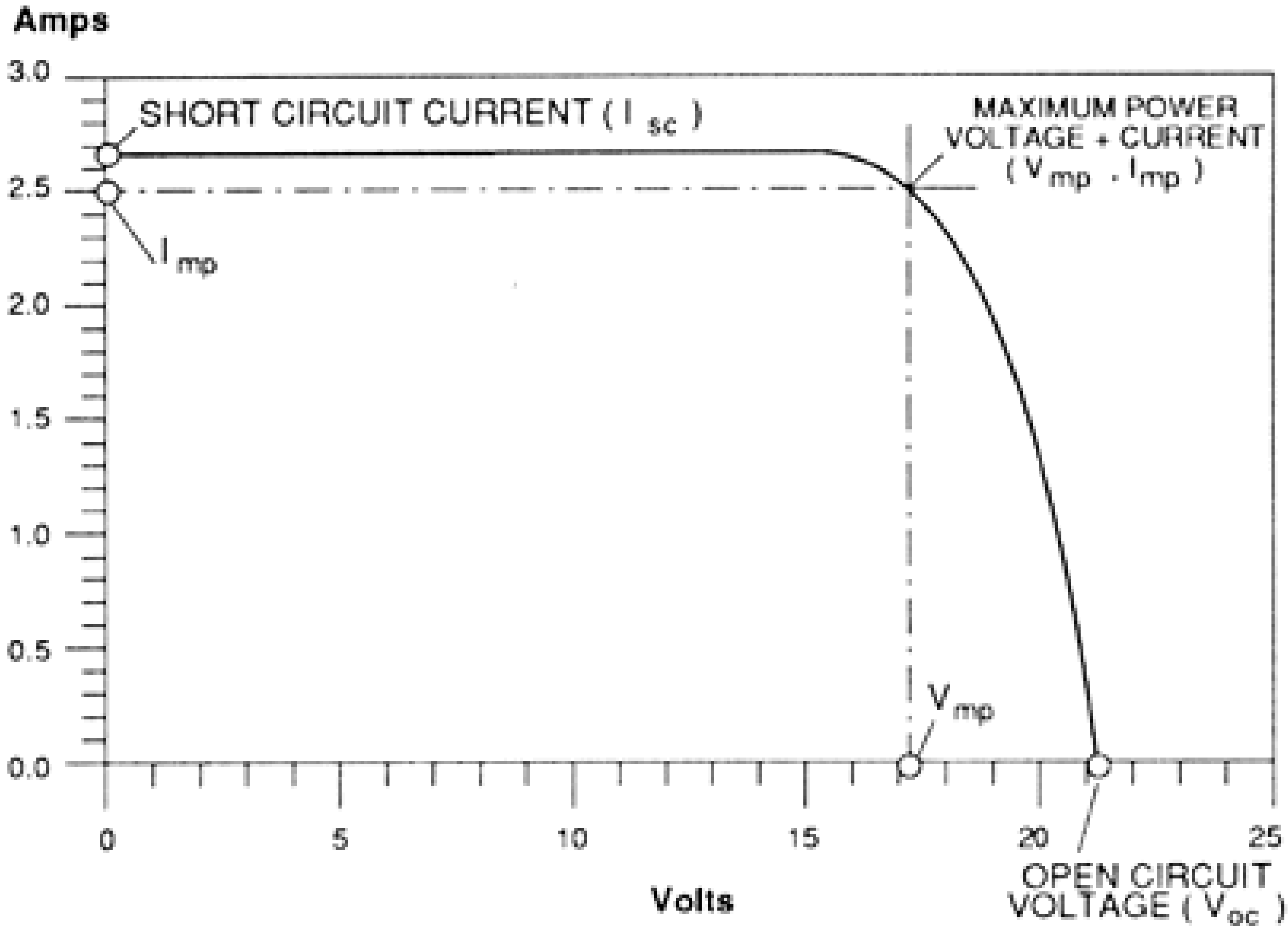
- Most inexpensive technology to produce
- Metal grid replaced with transparent oxides
- Efficiency = 6 – 8 %
- Can be deposited on flexible substrates
- Less susceptible to shading problems
- Better performance in low light conditions that with crystalline modules



Selecting the Correct Module

- Practical Criteria
  - Size
  - Voltage
  - Availability
  - Warranty
  - Mounting Characteristics
  - Cost (per watt)

Current-Voltage (I-V) Curve

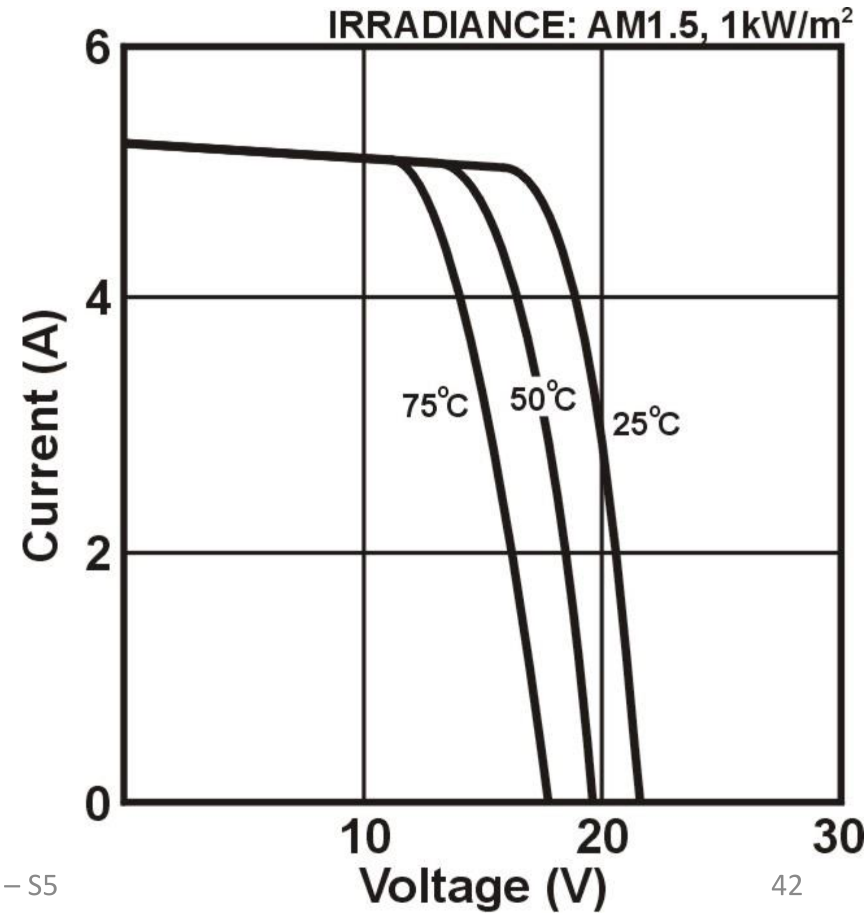


Voltage Terminology

- Nominal Voltage
  - Ex. A PV panel that is sized to charge a 12 V battery, but reads higher than 12 V)
- Maximum Power Voltage (V_{max} / V_{mp})
  - Ex. A PV panel with a 12 V nominal voltage will read 17V-18V under MPPT conditions)
- Open Circuit Voltage (V_{oc})
  - This is seen in the early morning, late evening, and while testing the module)
- Standard Test Conditions (STC)
  - 25 º C (77 º) cell temperature and 1000 W/m^2 insolation

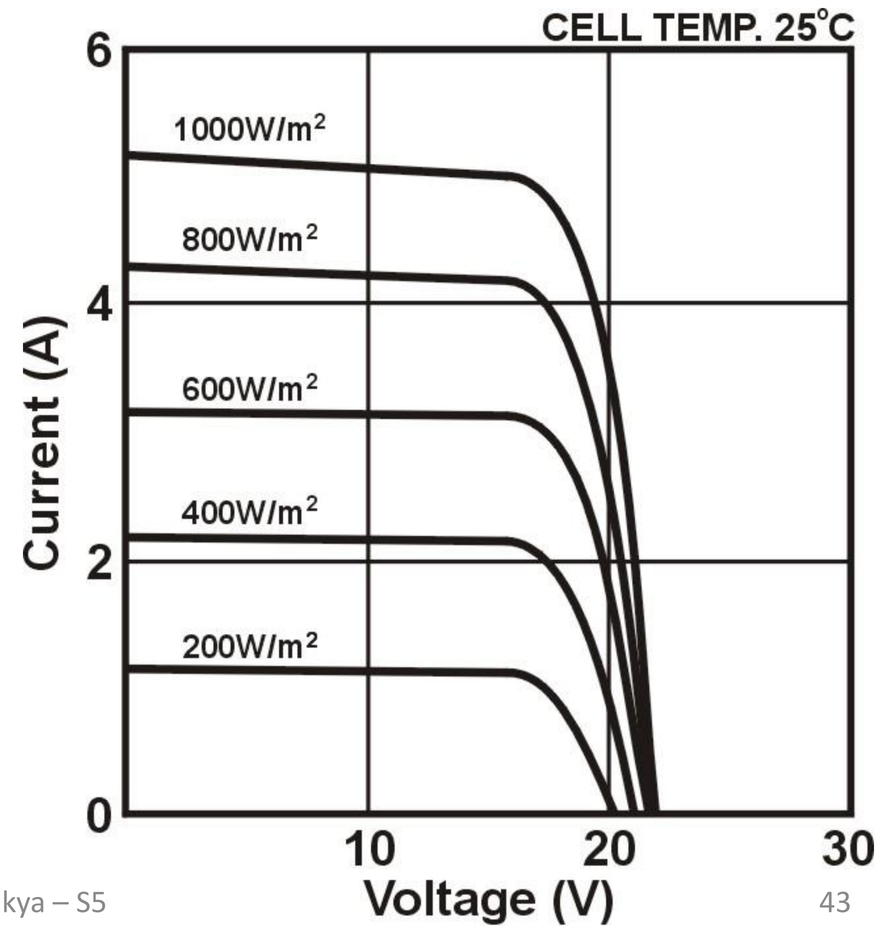
Effects of Temperature

- As the PV cell temperature increases above 25º C, the module V_{mp} decreases by approximately 0.5% per degree C



Effects of Shading/Low Insolation

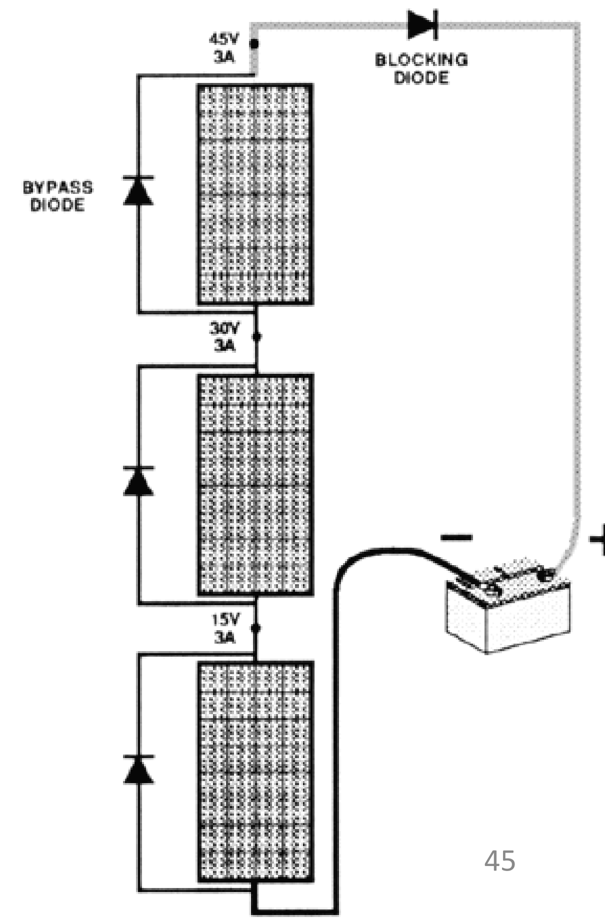
- As insolation decreases amperage decreases while voltage remains roughly constant



PV Wiring

Series Connections

- Loads/sources wired in **series**
  - VOLTAGES ARE ADDITIVE
  - CURRENT IS EQUAL
  - One interconnection wire is used between two components (negative connects with positive)
  - Combined modules make series string
  - Leave the series string from a terminal not used in the series connection

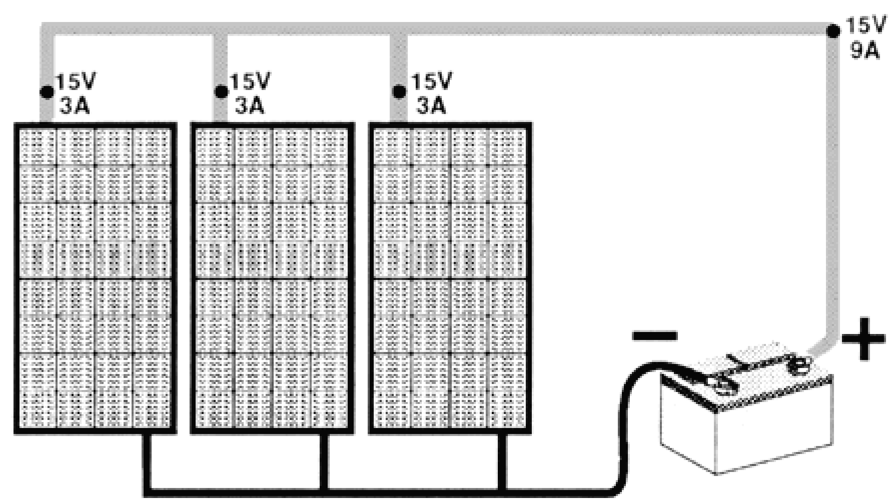


Parallel Connections

- Loads/sources wired in **parallel**:
  - VOLTAGE REMAINS CONSTANT
  - CURRENTS ARE ADDITIVE
  - Two interconnection wires are used between two components (positive to positive and negative to negative)
  - Leave off of either terminal
  - Modules exiting to next

component can happen

at any parallel terminal



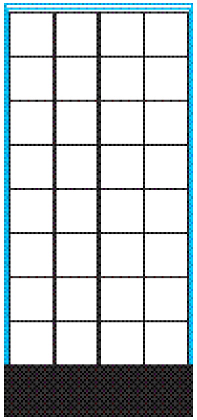
Shading on Modules

- Depends on orientation of internal module circuitry relative to the orientation of the shading.
- SHADING can half

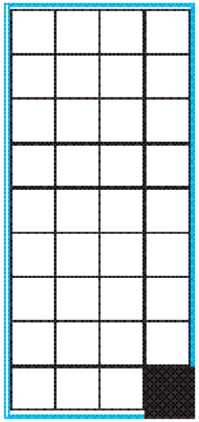
or even completely

eliminate the output

of a solar array!



Example of full-cell shading that can reduce PV module power to zero



Example of full-cell shading that can reduce PV module power by ½

Wiring Introduction

- PV installations must be in compliance with the National Electrical Code (NEC)
  - Refer to NEC Article 690 (Solar Photovoltaic Systems) for detailed electrical requirements
- Discussion points
  - Wire types, wire sizes
  - Cables and conduit
  - Voltage drops
  - Disconnects
  - Grounding

Wire Types

- Conductor material = copper (most common)
- Insulation material = thermoplastic (most common)
  - THHN: most commonly used is dry, indoor locations
  - THW, THWN, and TW can be used indoors or for wet outdoor applications in conduit
  - UF and USE are good for moist or underground applications
- Wire exposed to sunlight must be classed as sunlight resistant

Color Coding of Wires

- Electrical wire insulation is color coded to designate its function and use

Alternating Current (AC) Wiring		Direct Current (DC) Wiring	
Color	***Application***	***Color***	***Application***
Black	Ungrounded Hot	Red (not NEC req.)	Positive
White	Grounded Conductor	White	Negative or Grounded Conductor
Green or Bare	Equipment Ground	Green or Bare	Equipment Ground
Red or any other color	Ungrounded Hot		

Wire Size

- Wire size selection based on two criteria:
  - Ampacity
  - Voltage drop
- Ampacity: current carrying ability of a wire
  - The larger the wire, the greater its capacity to carry current
  - Wire size given in terms of American Wire Gauge (AWG)
    - The higher the gauge number, the smaller the wire
- Voltage drop: the loss of voltage due to a wire's resistance and length
  - Function of wire gauge, length of wire, and current flow in the wire

Batteries

Batteries in Series and Parallel

- Series connections
  - Builds voltage
- Parallel connections
  - Builds amp-hour capacity

Battery Basics

The Terms:

- **Battery**
  - A device that stores electrical energy (chemical energy to electrical energy and vice-versa)
- **Capacity**
  - Amount of electrical energy the battery will contain
- **State of Charge (SOC)**
  - Available battery capacity
- **Depth of Discharge (DOD)**
  - Energy taken out of the battery
- **Efficiency**
  - Energy out/Energy in (typically 80-85%)

Functions of a Battery

- Storage for the night
- Storage during cloudy weath
- Portable power
- Surge for starting motors

**Due to the expense and inherit inefficiencies of batteries it is recommended that they only be used when absolutely necessary (i.e. in remote locations or as battery backup for grid-tied applications if power failures are common/lengthy)

Batteries: The Details

Types:

- Primary (single use)
- Secondary (recharged)
- Shallow Cycle (20% DOD)
- Deep Cycle (50-80% DOD)

Charging/Discharging:

- Unless lead-acid batteries are charged up to 100%, they will loose capacity over time
- Batteries should be equalized on a regular basis

Battery Capacity

Capacity:

- Amps x Hours = Amp-hours (Ah)

		100 amps for 1 hour
100 Amp-hours	=	1 amp for 100 hours
		20 amps for 5 hours

- Capacity changes with Discharge Rate
- The higher the discharge rate the lower the capacity and vice versa
- The higher the temperature the higher the percent of rated capacity

Rate of Charge or Discharge

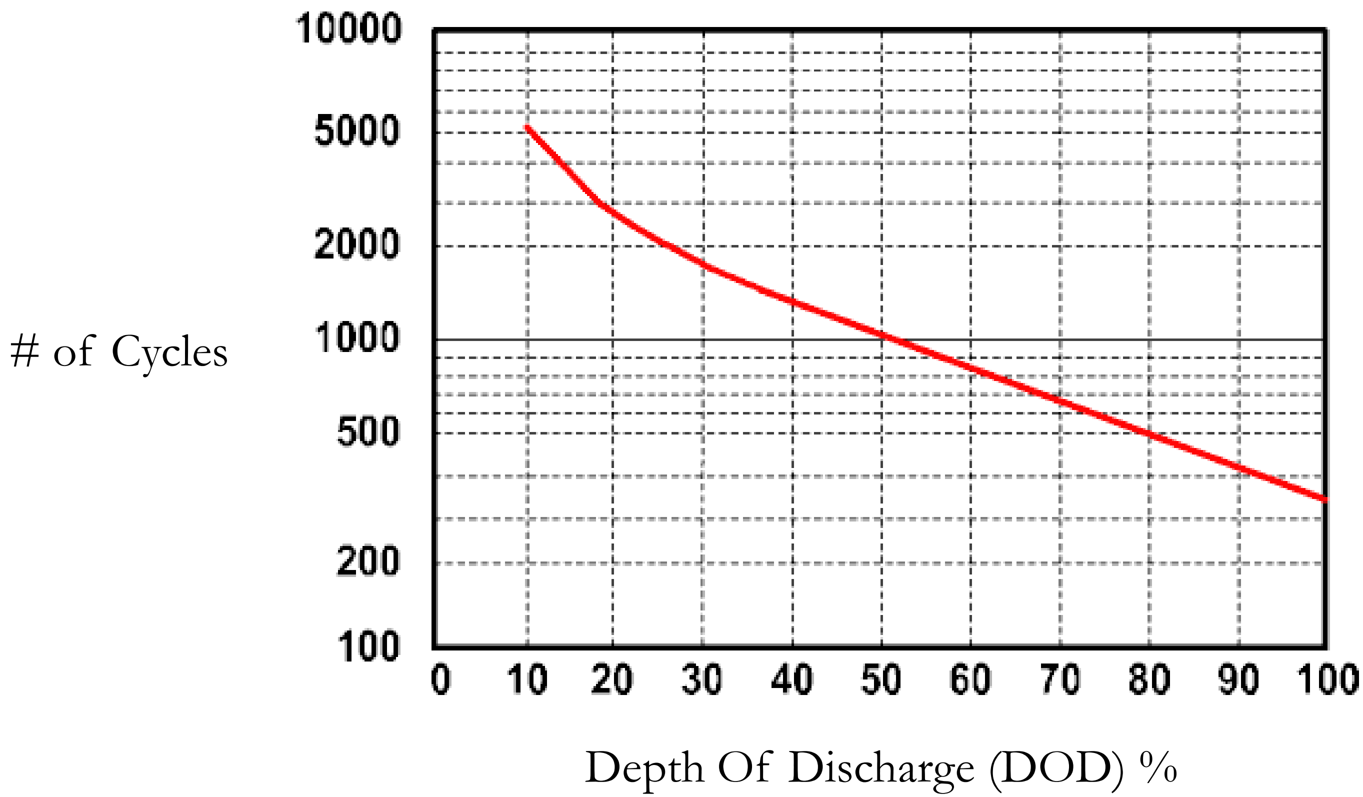
Rate = C/T

C = Battery's rated capacity (Amp-hours)

T = The cycle time period (hours)

Maximum recommend charge/discharge rate = C/3 to C/5

Cycle Life vs. Depth of Discharge



Battery Safety

- Batteries are EXTREMELY DANGEROUS; handle with care!
  - Keep batteries out of living space, and vent battery box to the outside
  - Use a spill containment vessel
  - Don’t mix batteries (different types or old with new)
  - Always disconnect batteries, and make sure tools have insulated handles to prevent short circuiting

Controllers & Inverters

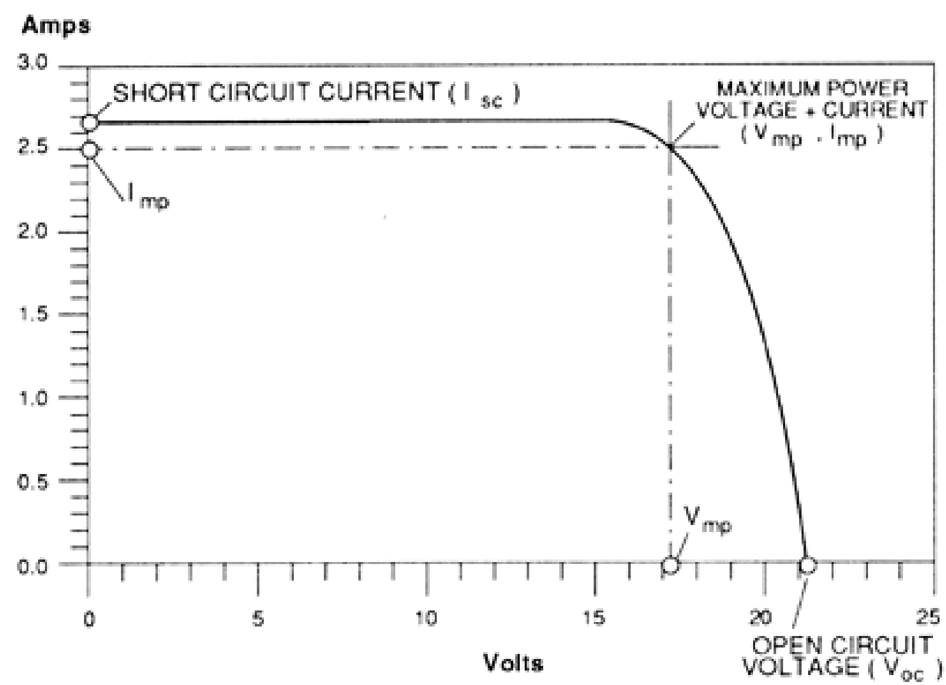
Controller Basics

Function:

- To protect batteries from being overcharged

Features:

- Maximum Power Point Tracking
  - Tracks the peak power point of the array (can improve power production by 20%)!!



Additional Controller Features

- Voltage Stepdown Controller: compensates for differing voltages between array and batteries (ex. 48V array charging 12V battery)
  - By using a higher voltage array, smaller wire can be used from the array to the batteries
- Temperature Compensation: adjusts the charging of batteries according to ambient temperature

Other Controller Considerations

- When specifying a controller you must consider:
  - DC input and output voltage
  - Input and output current
  - Any optional features you need
- Controller redundancy: On a stand-alone system it might be desirable to have more then one controller per array in the event of a failure

Inverter Basics

Function:

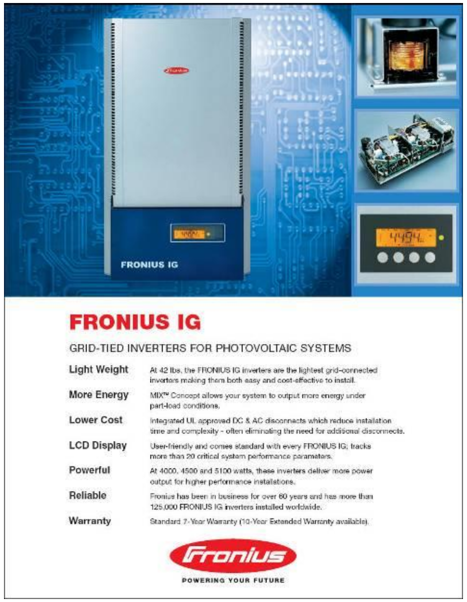
- An electronic device used to convert direct current (DC) electricity into alternating current (AC) electricity

Drawbacks:

- Efficiency penalty
- Complexity (read: a component which can fail)
- Cost!!

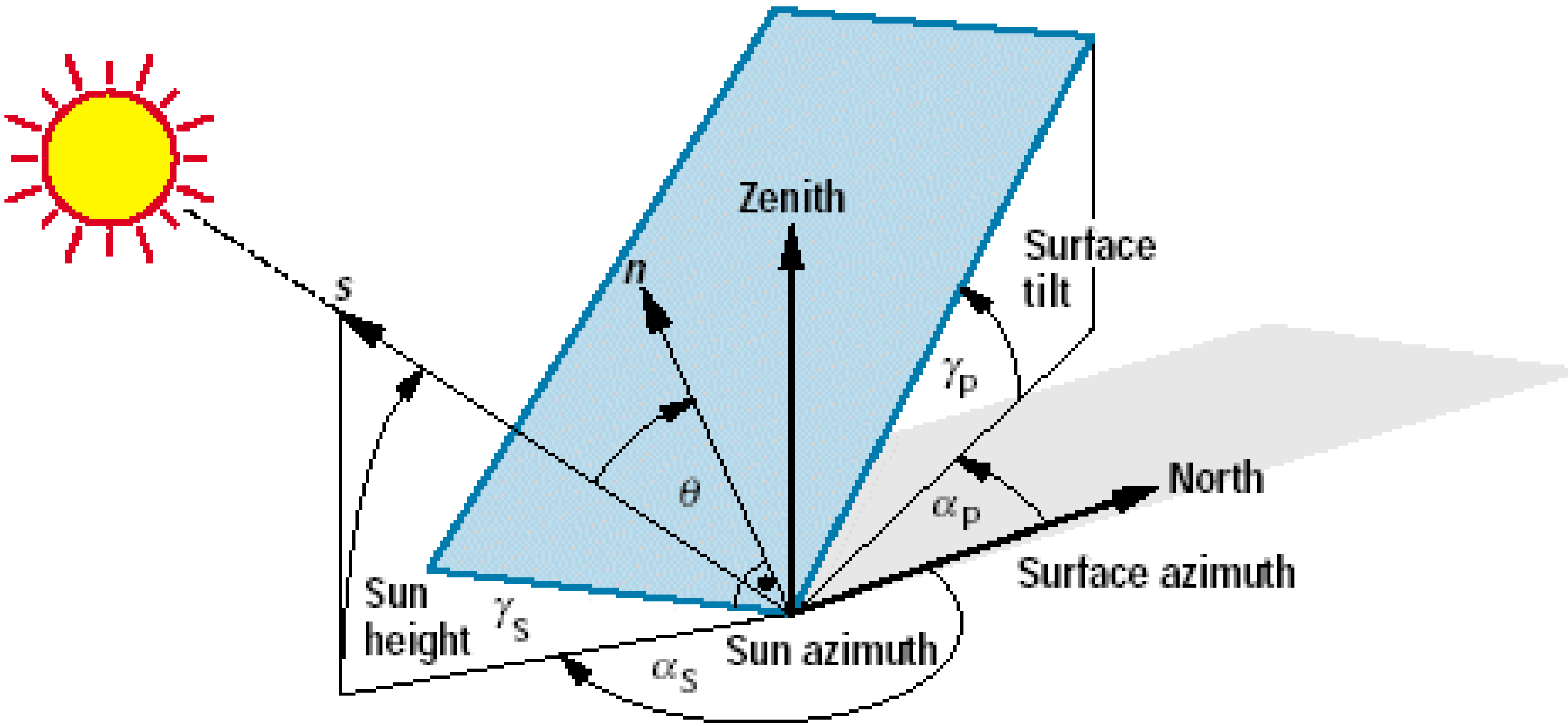
Specifying an Inverter

- What type of system are you designing?
  - Stand-alone
  - Stand-alone with back-up source (generator)
  - Grid-Tied (without batteries)
  - Grid-Tied (with battery back-up)
- Specifics:
  - AC Output (watts)
  - Input voltage (based on modules and wiring)
  - Output voltage (120V/240V residential)
  - Input current (based on modules and wiring)
  - Surge Capacity
  - Efficiency
  - Weather protection
  - Metering/programming

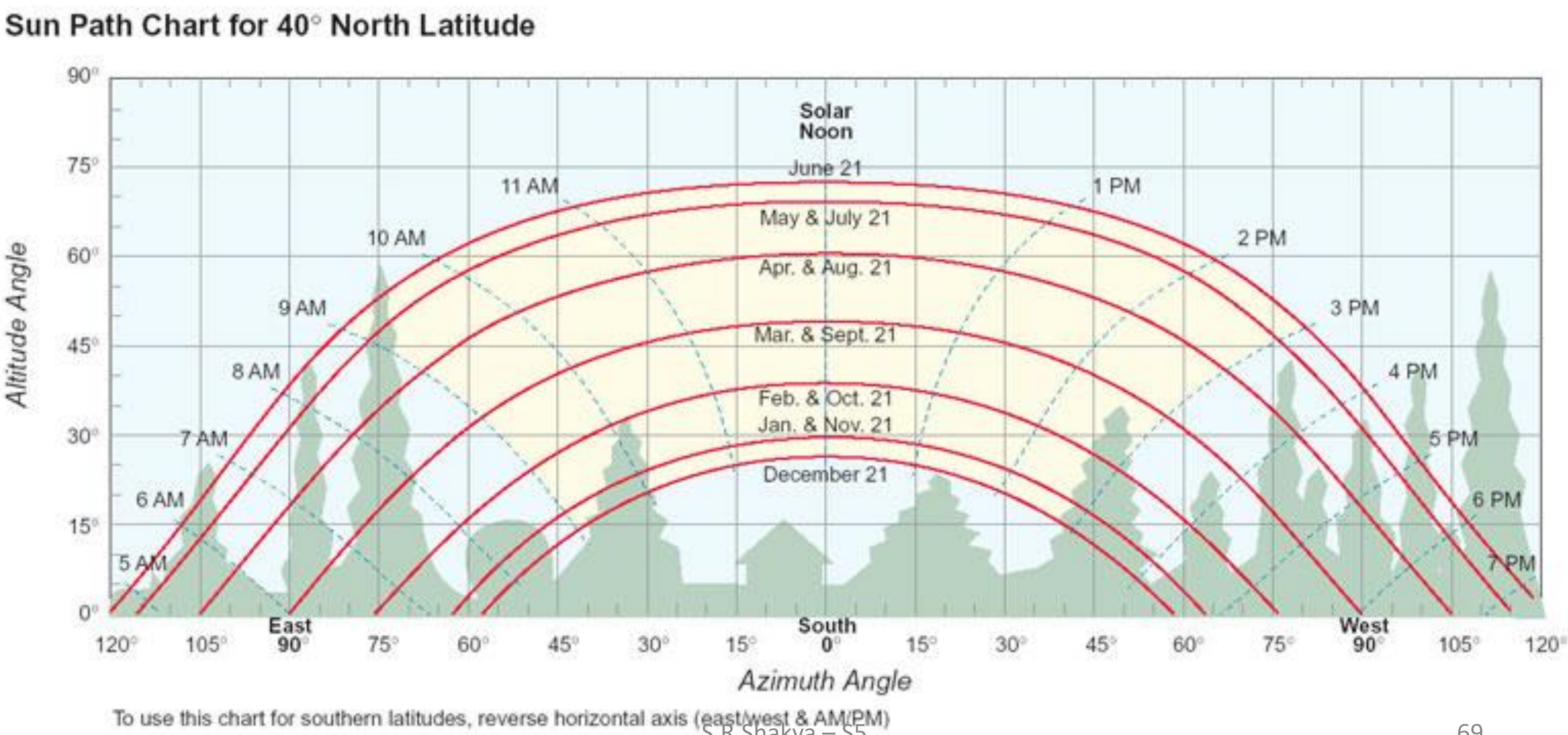


Solar Site

Orientation and Tilt Angle

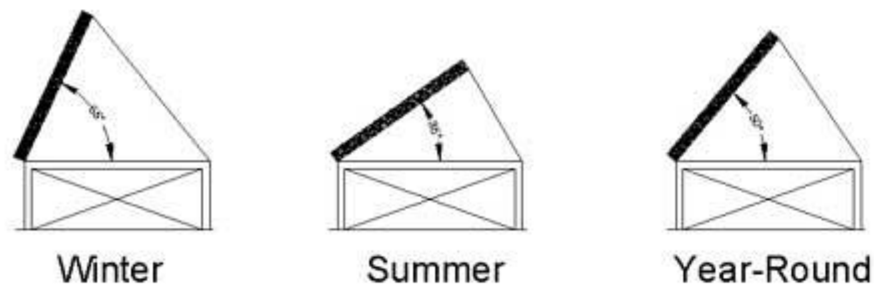


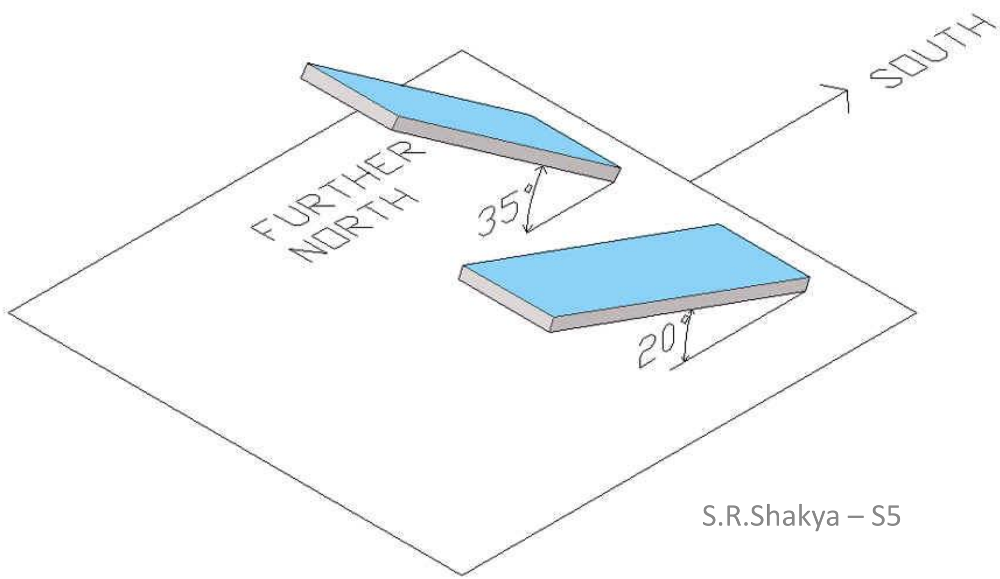
Sun Chart for 40 degrees N Latitude



Site Selection – Tilt Angle

Max performance is achieved when panels are perpendicular to the sun's rays





Year round tilt = latitude
Winter + 15 lat.
Summer – 15 lat.

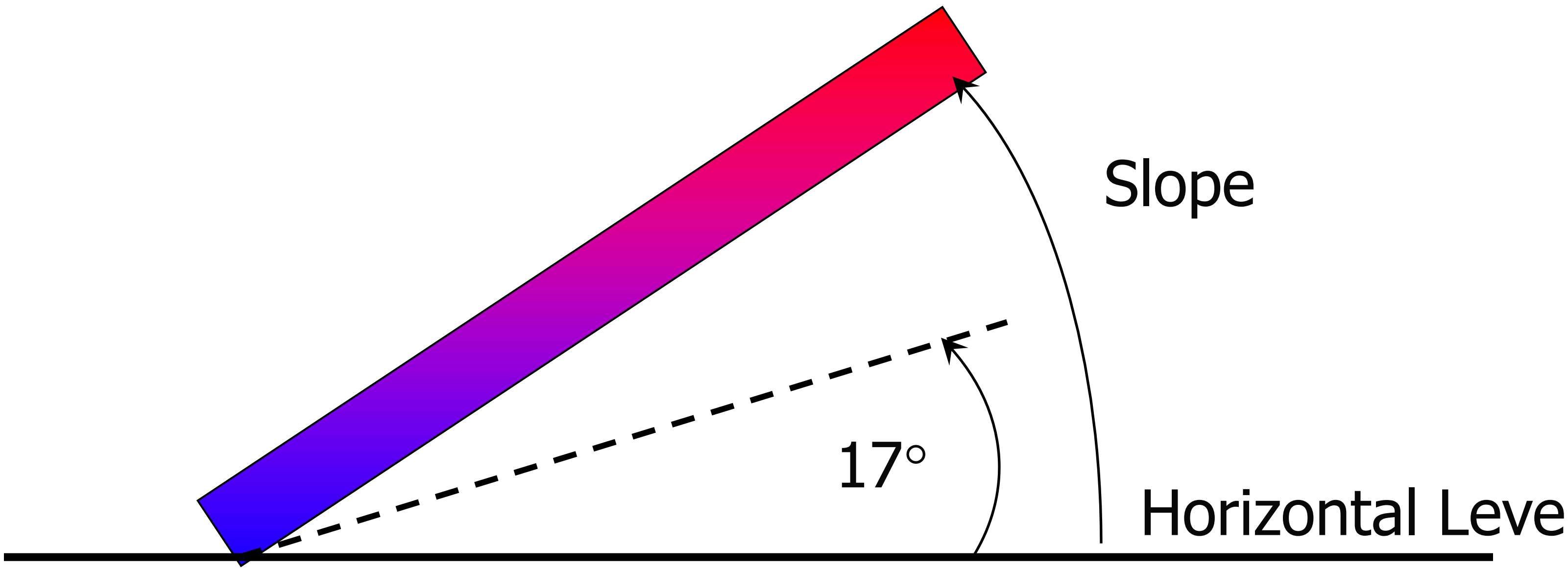
Angle and direction of Panel:

- directly facing South in Northern Hemisphre (and due North in the Southern Hemisphere), deviation 15 to 20 degrees, slightly to the West

- Example

  The latitude of Kathmandu is about 27°
  Therefore, 27°+10° = 37°
  So, an angle of 37° is recommended for Kathmandu

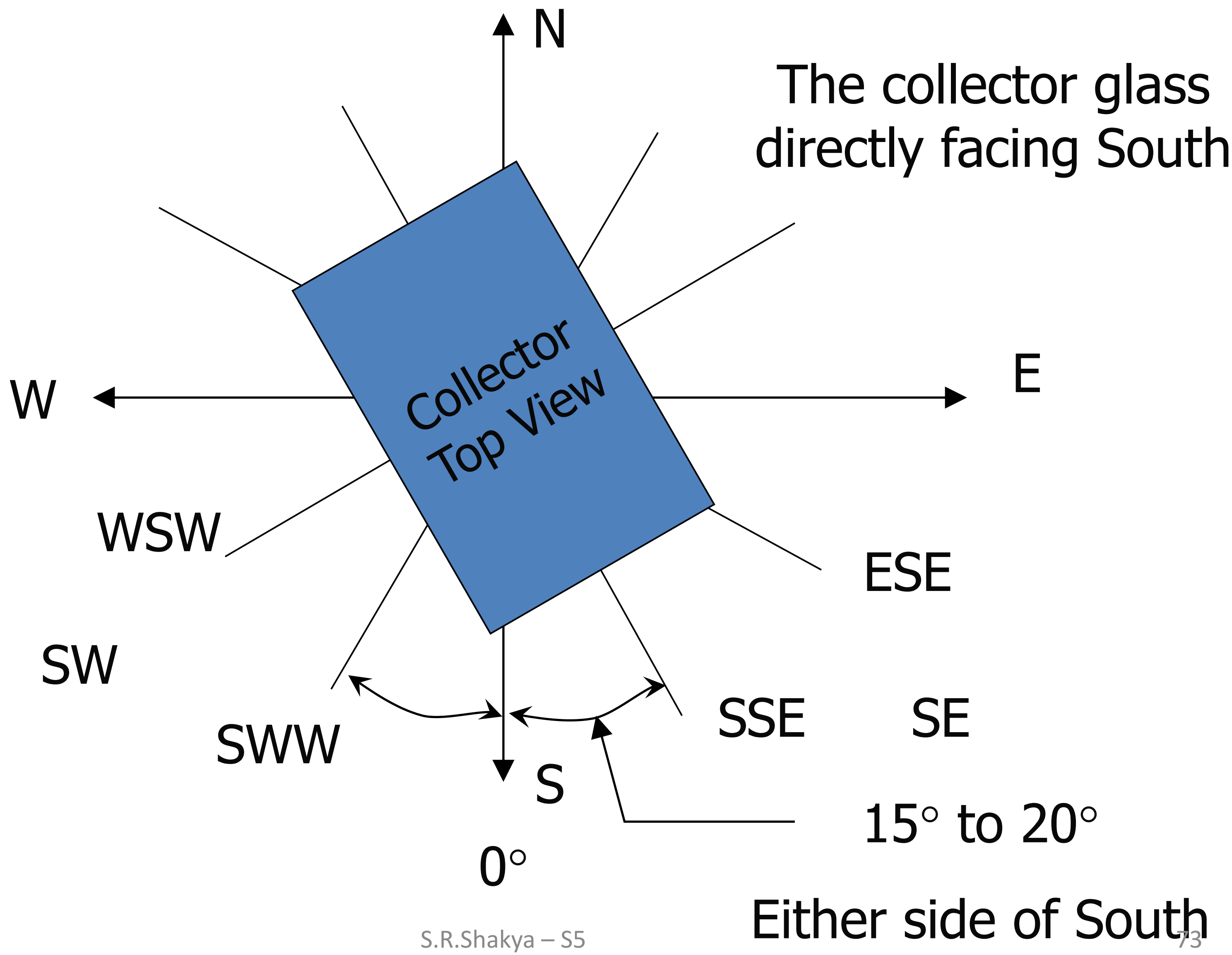
Angle of Panel



- Slope for Bhutan: Latitude of Bhutan + 10°C is recommended
  - Eg: for Kathmandu: 27°+10° = 37° is recommended!

- However, minimum slope should be 17°.

Direction of Panel



Solar Home System System Design

Load profile of the SHS user

Particular	Quantity	Power (Watt)	Daily operation (Hours)	Remarks
Electric lamp	1	10	3	Living room
Electric lamp	1	7	3	Kitchen
Electric lamp	1	5	1	Bed room
Radio	1	3	3	Living room
Television (Black/White)	1	15	2	Living room
Total		48		

The daily-required electric energy for operating all the devices for the mentioned number of time ?

Load profile of the SHS user

<u>Energy required for electric lamp</u>

Energy consumption for operating each lamp is calculated by multiplying the power rating (Watt) of it by the time of operation in hour.

$$E_L = P_L H_L \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (7.1.1)$$

where,

E_L = Energy consumption by the lamp (Watt-hours)
P_L = Power rating of the lamp (Watt)
H_L =– Daily operation time of the lamp (hours)

For example daily energy consumed by the 10 watt lamp in the table 7.1.1 for operating it for 3 hours per day is $E_L = 10 \times 3 = 30$ Watt hours.

For the lamps given in the table 7.1.1, the total energy consumption for lighting lamps becomes,

$$\begin{aligned} E_{L\ Total} &= (10W \times 3 \text{ hours}) + (7W \times 3 \text{ hours}) + (5W \times 1 \text{ hour}) \\ &= 30 \text{ Wh} + 21 \text{ Wh} + 5 \text{ Wh} \\ &= 56 \text{ Wh.} \end{aligned}$$

Load profile of the SHS user

Finally total daily energy requirement for operating all the devices of the solar home system users is calculated by using the equation 7.1.7.

$$E = E_{L\ Total} + E_{R\ Total} + E_T + \ldots.. \qquad (7.1.7)$$

For the devices mentioned in the table 7.1.1 the total daily energy requirement is given by,

$$E = 56\ Wh + 9\ Wh + 30\ Wh = 95\ Wh$$

Selection of Solar PV module

After determining the Peak Sun, the current to be generated by the solar module is given by using the following equaltion.

$$I_M = \frac{E}{H_P \ x \ B_v} \qquad (7.1.8)$$

where,

I_M	=	current generated by solar module (Ampere)
E	=	required total energy (Watt Hour)
H_P	=	peak sun (hours)
Bv	=	battery voltage (Volt)

Generally 12 V battery is used in the solar home system, so use B_V = 12V in the above equation.

using equation 7.1.8 for the table 7.1.1, we get,

$$I_M = \frac{\text{95 Watt-hours}}{\text{4.5 Hours x 12V}} = 1.75 \text{ Ampere}$$

After determining the value of I_M consult the solar module catalogue to select the module that rated current or current at Peak Power is equal to or greater than I_M calculated.

Selection of Battery

Selection of battery consists of determining the capacity of battery (Ampere-hour), voltage of battery (Volt) and type of battery (Ordinary battery or Deep Cycle battery).

Capacity of the battery is given by using the following expression,

$$C_B = \frac{E}{\eta_B \text{ x DOD x } B_V} x N_A \qquad (7.1.9)$$

where,

C_B	=	battery capacity (Ampere-hour or Ah)
E	=	daily energy consumption (Wh)
η_B	=	battery charging efficiency (normally 0.8 to 0.95)
B_V	=	battery voltage (Volt)
N_A	=	number of days to be operated without sunshine (Autonomy Days)
DOD	=	Depth of Discharge

Selection of Battery

Now considering N_A = 3 day, η_B = 0.8 and DOD = 50% (or 0.5) and using the equation 7.1.9 for conditions given in table 7.1.1 to determine the capacity of battery, we get

The capacities of the battery available in the market are of standard sizes so during selection of the battery choose the available battery with the capacity that is just above the calculated capacity of the battery required. For example if calculated battery capacity is 59.37 Ah than select the standard 60 Ah battery. Since we have considered DOD = 50% and B_V = 12V the selected battery should be deep cycle battery.

If ordinary (swallow cycle) battery with DOD = 20% (or 0.2) is taken instead of deep cycle battery, then capacity of the required battery becomes,

$$C = \frac{95\ \text{Wh x 3 days}}{0.8 \times 0.2 \times 12V} = 148.43\ \text{Ah}$$

That is we need to select battery with the capacity of 150 Ah.

Selection of Charge Controller

Charge controller should be able to with stand short circuit current (I_{SC}) of the module and maximum battery to load current ($I_{L\ max}$). Load current can be calculated by using following equation,

$$I_{L\max} = \frac{P_T}{B_V} \qquad (7.1.10)$$

where,

$I_{L\ max}$	=	maximum battery to load current (Ampere)
B_V	=	solar energy storing battery voltage (Volt)
P_T	=	Total power (Watt)

To determine total power (P_T) the power consumed by all the appliances like lamps, radio, TV has to be added. For the example in the table 7.1 the total power is calculated as

$$P_T = 10 \text{ watt} + 7 \text{ watt} + 5 \text{ watt} + 3 \text{ watt} + 15 \text{ watt} = 40 \text{ watt}$$

Selection of Charge Controller

and maximum load current is given by

$$I_{L\max} = \frac{P_T}{B_V} = \frac{40 \text{ watt}}{12 \text{ V}} = 3.33 \text{ A}$$

Generally the charge controller should be selected whose current bearing capacity should be two times that of $I_{L\ max}$ and I_{SC}. The voltage rating of the charge controller should be same as the operating voltage of the solar home system.

Selection of DC/AC Inverter

Inverter are generally use in the solar home system to operate color television. Hence the input DC voltage of the inverter should be 12 V and output AC voltage should be 220 V. the frequency of inverter should be that of the national grid frequency (50 Hz). Waveform of the inverter should be pure sine wave but the cost of this type of inverter is little higher than the inverter with square wave. The power rating of the required inverter is calculated by using the following equation,

$$P_{\text{inverter}} = \frac{P_{load}}{PF \ x \ Efficiency} \qquad (7.1.11)$$

where,

$P_{inverter}$	=	Power rating of inverter (VA)
P_{load}	=	Load power (Watt)
PF	=	Load Power factor
Efficiency	=	Inverter Efficiency

Usually during selection of the inverter power factor PF is taken as 0.8 and efficiency is taken as 0.8.

Selection of DC/AC Inverter

Example: If 21" color television whose rated power is 50 Watt is to be operated with 220V AC supply then capacity of the inverter to be selected is determined by using the equation 7.1.11 as following,

$$P_{\text{inverter}} = \frac{50Watt}{0.8 \text{ x } 0.8} = 78 \text{ VA}$$

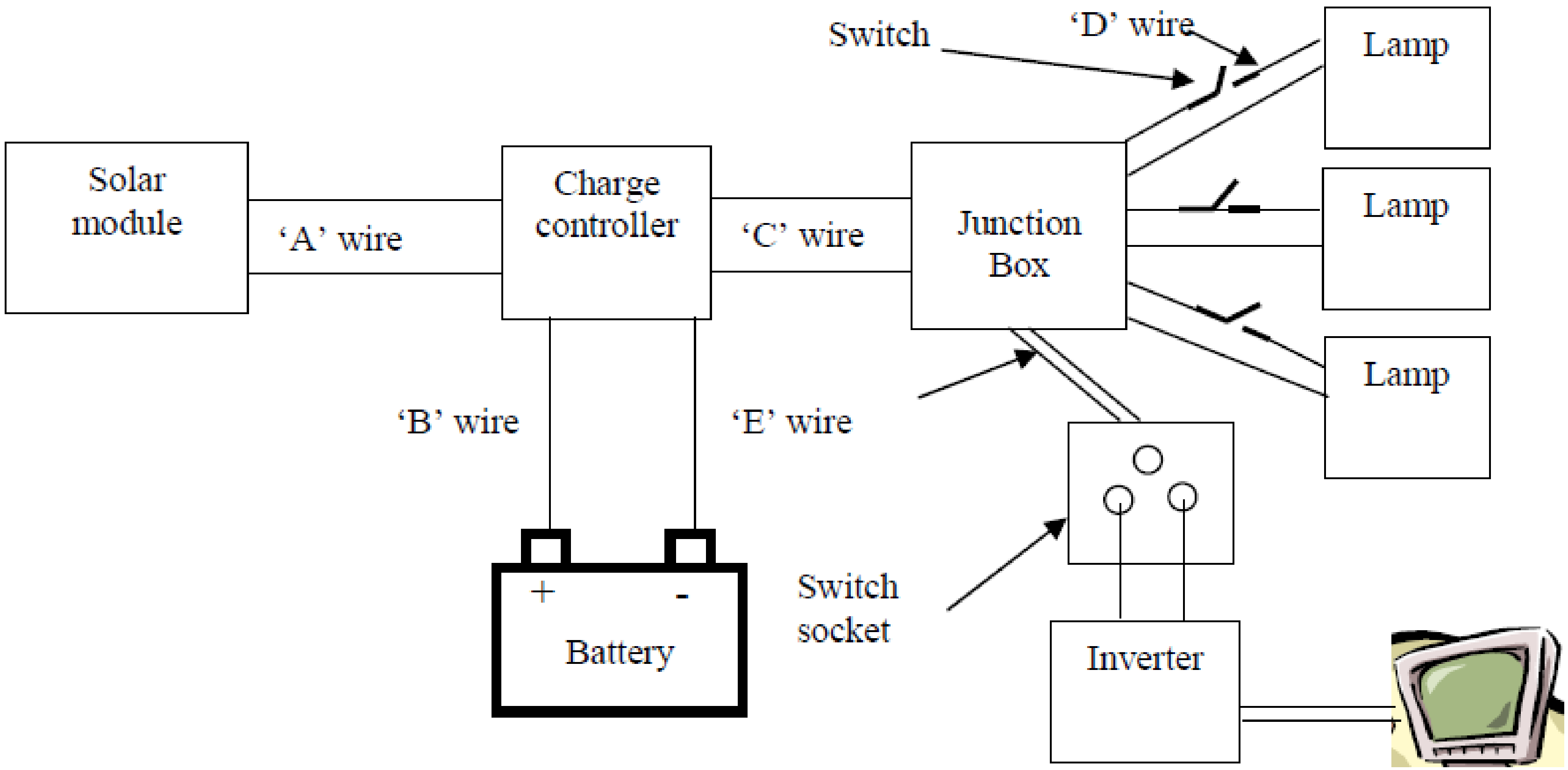
It is to be noted that during turning ON of the switch of the television the initial power consumed by the television will be higher than the rated power. The inverter should be capable of supplying this surge power. Therefore, the power rating of the inverter selected should be 2 to 3 times of this calculated power. For the above example, the inverter with the capacity of 200 VA should be selected.

Selection of DC/DC converter

Some small electrical appliances like radio, cassette player will operate at the voltage lower than 12V DC. For example small radio can operate in 3V DC with 500 mA current and some cassette player have 25 Watt capacity which can operate in 9V DC with 3A current. During selection of the inverter, attention should be given to determine if the selected inverter could supply the required voltage and current. The size and cost of the inverter for 12V DC supply with 3V DC, 500mA output is quite different from the inverter for 12V DC supply with 9V DC, 3A output. Therefore, during the selection of the inverter for solar home system detail information on the required voltage and current of the appliances to be operated by the system should be known before selection process.

The output voltage of the selected DC-DC converter should match the required input voltage of the appliance.

Selection of the wire size



Selection of the wire size

The inner diameter of the conductor of the wire depends upon the voltage drop between the solar module and charge controller. The thickness of the conductor indicates how much energy can be dropped between the solar module and charge controller. The size of the wire required is calculated by using the Standard Wire Gauge (SWG) formula as following.

$$S = \frac{0.3 \times L \times I_M}{\Delta V} \qquad (7.1.12)$$

where,

S = Cross Sectional Area of wire (mm^2)

L = Length of wire joining solar module and charge controller (meter)

I_M = current flowing from solar module to charge controller (Ampere)

ΔV = maximum allowed voltage drop percentage (5%)

ΔV indicates the voltage drop or voltage loss across the wire.

Selection of the wire size

For example, if L = 3 m, I_M= 4A and ΔV= 3% then using equation 7.1.12, we get

$$S = \frac{0.3 \times 3 \times 4}{3} \text{mm}^2 = 1.2\,\text{mm}^2$$

Use the table in appendix 4 to select the wire with cross sectional area of 1.2 mm². Here the size of the wire (diameter) is given in Standard Wire Gauge (SWG), American Wire Gauge (AWG) and British Wire Gauge (BWG).

The S cross sectional area of the wire is calculated by using following expression

$$S = \frac{\pi d^2}{4}$$

or,

$$d = \sqrt{\frac{4S}{\pi}}$$

where,

S = Cross sectional area of wire (mm^2)

d= Diameter of wire (mm)

π= 3.14 (Constant)

Selection of the wire size

For above wire having calculated wire diameter of 1.23 mm, SWG wire number 18 should be selected. Instead of selecting single strands containing wire, multiple strands containing wire can also be selected which has more bending strength, less voltage loss and hence help to store more energy in the battery. Hence instead of SWG 18, SWG 7/22 (7 strands of SWG 22 wire) can be used which cross-sectional area becomes 3.57 mm2 (nearly 3 times more than SWG 18).

Wire joining charge controller and battery 'B'

The size of the wire joining the charge controller and battery is also calculated by using the equation 7.1.12 as above but the value of ΔV should be taken as 1%. Besides, for this purpose there is no need to use UV protected wire, as it is located inside the house. While sizing 'B' wire the value of current (I) should be the largest value of current flowing through the wire. During the charging process, the current flowing through this wire is similar to the current received from module I_M and during discharging process the current in this wire is equal to the total load current connected to it. The value of current taken for calculating the cross sectional area should be the higher value of both current.

In the above example if the maximum load current is 4A or less and distance between the charge controller and battery is 1 m then required wire size is given by,

$$S = \frac{0.3 \text{ x } 1m \text{ x } 4A}{1} = 1.2 \text{ mm}^2$$

Selection of the wire size

Wire joining charge controller and junction box 'C'

For calculating the size of the wire joining the charge controller and junction box use equation 7.1.12 with the value of ΔV taken as 1%. The current is taken as the maximum total load current flowing through it.

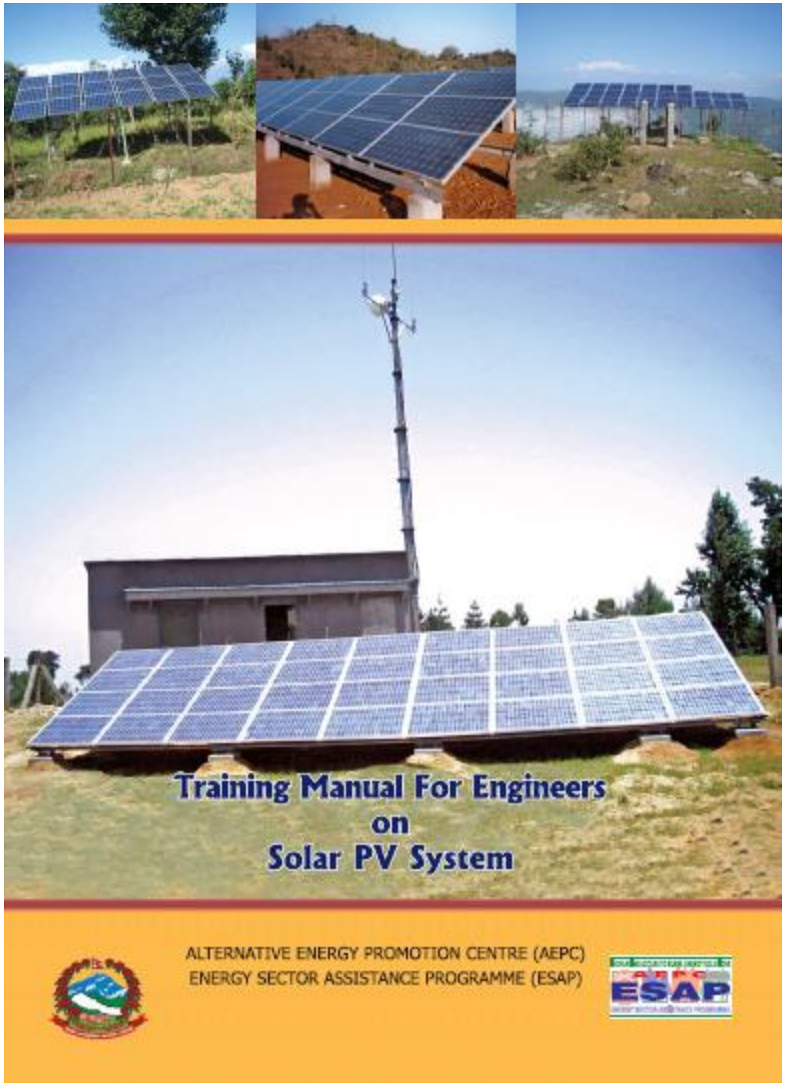
Wire joining junction box and lamp 'D'

Take ΔV up to 5% in the equation 7.1.12 for calculating the size of the wire joining the junction box and lamp.

Wire joining junction box to DC switch socket or inverter or TV (Black/White) 'E'

Take ΔV less than 5% in the equation 7.1.12 for calculating the size of the wire joining the junction box to DC switch socket or inverter or TV (Black/White).

See the manual for the detail design



Assignment 2

Particular	Quanitity	Power (Watt)	Daily operation (hours)
AC LED lamp	10	8	4
AC LED lamp	6	12	5
AC LED Television	1	40	1
AC LED Television	1	60	3
AC Rice cooker	1	700	1
AC Electric heater	1	1000	2

Design Solar PV home system containing design for the Solar Panels, Battery system, charge controller and inverter.
Select Day of autonomy as 3, DoD of battery as 60%-80%, average sunshine hour as 5 and assume other parameters as necessary.

Thank you !

E-mail: shreerajshakya@ioe.edu.np
shreerajshakya@gmail.com