Promotion of Energy Science Education for Sustainable Development in Cambodia

Theme 5: Renewable Energy

Dr. Bun Long and Dr. Kuok Fidero

Objectives and learning outcome of theme 5

- The objective of this theme is give a general overview of different technologies, especially those which are potentially feasible in Cambodia
- After completing this theme, the participants should be able to
  - List different technologies of renewable energy
  - Describe the advantages and disadvantages of different technologies
  - Explain the concept of different technologies
  - Describe the role of different components used in each technology
  - To identify the different factors affecting the potential of each technology locations for each technology

Content

- Content
  - Theme 5.1: Introduction (20 mn) – Bun Long
  - Theme 5.2: Introduction (90 mn) – Bun Long
  - Theme 5.3: Introduction (30 mn) – Bun Long
  - Theme 5.4: Introduction (40 mn) – Bun Long
  - Theme 5.5: Introduction (40 mn) – Bun Long
  - Theme 5.6: Introduction (60 mn) – Kuok Fidero

Promotion of Energy Science Education for Sustainable Development in Cambodia

Theme 5: Renewable Energy

Theme 5-1: Introduction to renewable energy

Dr. Long Bun

Vice Head of Department of Electrical and Energy Engineering

Institute of Technology of Cambodia

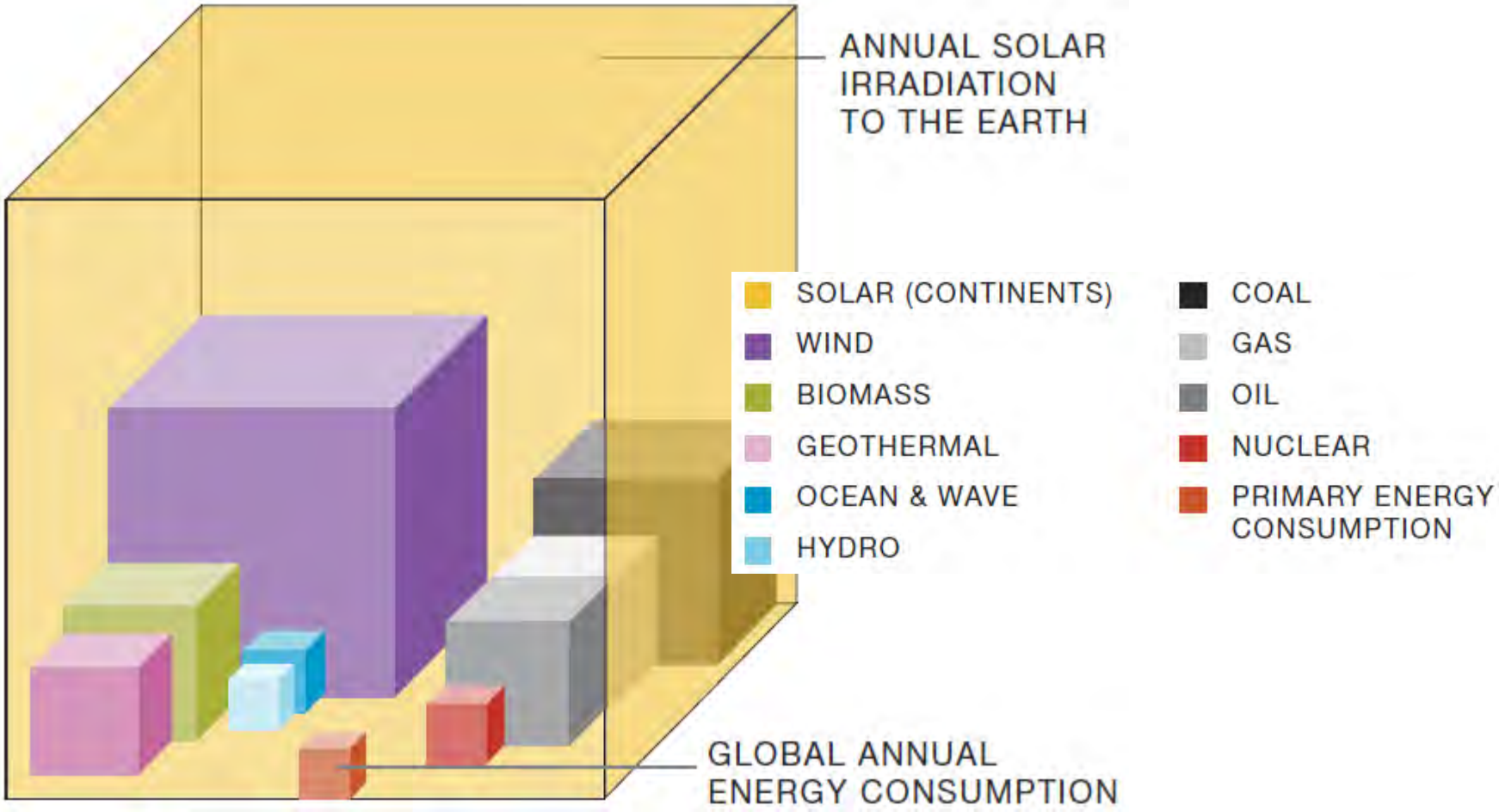
Layout

- Definition and characteristics of renewable
- Technologies
- Some statistics

Definition of renewable energies

- Renewable energy is generally defined as energy that comes from resources which are continually replenished on a human timescale such as sunlight, wind, rain, tides, waves and geother mal heat.
- Characteristics of renewable energy sources:
  - High capital costs
  - Low fuel costs, generally
  - Highly site-specific
  - Modularity
  - Intermittent

AVAILABILITY OF ENERGY



TECHNOLOGIES

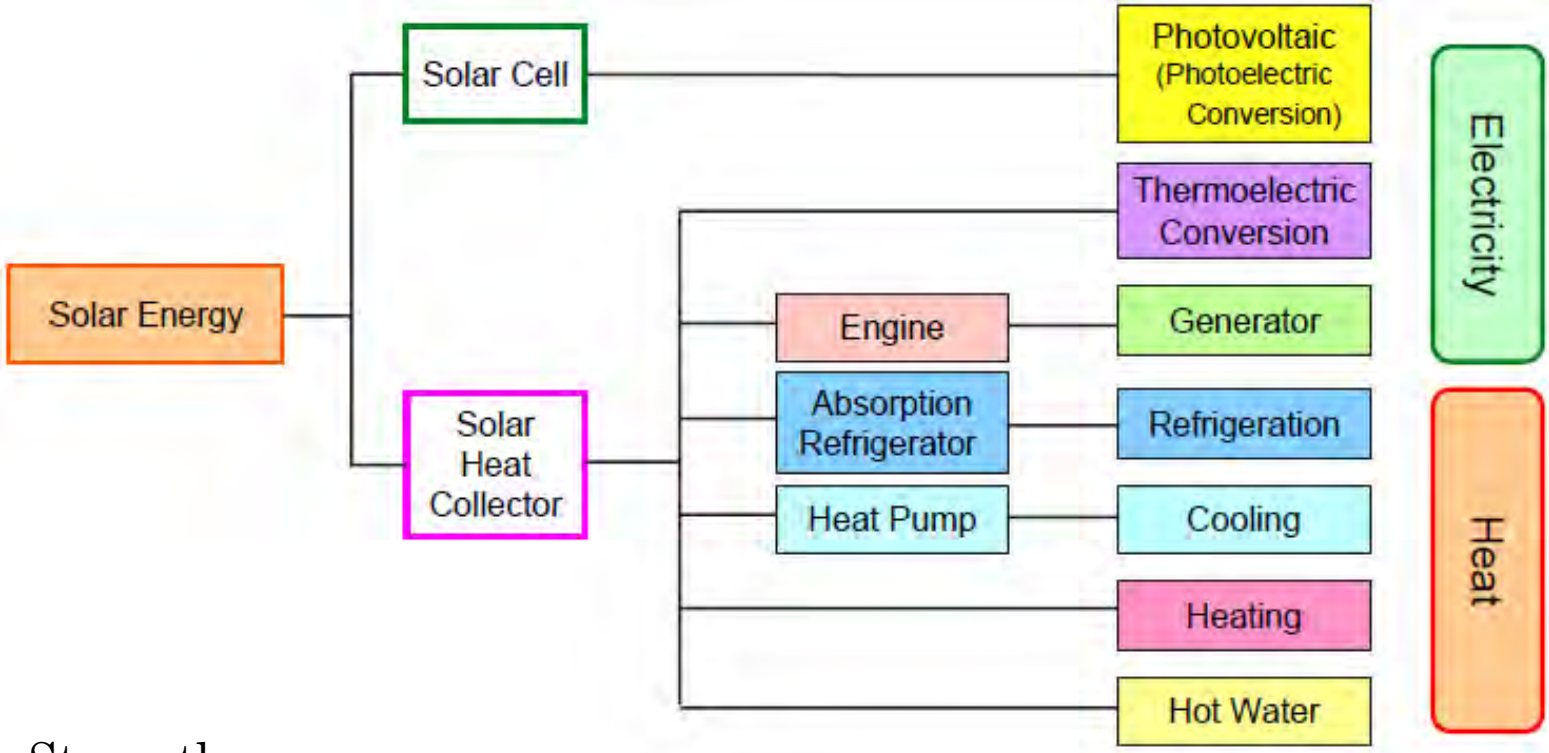
Category	Classification by Method of Power Generation	
Solar Energy	Solar Photovoltaic (PV) System	
	Solar Thermal Electricity System	
	Solar Thermal System	
Wind Energy	Wind Turbine Generator System	
	Wind Pumping System	
Biomass Energy (Bioenergy)	Combustible Renewables and Waste (CRW)	Solid Biomass
		Liquid Biomass (Biofuel)
		Biogas (Gas from Biomass)
Biomass from Waste Materials		Municipal Waste
		Industrial Waste
Geothermal Energy	Geothermal Power Generation	
	Direct Use of Geothermal Energy	
Hydropower Energy	Hydroelectric Power Generation	
Tidal/Wave/ Ocean Energy	Tidal Power Generation	
	Wave Power Generation	
	Ocean Current Power Generation	
	Ocean Thermal Energy Conversion	

(Source) International Energy Agency (IEA), etc.

Layout

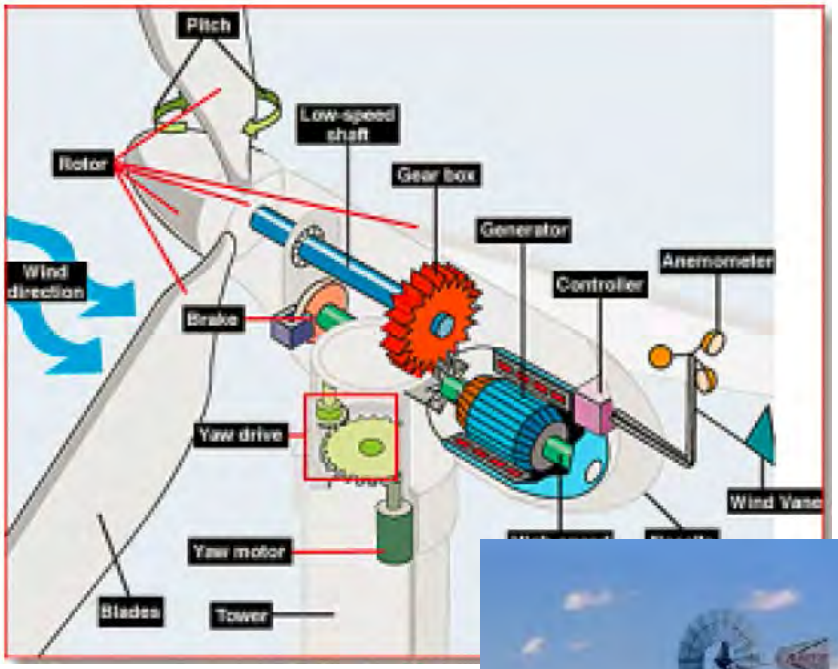
- Definition and characteristics of renewable
- Technologies
- Some statistics

Solar energy



- Strength
  - Large resources
  - Sustainable energy resources
  - Clean energy
  - Non-localized resources
- Weakness
  - Low energy density
  - Intermittent ⇒ depending on climate and time

Principle of wind energy



- Strength
  - Renewable
  - Environmentally friendly
  - Take up less space than average power station
  - Suitable for remote area
- Weakness
  - Fluctuation
  - Site specific
  - Ecological impact when construction and during operation

Definition of biomass

- Biomass is organic compounds derived from plants and animals, excluding fossil fuels.
- Biomass is receiving attention because it is a renewable energy source that does not result in an increase in carbon dioxide, a major cause of global warming.
- While biomass is generally converted into heat and electricity through the combustion process, it can also be converted into many fuels.

Definition of biomass

Categories			Materials
Cultivated Crops	Terrestrial Plants (Land)	Saccharine	Sugar Cane, Beet, Sweet Sorghum, etc.
		Starch	Maize, Cassava, Sweet Potato, etc.
		Cellulose	Napier grass, Bamboo Grass, Poplar, Plane Tree, etc.
		Carbohydrate	Eucalyptus, Blue Coral, etc.
		Oil and Fat	Oil Palm, Rapeseed, Sunflower, etc.
	Aquatic Plants (Water)	Freshwater	Water Hyacinth, Canadian Pondweed, etc.
		Oceanic	Kelp, Giant Kelp, Sea Lettuce, etc.
		Micro-organism	Chlorella, Photosynthesis Bacteria, etc.
Waste Materials	Agricultural, Fishery and Forestry	Agricultural Waste	Rice Husks, Rice Straw, Straw, etc.
		Livestock Waste	Cattle Swine, Excreta, Hen Down, etc.
		Forestry Waste	Brushwood, Branches, Thinned Wood, etc.
	Waste	Industrial	Sludge, Pulp Sludge, Food Processing Residue, Wood Waste, etc.
		Domestic	Domestic Garbage, Human Waste, etc.
		Landfill Gas (LFC)	Gas from Landfills

Biomass conversion process

Technological Category		Description	Products
Direct Combustion	Direct Combustion	Produces thermal energy through direct combustion	Heat, Electricity
	Multi-fuel Combustion	Co-fires biomass with other fossil fuels such as coal (at coal fired power plants, etc.)	Heat, Electricity
	Solid Fuel Production	Processes biomass into chips and pellets for use in heating equipment.	Solid Fuel
Thermo-chemical Conversion	Gasification	Decomposes biomass by heat	Gas
	Rapid Pyrolysis	Heats biomass to 400-600° C for few seconds and then cool it down quickly	Liquid Fuel
	Carbonization	Heats biomass in the absence of air	Solid Fuel (Charcoal)
	Hydrothermal Gasification	Gasifies biomass in water at high temperatures and pressures (thermo-chemical treatment)	Gas
	Direct Liquefaction	Heats biomass in water at high pressures	Liquid Fuel
	Slurry Fuel Production	Heats biomass in water at high pressures for carbonization to produce slurry	Liquid Fuel
Biochemical Conversion	Esterification	Reacts edible oil (vegetable oil, etc.) with methanol (esterification) to produce fuel for diesel vehicles	Liquid Fuel (Bio-diesel)
	Methane Fermentation	Ferments biomass in the absence of air to decompose it into methane and CO2	Gas (Methane)
	Ethanol Fermentation	Ferments saccharides (glucose, fructose, saccharose) with yeast to decompose them into ethanol	Liquid Fuel (Mixed Gasoline)

Waste to energy

- Thermal technologies:
  - Gasification (produces combustible gas, hydrogen, synthetic fuels)
  - Thermal depolymerization (produces synthetic crude oil, which can be further refined)
  - Pyrolysis (produces combustible tar/biooil and chars)
  - Plasma arc gasification or plasma gasification process (PGP) (produces rich syngas including hydrogen and carbon monoxide usable for fuel cells or generating electricity to drive the plasma arch, usable vitrified silicate and metal ingots, salt and sulphur)
- Non-thermal technologies:
  - Anaerobic digestion (Biogas rich in methane)
  - Fermentation production (examples are ethanol, lactic acid, hydrogen)
  - Mechanical biological treatment (MBT)
    - MBT + Anaerobic digestion
    - MBT to Refuse derived fuel

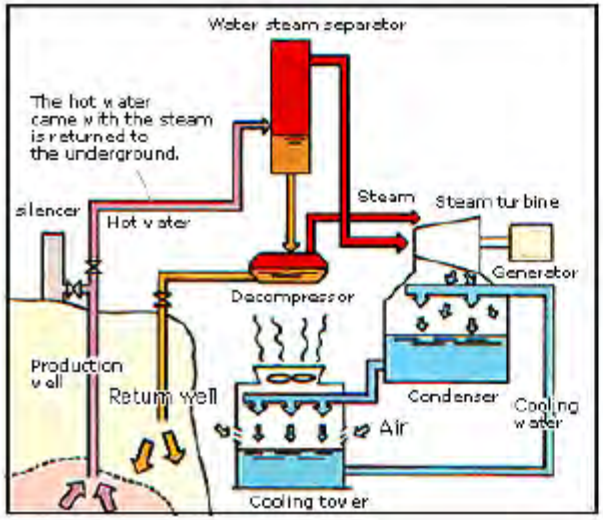
Advantages and disadvantages of biomass

- Advantages
  - No Harmful Emissions
  - Clean Energy
  - Abundant and Renewable
  - Reduce Dependency on Fossil Fuels
  - Reduce Landfills
  - Can be Used to Create Different Products
- Disadvantages
  - Expensive
  - Inefficient as Compared to Fossil Fuels
  - Harmful to Environment
  - Consume More Fuel
  - Require More Land

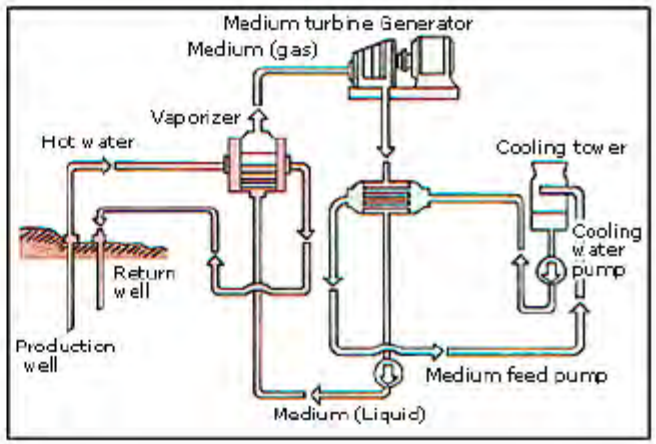
Principle of geothermal energy

- High-temperature water is heated up by geothermal heat and stored underground.
- Separated steam are feeded to the turbine while returning the hot water back to underground.
- Another geothermal power generation method is the binary cycle power generation, which makes the effective use of the hot water

Steam Power Generation



Binary Cycle Power Generation

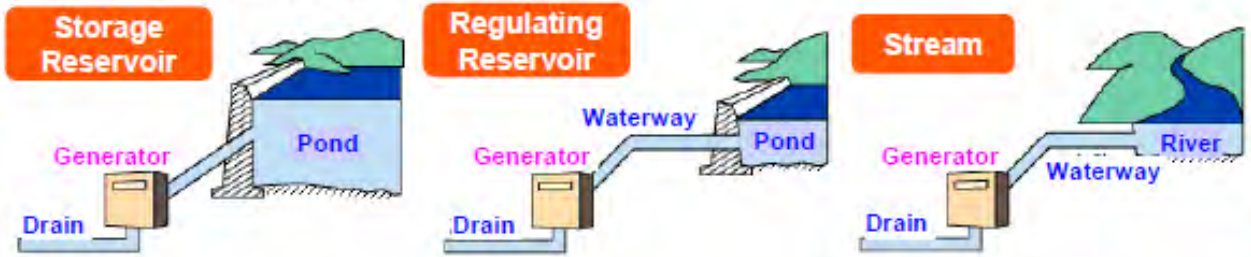


Advantages and disadvantages of Geo-thermal

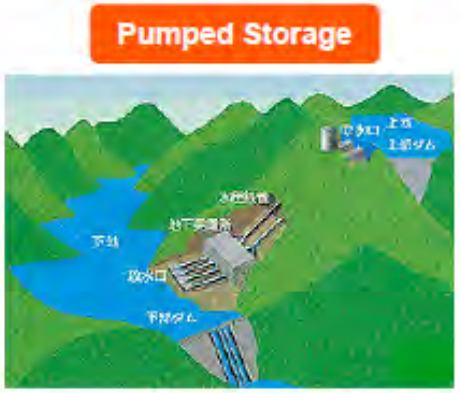
- Advantages
  - Significant Cost Saving
  - Reduce Reliance on Fossil Fuels
  - No Pollution
  - Direct Use
  - Job Creation and Economic Benefits
- Disadvantages
  - Not Widespread Source of Energy
  - High Installation Costs
  - Can Run Out Of Steam
  - Suited To Particular Region
  - May Release Harmful Gases
  - Transportation

Principle of hydropower

【Types by Utilization】



【Types by Structure】



【Types by Output】

Large Hydropower	100,000 kW or more
Medium Hydropower	10,000 – 100,000 kW
Small Hydropower	1,000 – 10,000 kW
Mini Hydropower	100 – 1,000 kW
Micro Hydropower	less than 100 kW

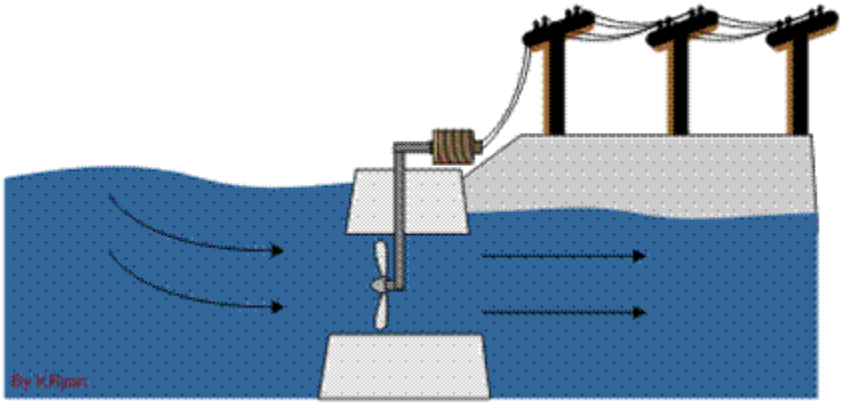
Advantages and disadvantages of Micro-Hydropower

- Advantages
  - Efficient energy source
  - Reliable electricity source
  - No reservoir required
  - Cost effective energy solution
  - Power for developing countries
  - Integrate with the local power grid
- Disadvantages
  - Suitable site characteristics required
  - Energy expansion not possible
  - Low-power in the summer months
  - Environmental impact

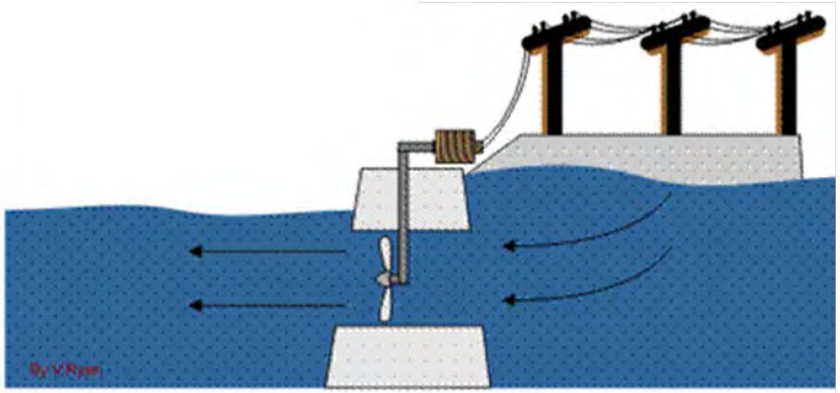
TIDAL POWER

- **Tidal power**, also called **tidal energy**, is a form of hydropower that converts the energy of tides into useful forms of power - mainly electricity.

- The electricity is produced as the tide comes in and again when it goes out. The turbines are driven by the power of the sea in both directions.



TIDE COMING IN



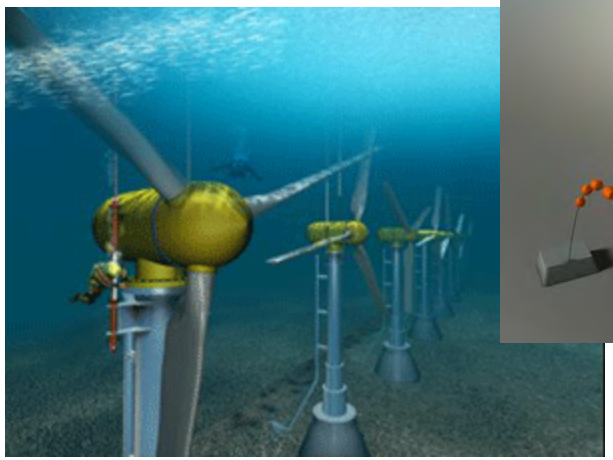
TIDE GOING OUT

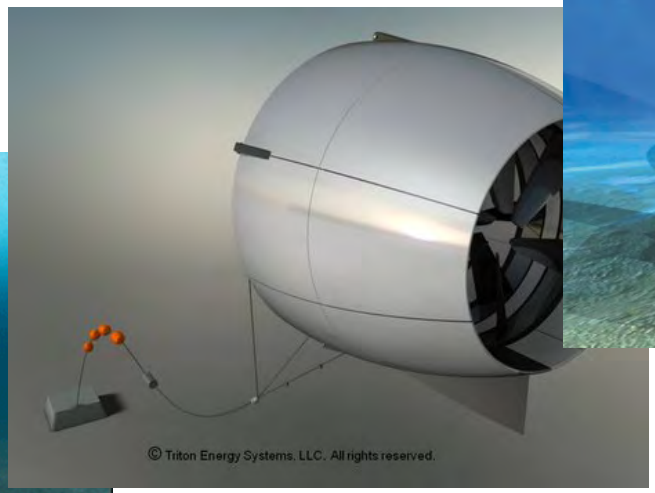
Wave energy

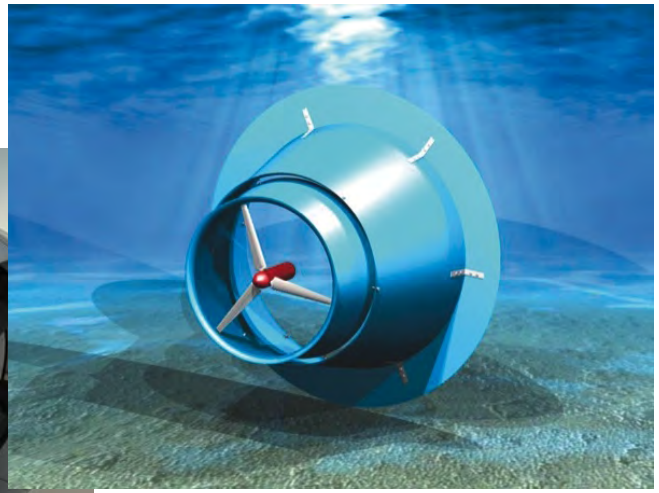
- **Wave power** is the transport of energy by ocean surface waves, and the capture of that energy to do useful work – for example, electricity generation, water desalination, or the pumping of water (into reservoirs).
- Energy output is determined by wave height, wave speed, wavelength, and water density.

Ocean current energy

- **Ocean currents** flow in complex patterns affected by wind, water salinity, temperature, topography of the ocean floor, and the earth's rotation.







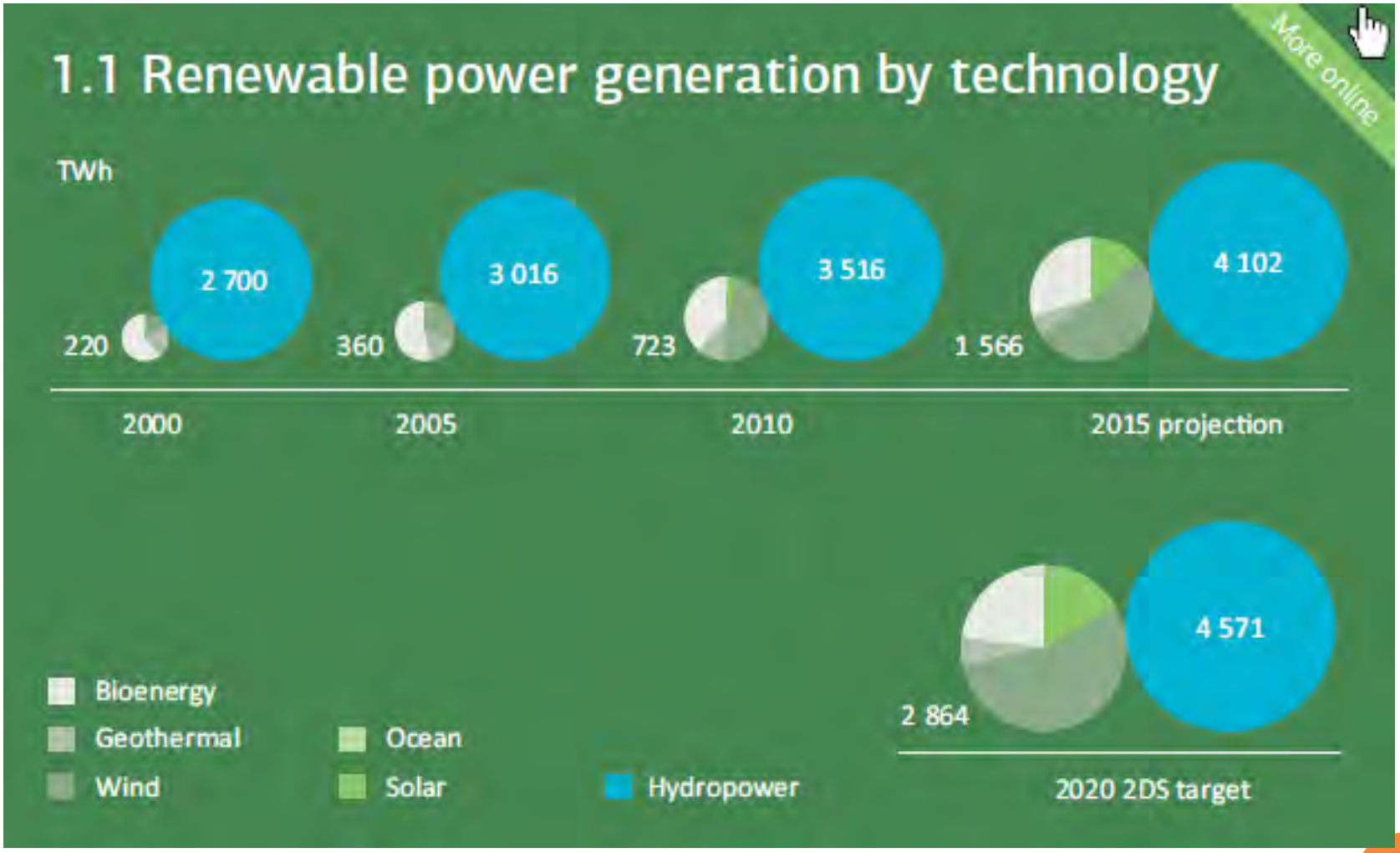
Advantages and disadvantages of Marine Energy

- Advantages
  - Renewable
  - Environmental friendly
  - Abundant and widely available
  - Variety of ways to harness
  - Easily predictable
  - No damage to land
- Disadvantages
  - Suitable to certain locations
  - Effect on marine ecosystem
  - Source of disturbance for private and commercial vessels
  - Wavelength
  - Weak performance in rough weather
  - Noise and visual pollution

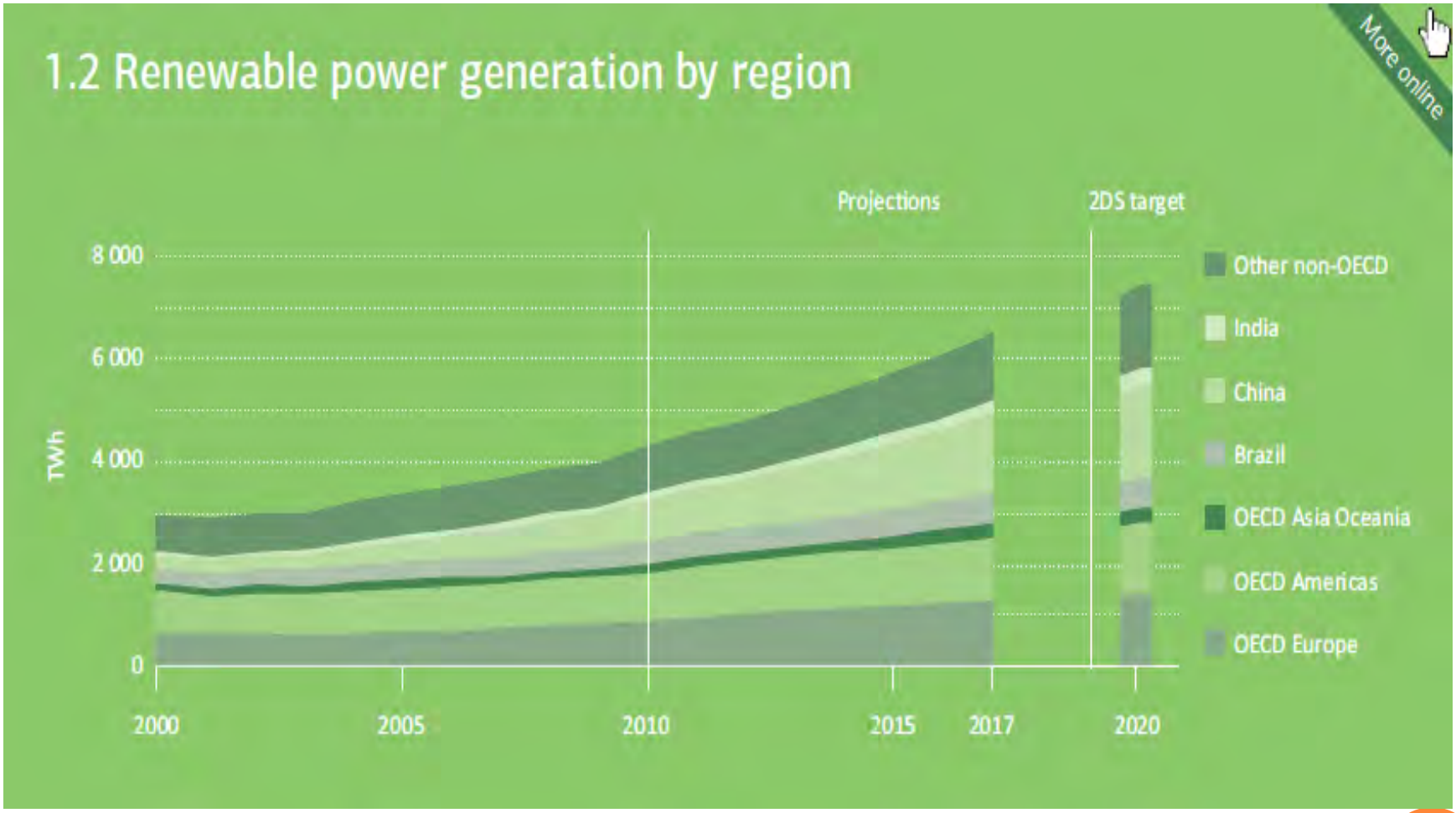
Layout

- Definition and characteristics of renewable
- Technologies
- Some statistics

Some statistics – Worldwide

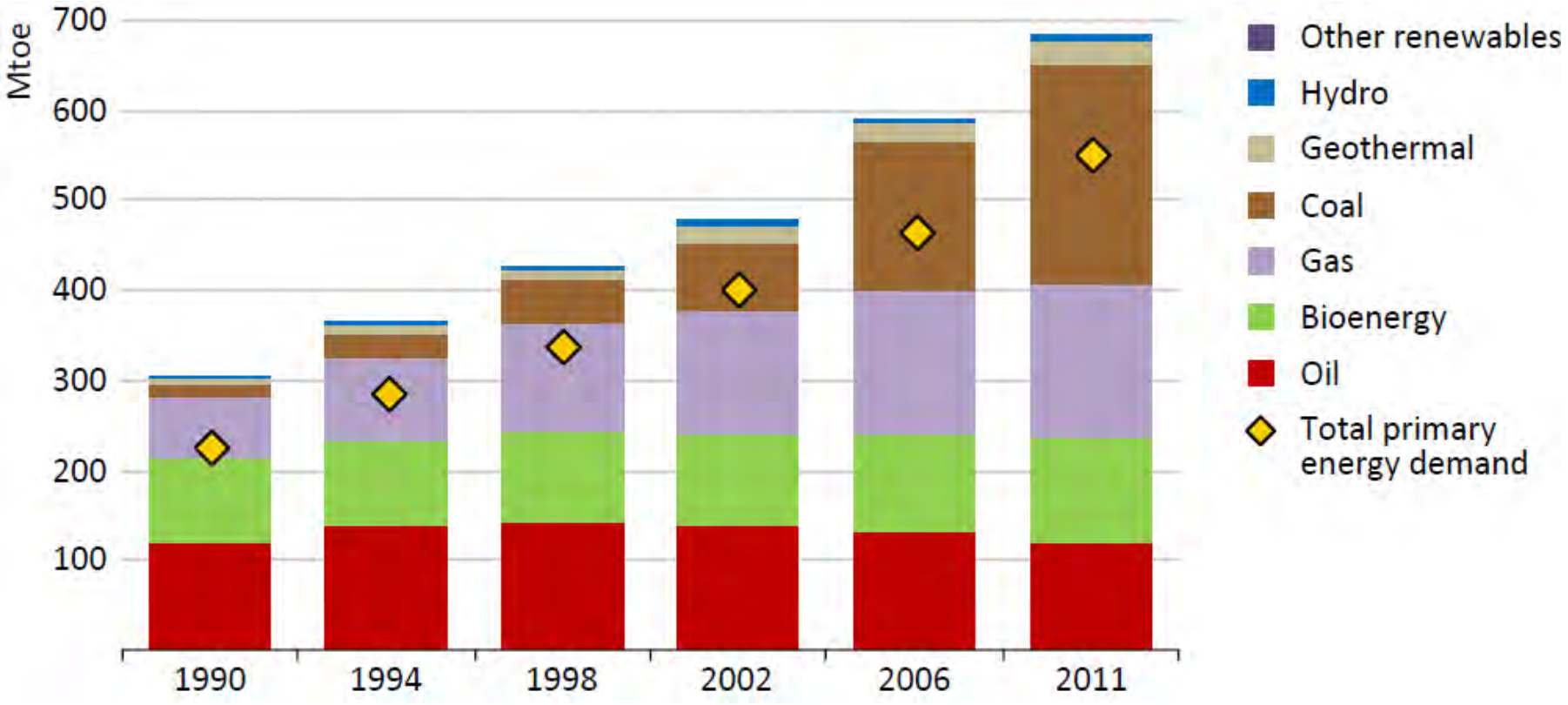


Some statistics – Worldwide



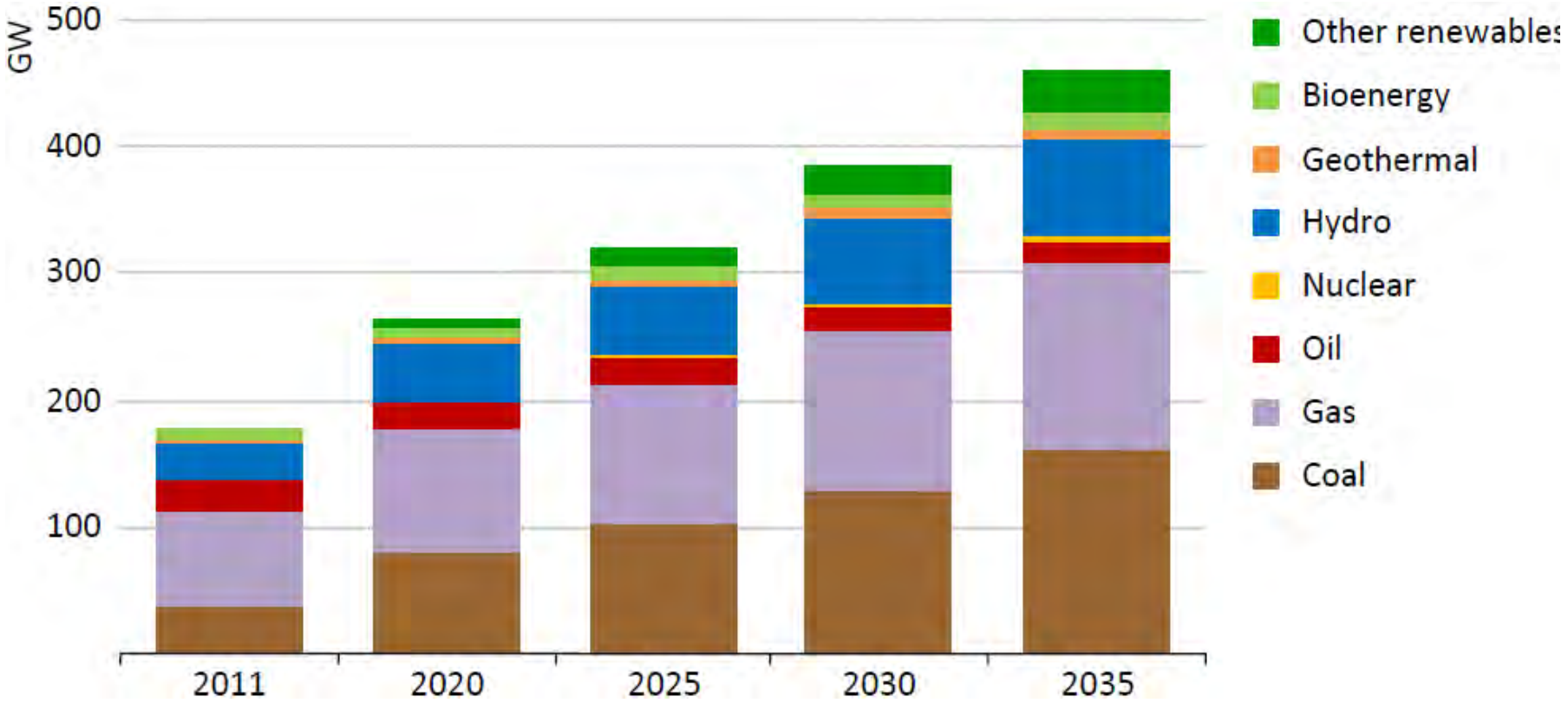
Some statistics – ASEAN

- Total energy production in ASEAN by source



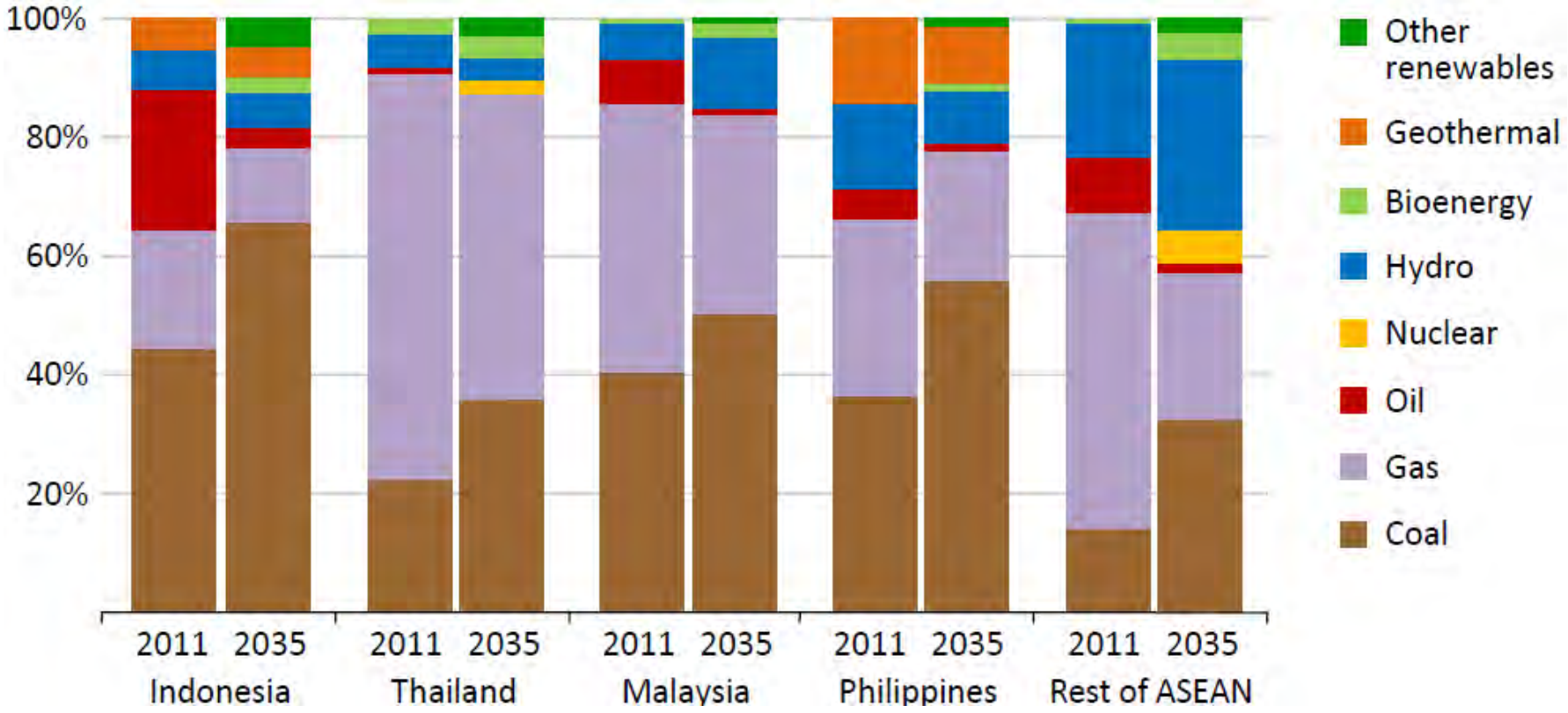
Some statistics – ASEAN

- ASEAN electricity generation capacity



Some statistics – ASEAN

- Electricity generation mix by country



Some statistics – CAMBODIA

- Bio-fuel: 1,000 ha plantation of Jatropha
- Bio-ethanol: 36,000 t/year from cassava
- Solar PV: 3 MW
- Solar battery charging station: ~110KW
- Solar Home System: 12,000 systems
- Biomass gasification: ~90KW
- Micro hydropower: ~500KW
- Large hydropower: ~230MW

THANK YOU

Promotion of Energy Science Education for Sustainable Development in Cambodia

Theme 5: Renewable Energy

Theme 5-2: Solar Photovoltaic

Dr. Long Bun

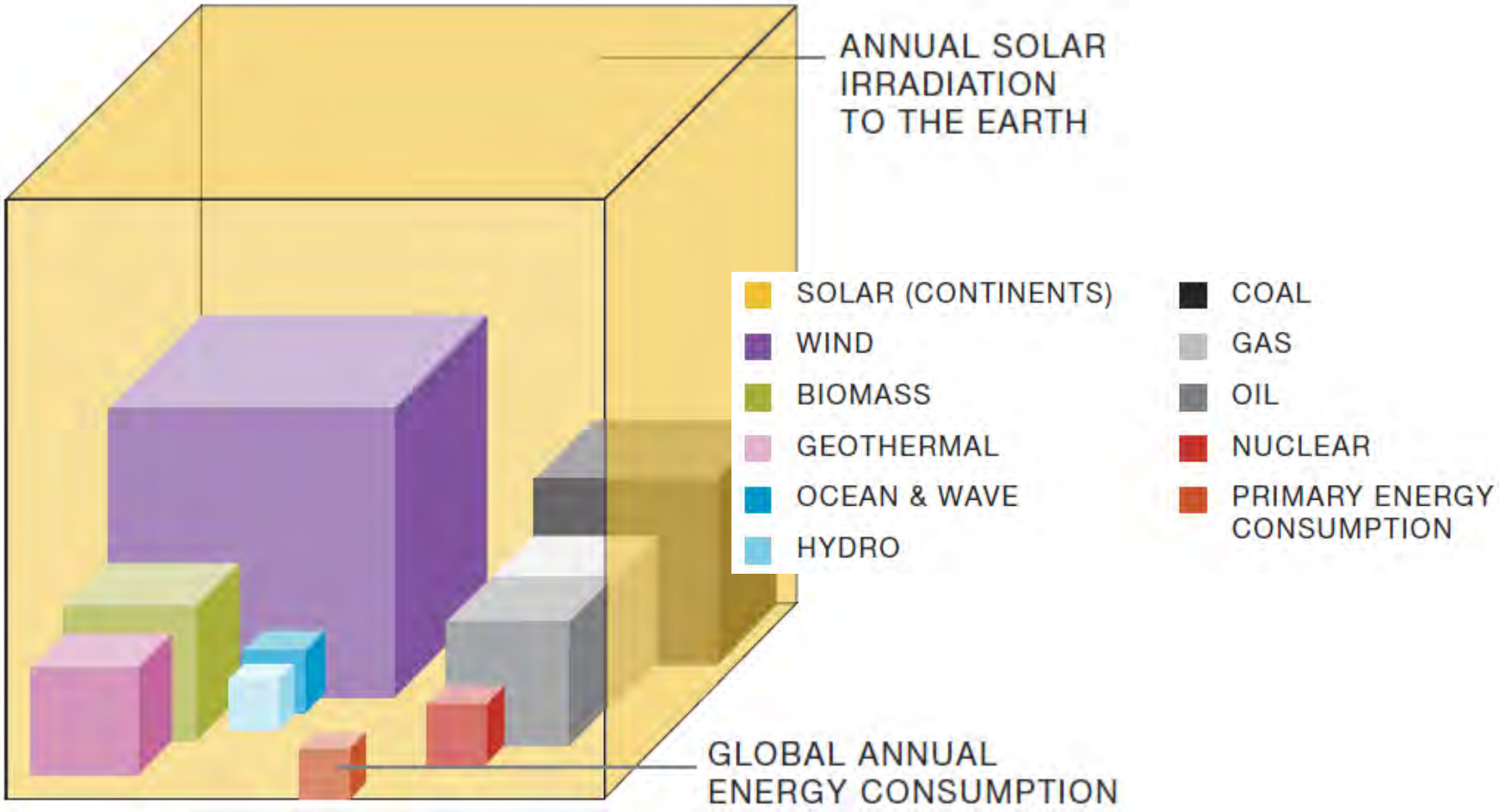
Vice Head of Department of Electrical and Energy Engineering

Institute of Technology of Cambodia

Layout

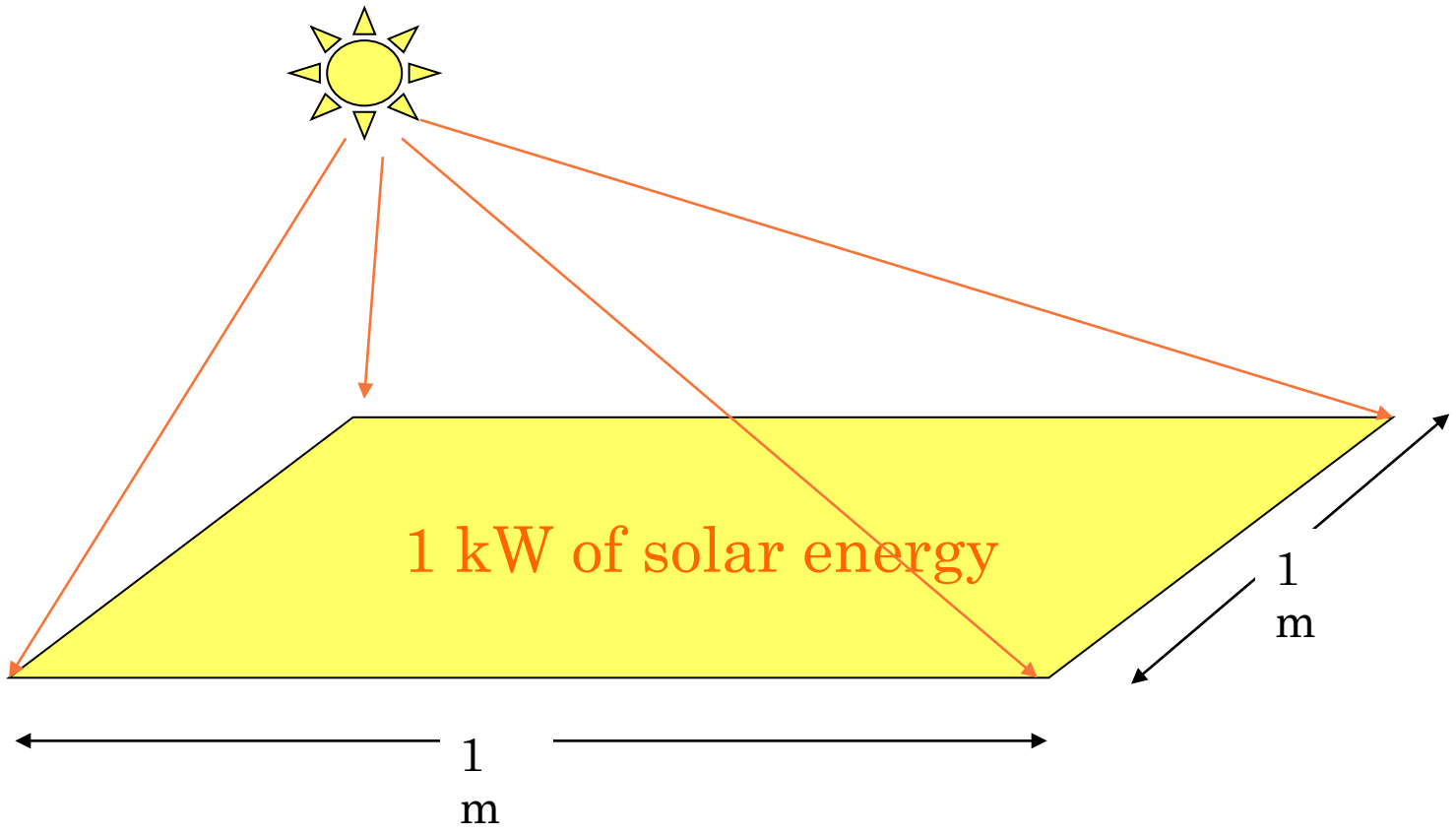
- Solar resources
- How does it works?
- Technologies
- PV characteristics and affecting parameters
- PV system types and balance of system
- Utilization of PV systems

Availability of energy

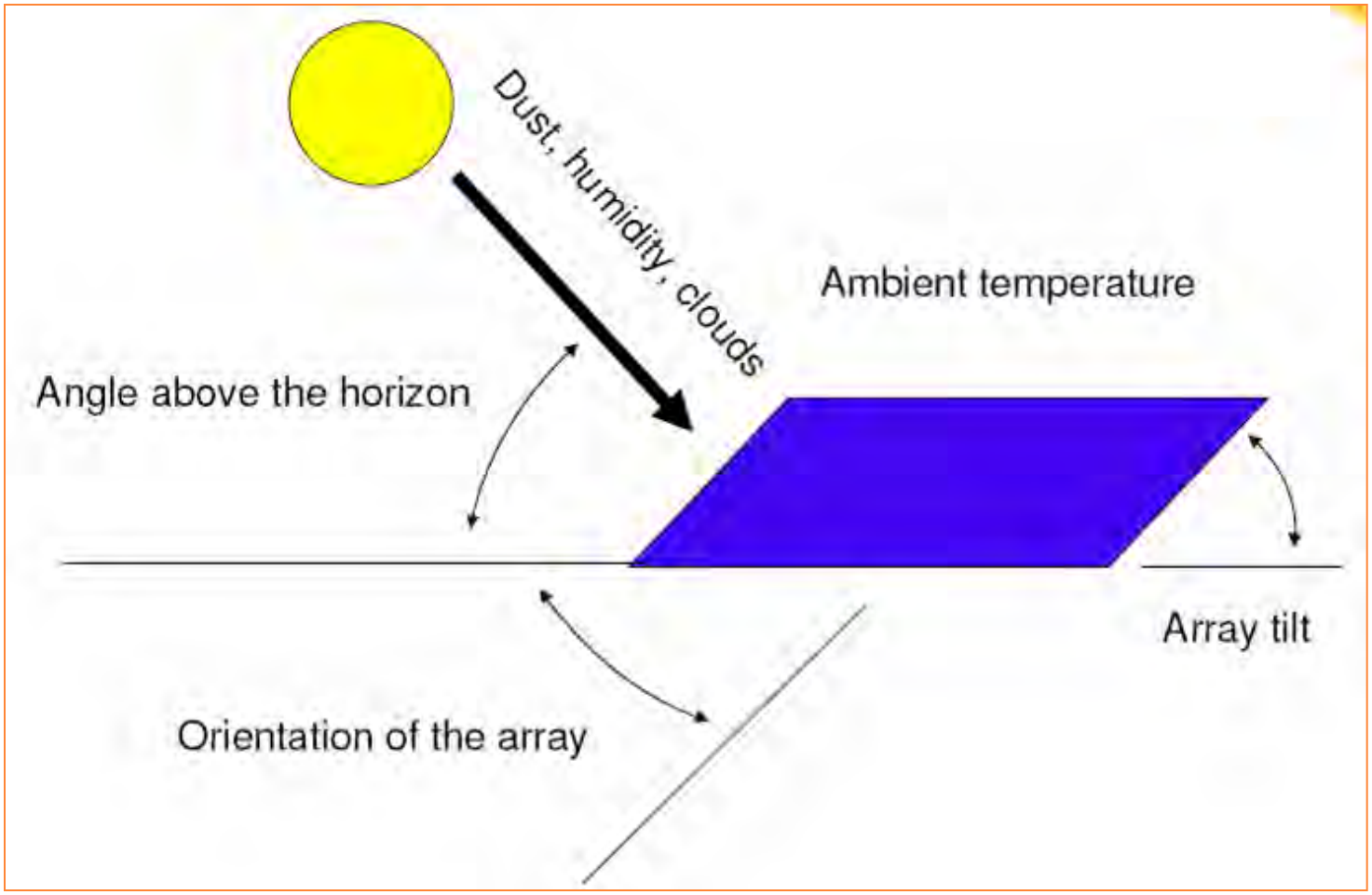


Solar radiation on the Earth's surface

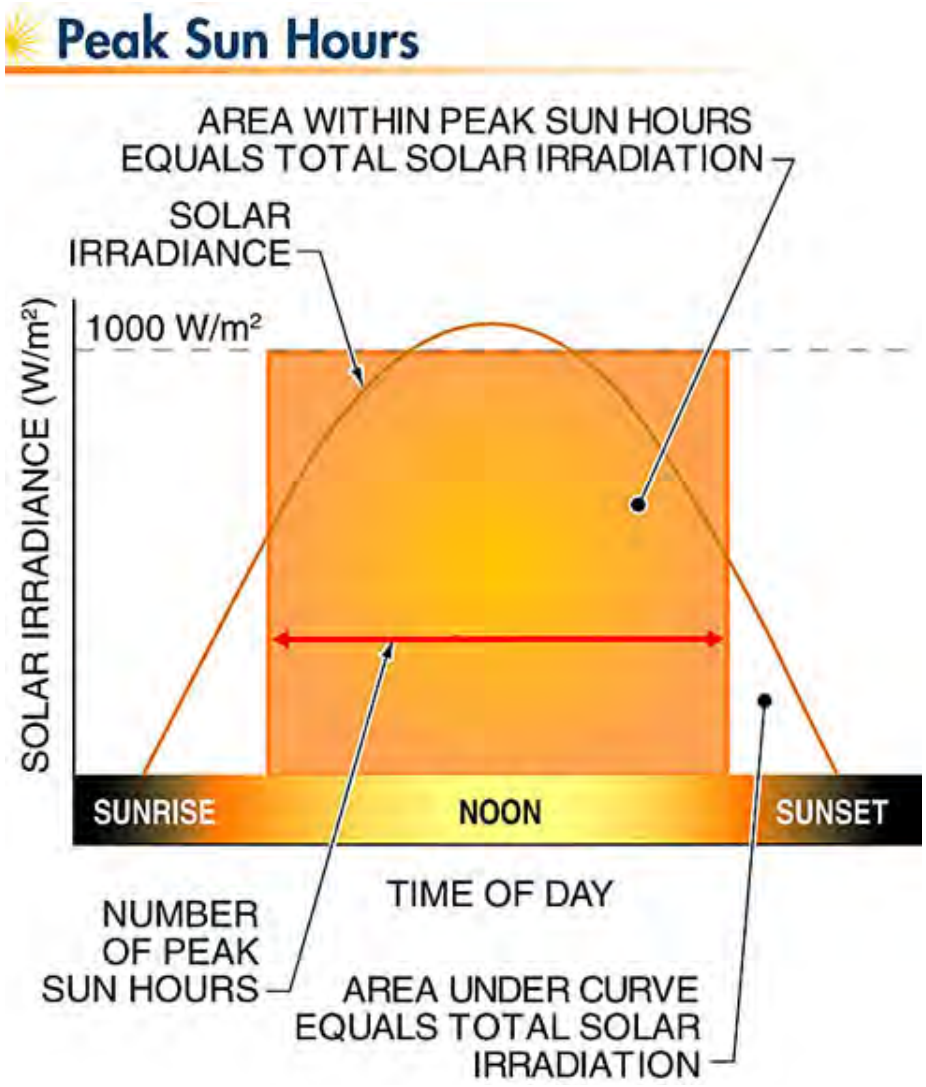
- Under clear sky, 1 m^2 of the Earth's surface intercepts 1 kW solar energy



How Does PV System Output Vary?

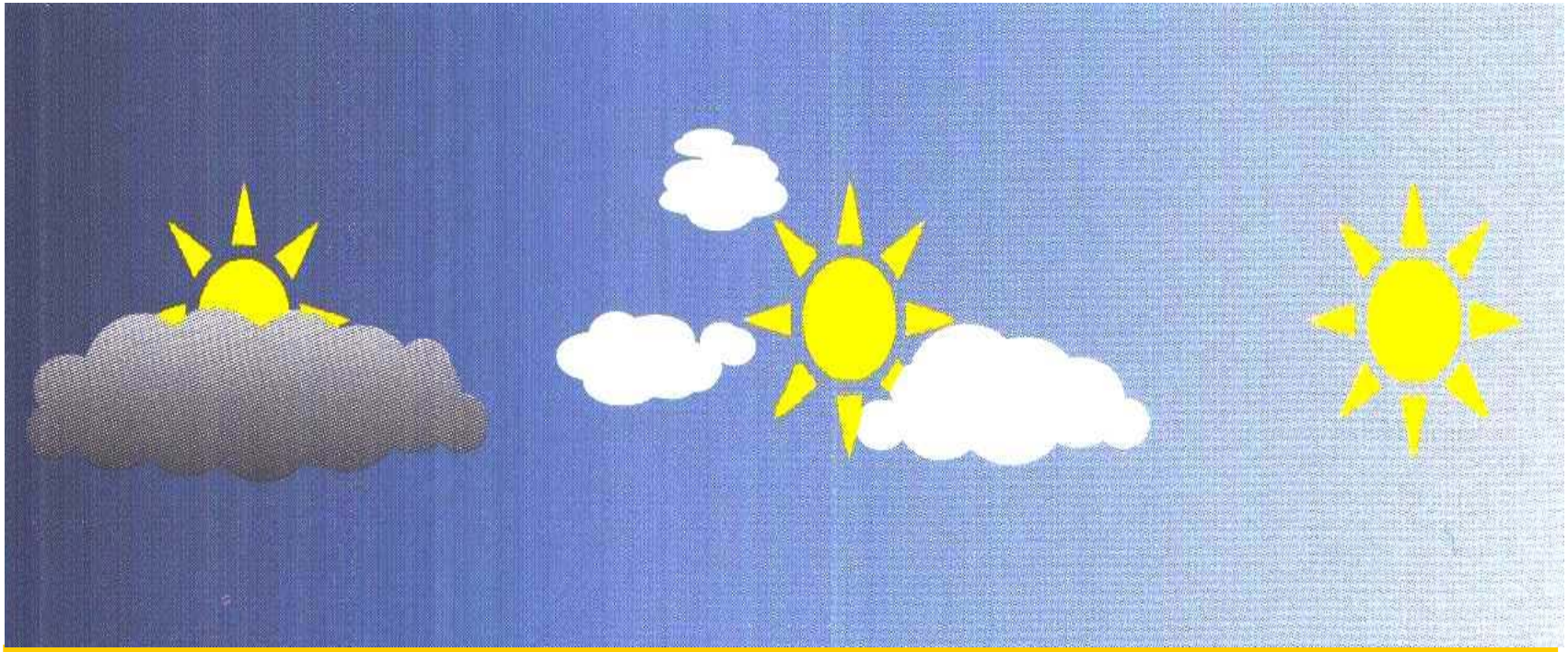


Solar irradiance



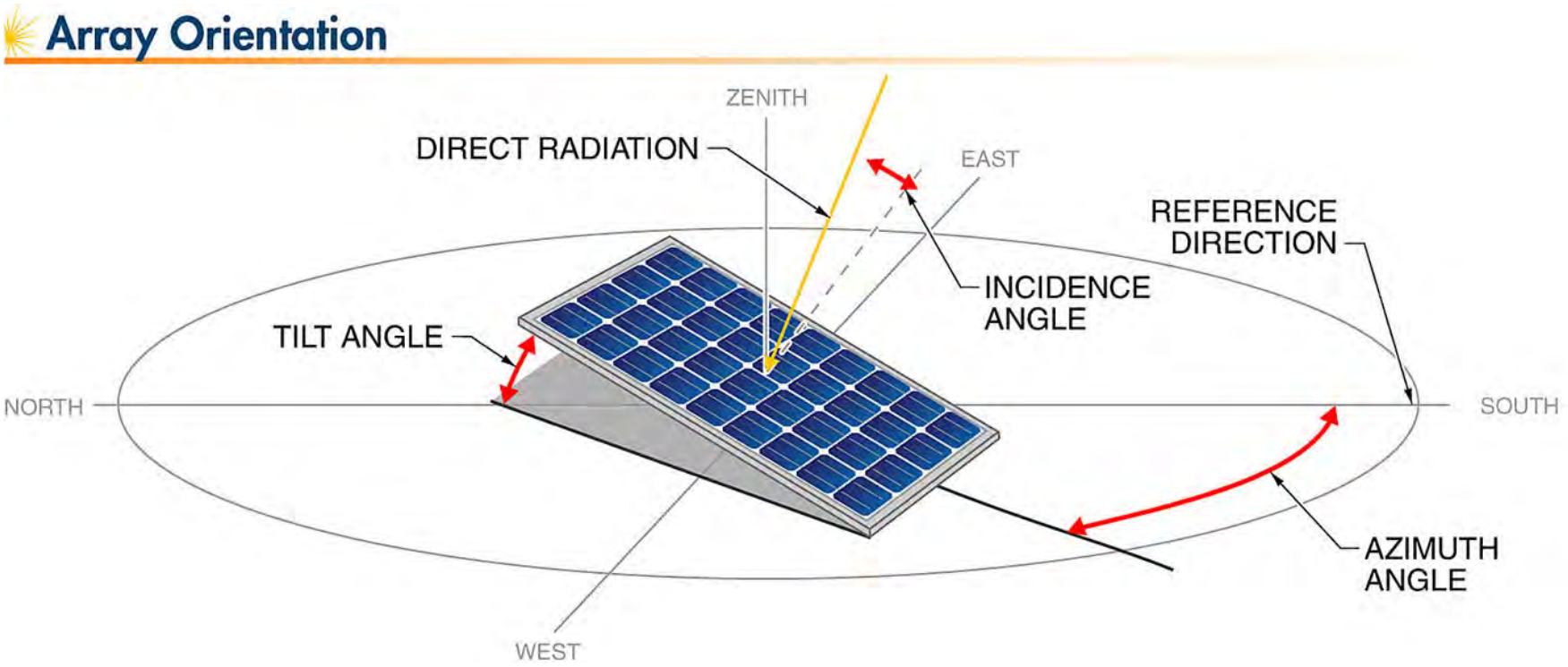
Solar radiation intensity

- Insolation intensity in different clearness of the sky

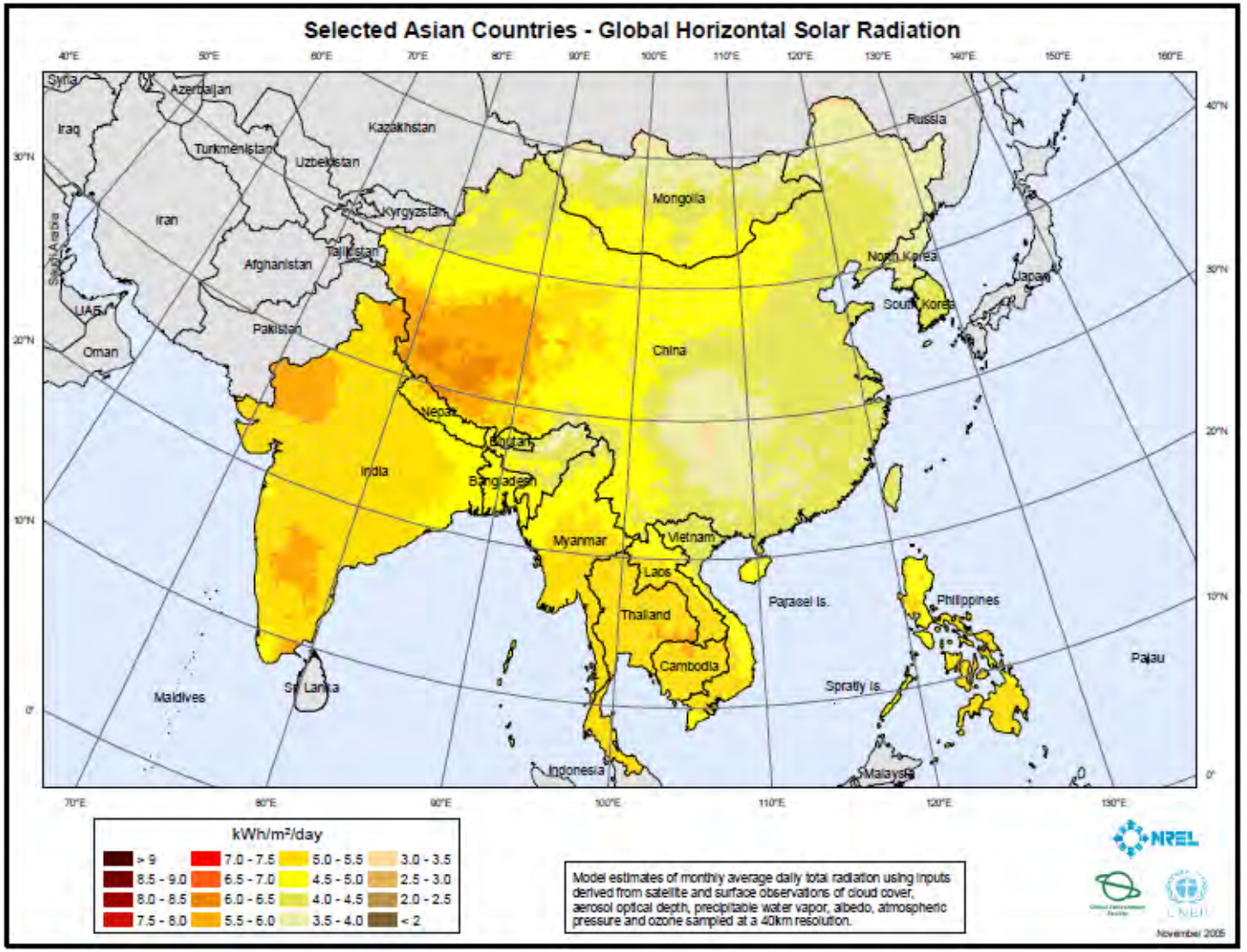


50 - 200 W/m^2 200 - 700 W/m^2 700 - 1000 W/m^2

Array orientation

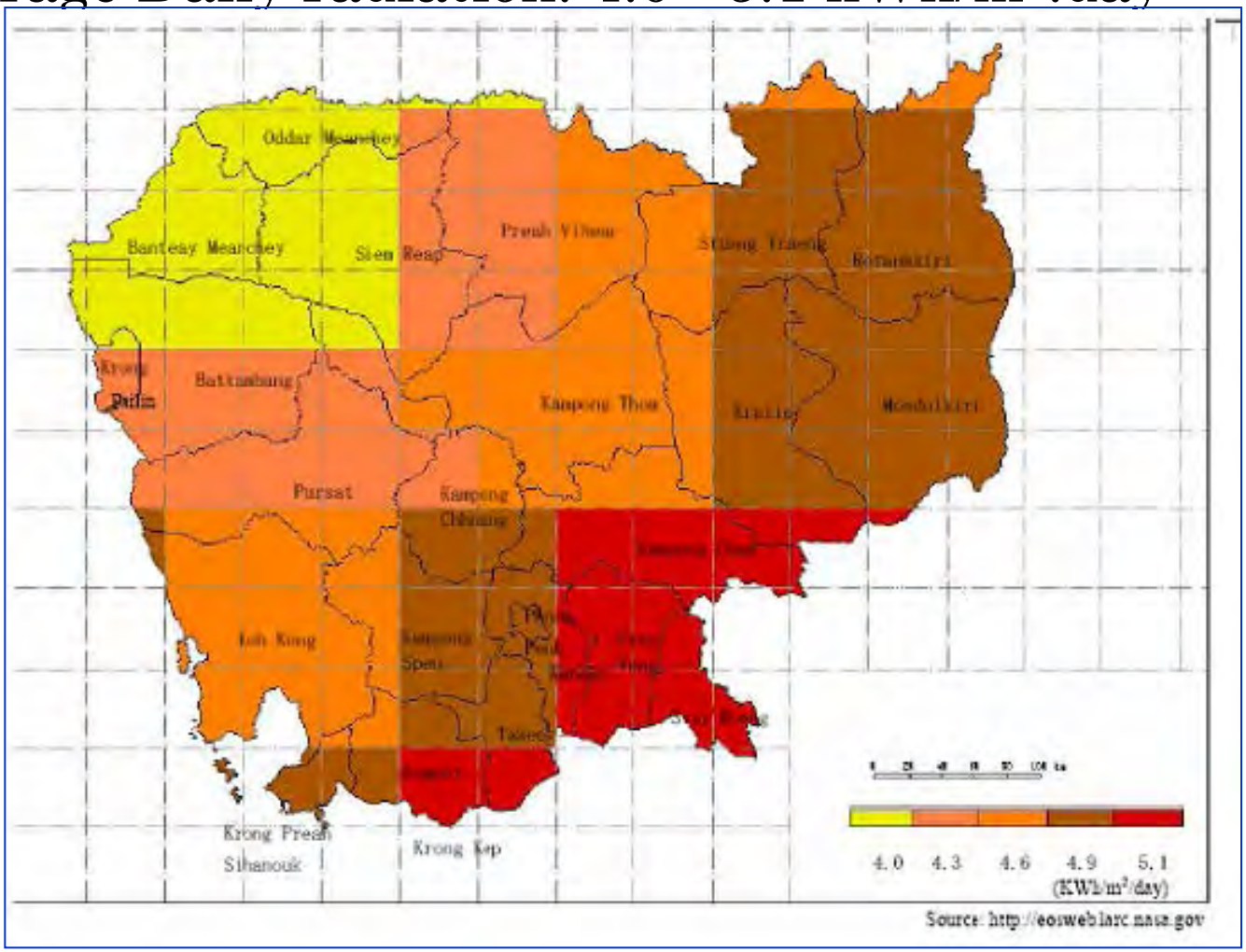


Solar resource in Asian countries



Solar resource in Cambodia

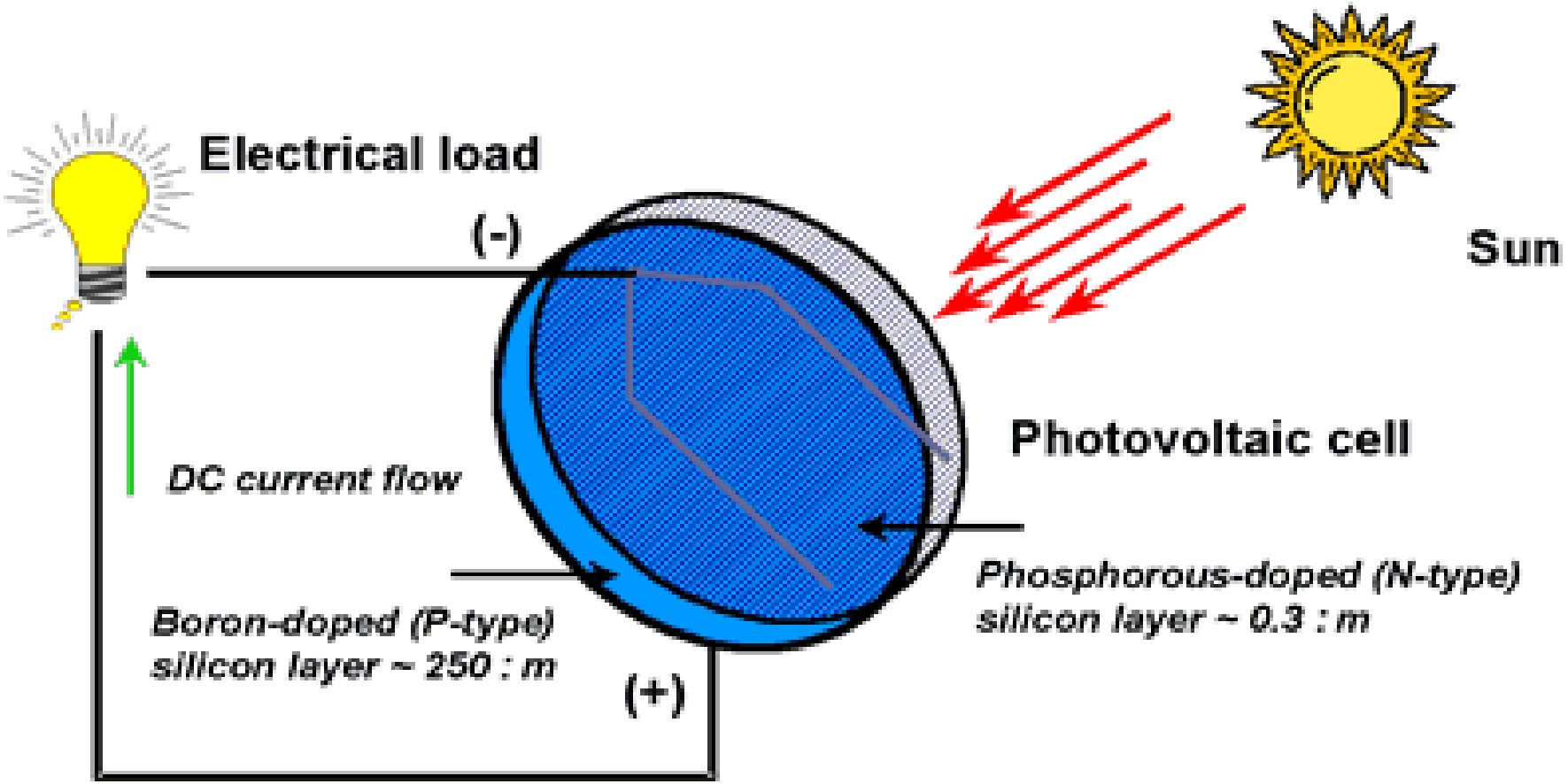
- Average Daily radiation: 4.0 - 5.1 kWh/m^2.day



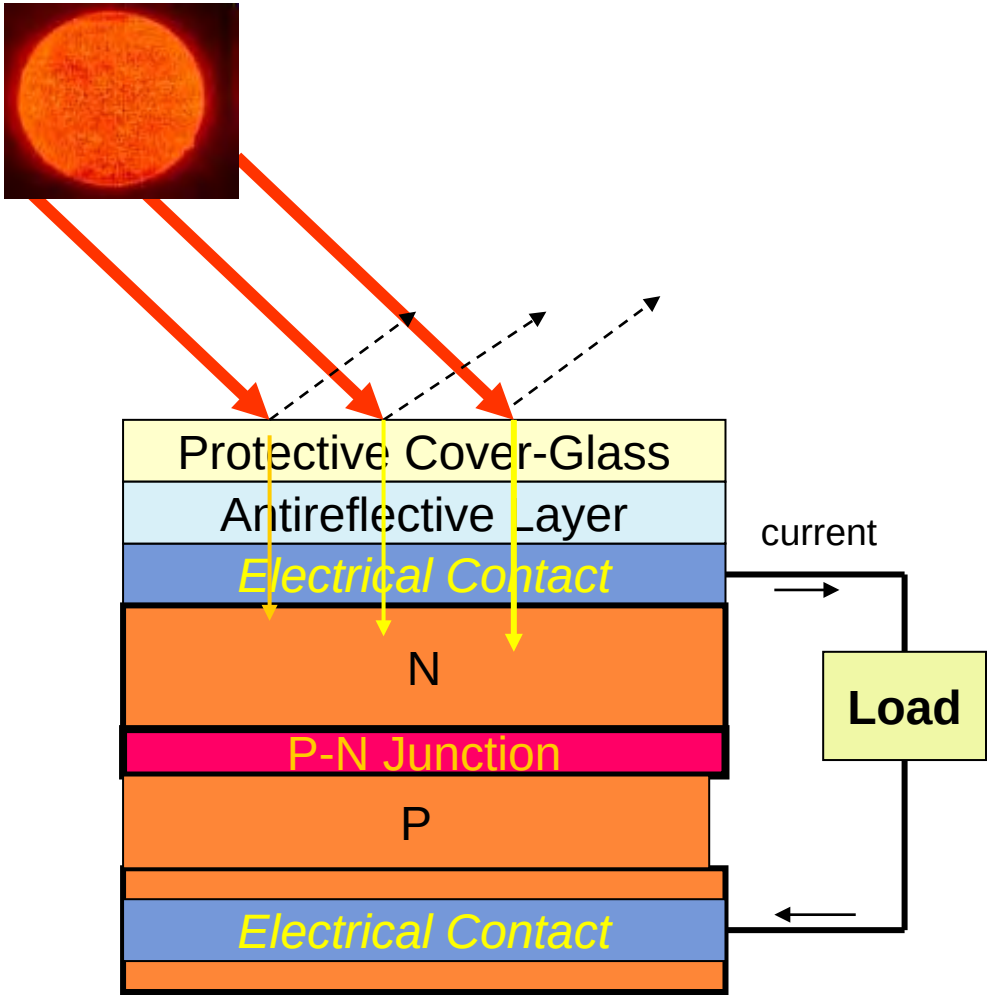
Layout

- Solar resources
- How does it works?
- Technologies
- PV characteristics and affecting parameters
- PV system types and balance of system
- Utilization of PV systems

How solar cells generate electricity

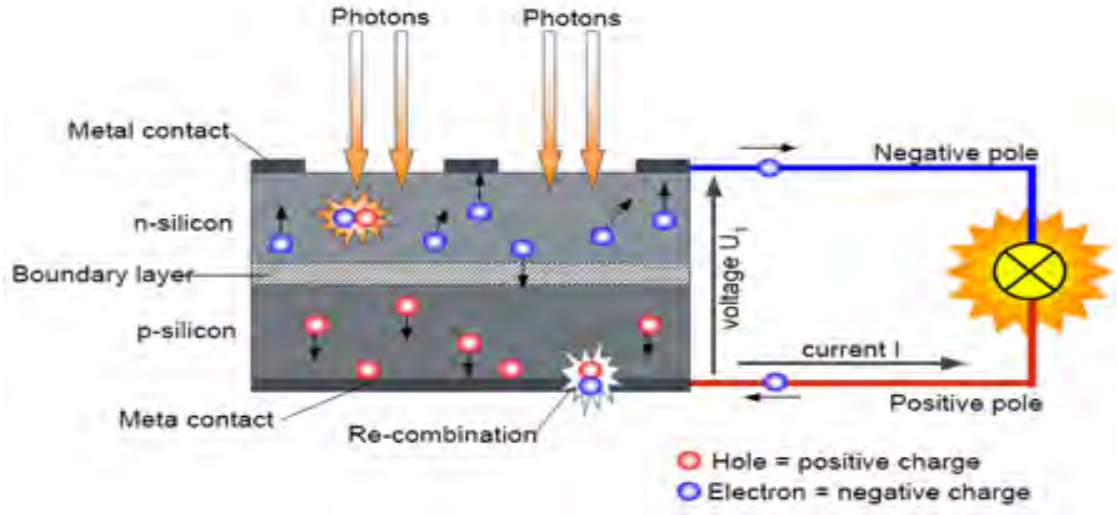


Solar cell schematic



The process

- Sunlight is made of photons, small particles of energy.
- These photons are absorbed by and pass through the material of a solar cell or solar PV panel.
- The photons 'agitate' the electrons found in the material of the photovoltaic cell.
- As they begin to move (or are dislodged), these are 'routed' into a current.
- This, technically, is electricity - the movement of electrons along a path.

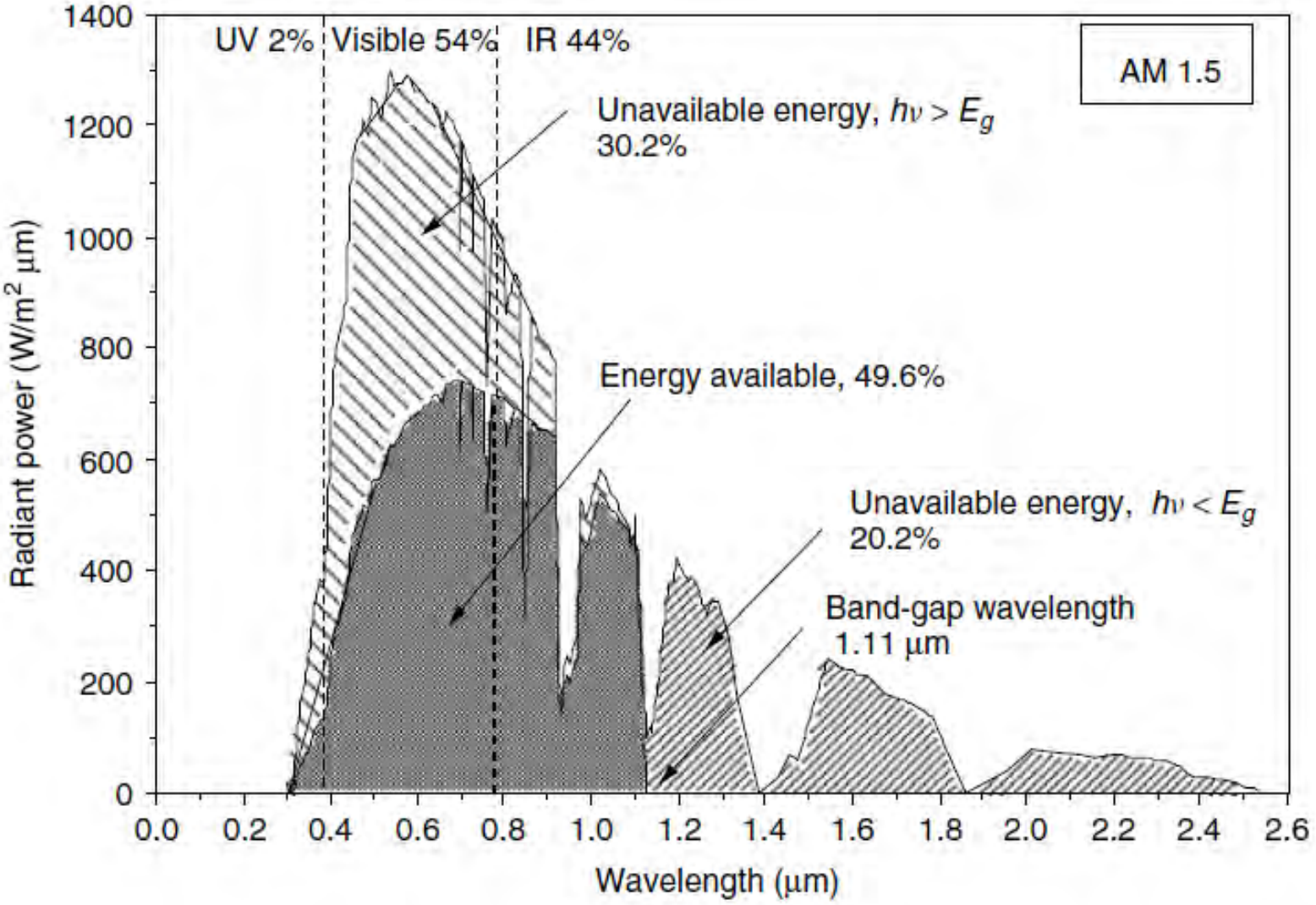


Solar spectrum

- The amount of energy in order for the electrons to agitate in the semiconductor is 1.12 eV, for the case of silicon solar cell.
- This amount of energy may vary according to the material used to fabricate the solar cell.
- Photon themselves contain energy less than or more than 1.12 eV, depending on the type solar radiation (wavelength of the solar radiation).

Quantity	Si	GaAs	CdTe	InP
Band gap (eV)	1.12	1.42	1.5	1.35
Cut-off wavelength (μm)	1.11	0.87	0.83	0.92

Solar spectrum



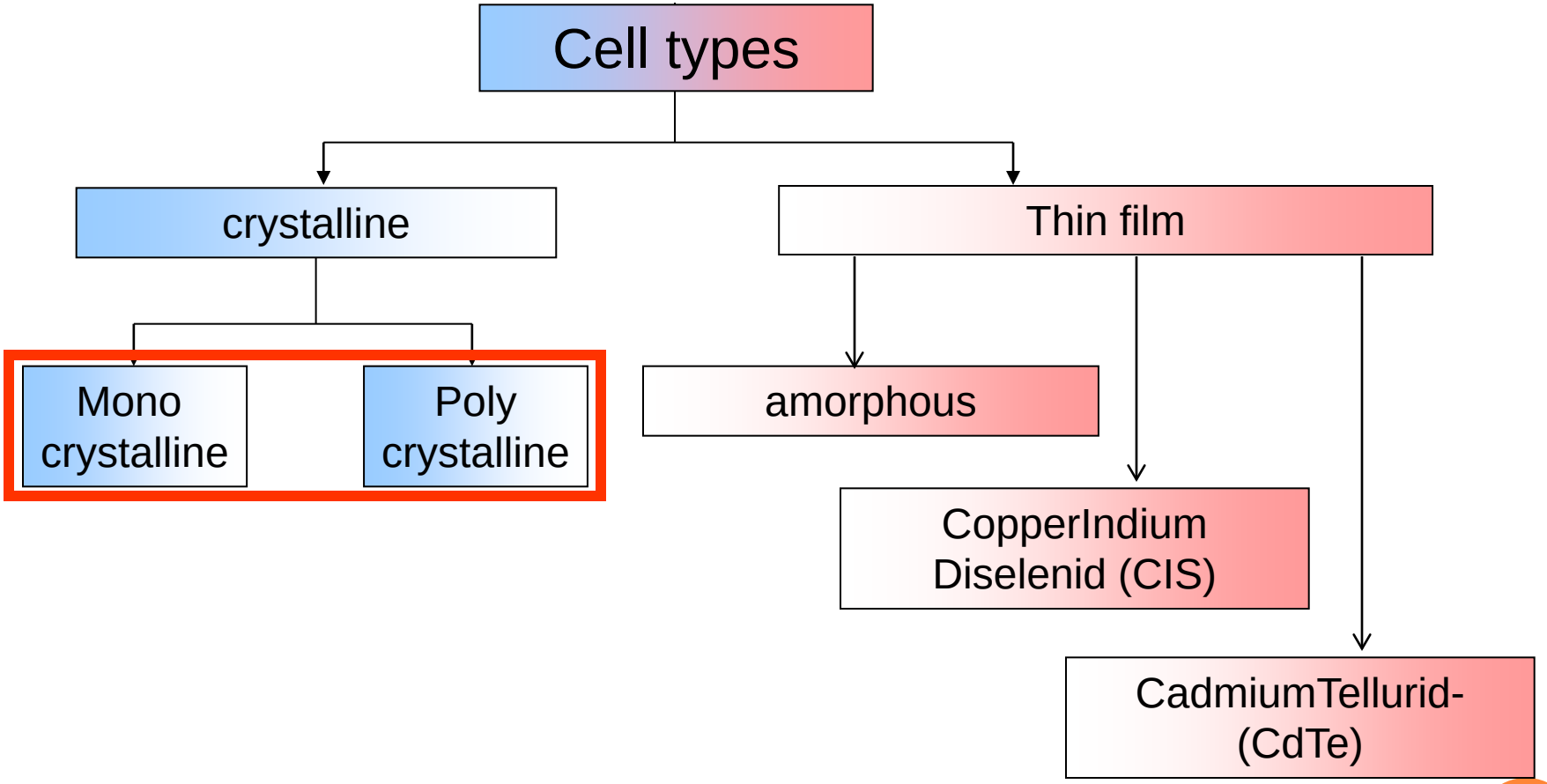
Solar spectrum

- 20.2% of the energy in the spectrum is lost due to too low energy of the photons, and another 30.2% is lost due to too high energy of the photons.
- The remaining 49.6% represents the maximum possible fraction of the sun's energy that could be collected with a silicon solar cell.
- Other factors that contribute to the drop in theoretical efficiency:
  - Only about half to two-thirds of the full band-gap voltage across the terminals of the solar cell.
  - Recombination of holes and electrons before they can contribute to current flow.
  - Photons that are not absorbed in the cell either because they are reflected off the face of the cell, or because they pass right through the cell, or because they are blocked by the metal conductors that collect current from the top of the cell.
  - Internal resistance within the cell, which dissipates power.

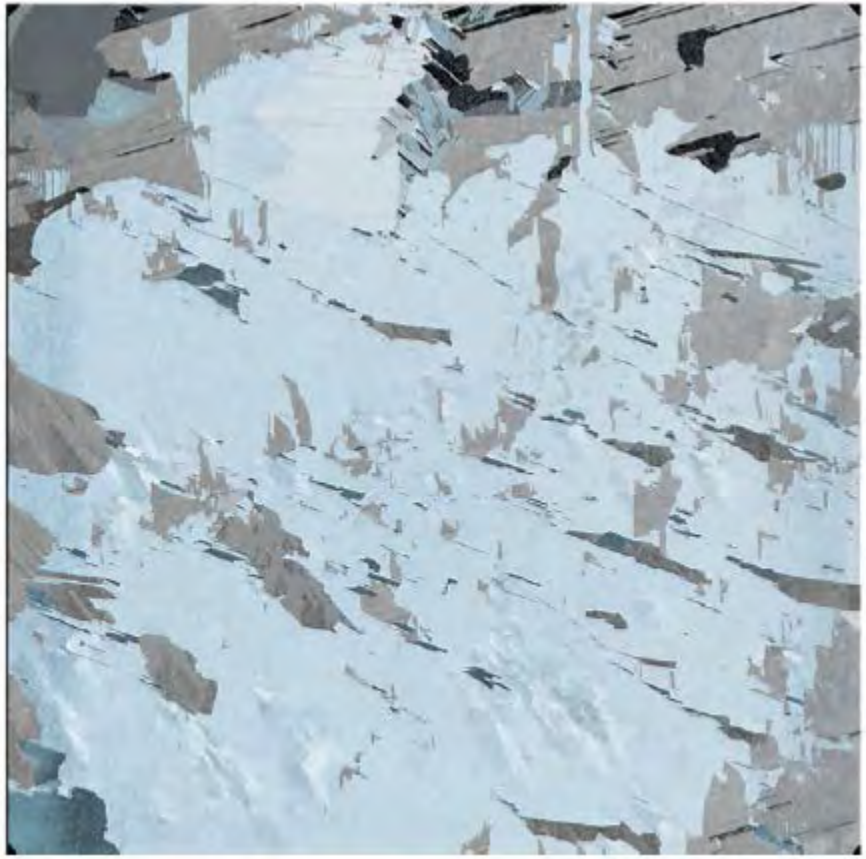
Layout

- Solar resources
- How does it works?
- Technologies
- PV characteristics and affecting parameters
- PV system types and balance of system
- Utilization of PV systems

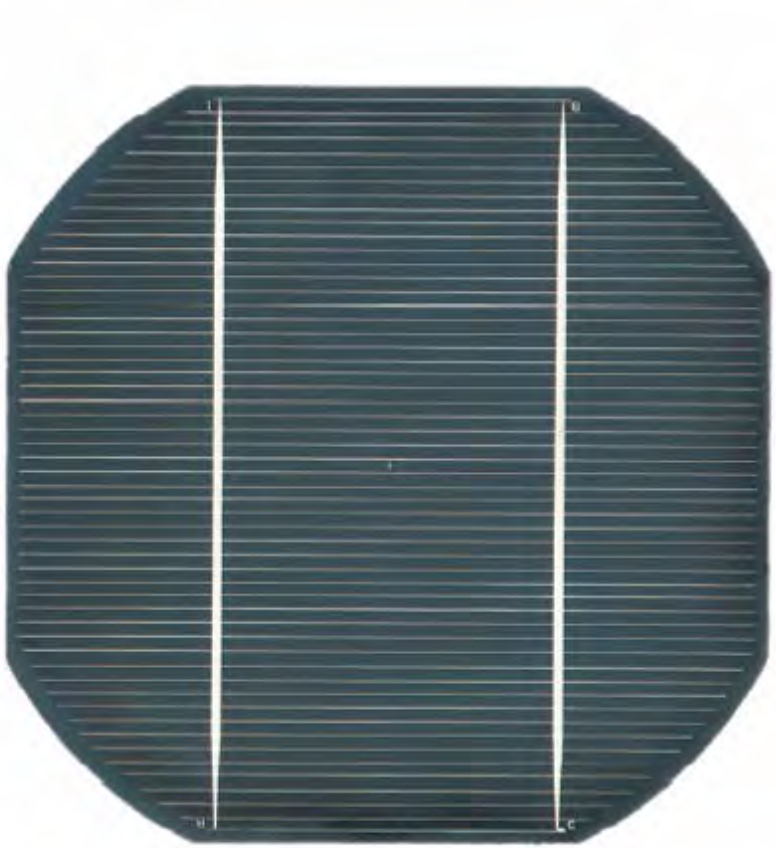
Cell technology

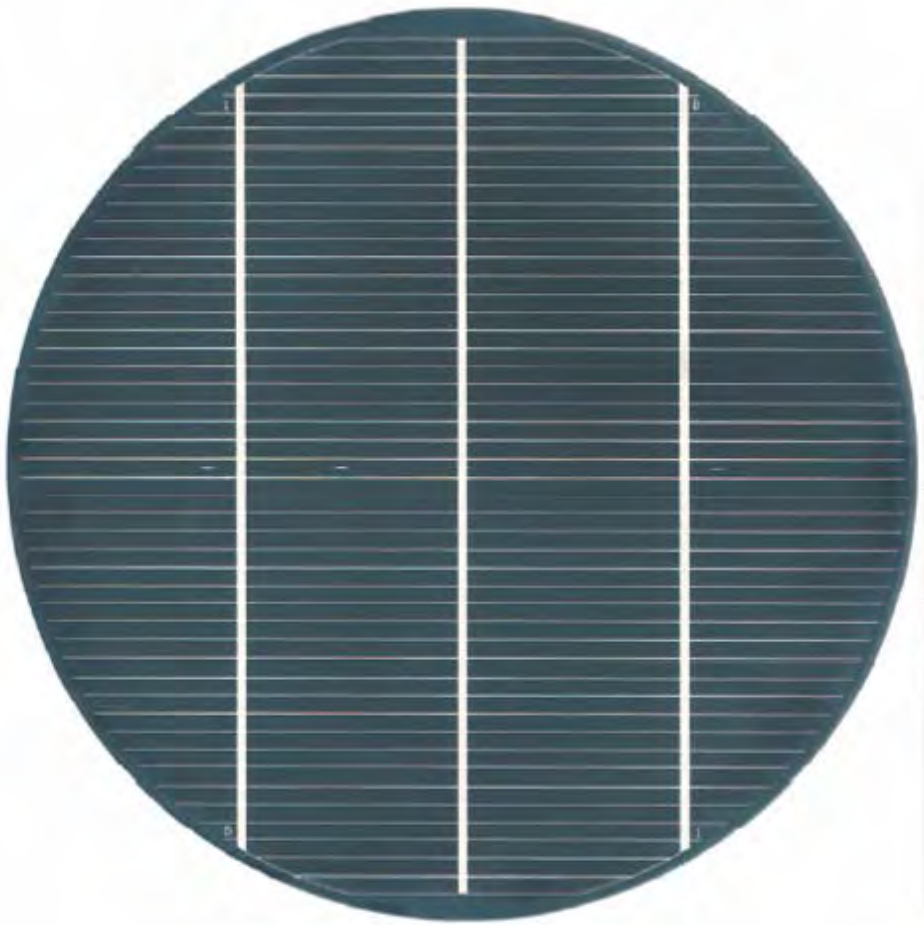


Poly crystalline

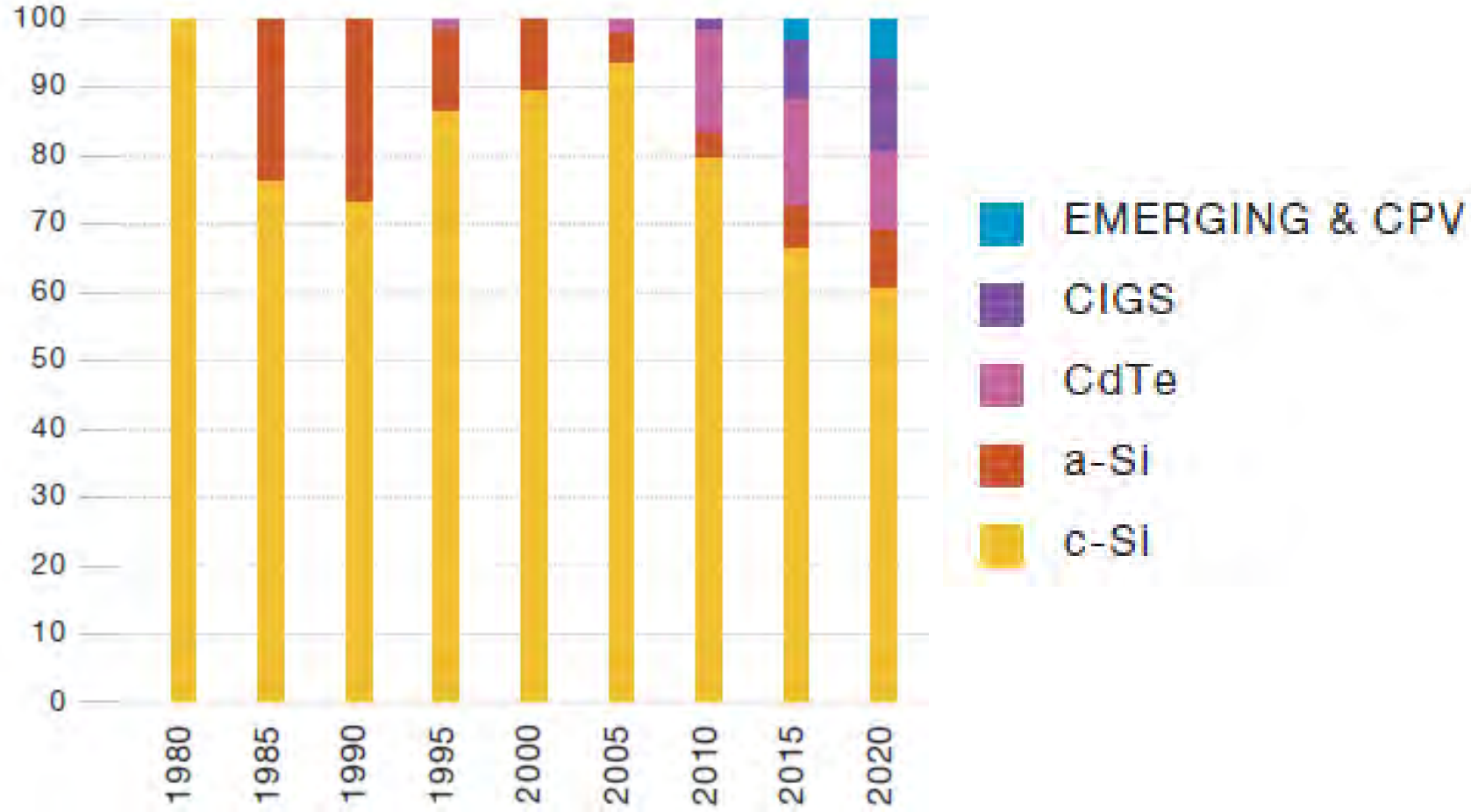


Mono crystalline

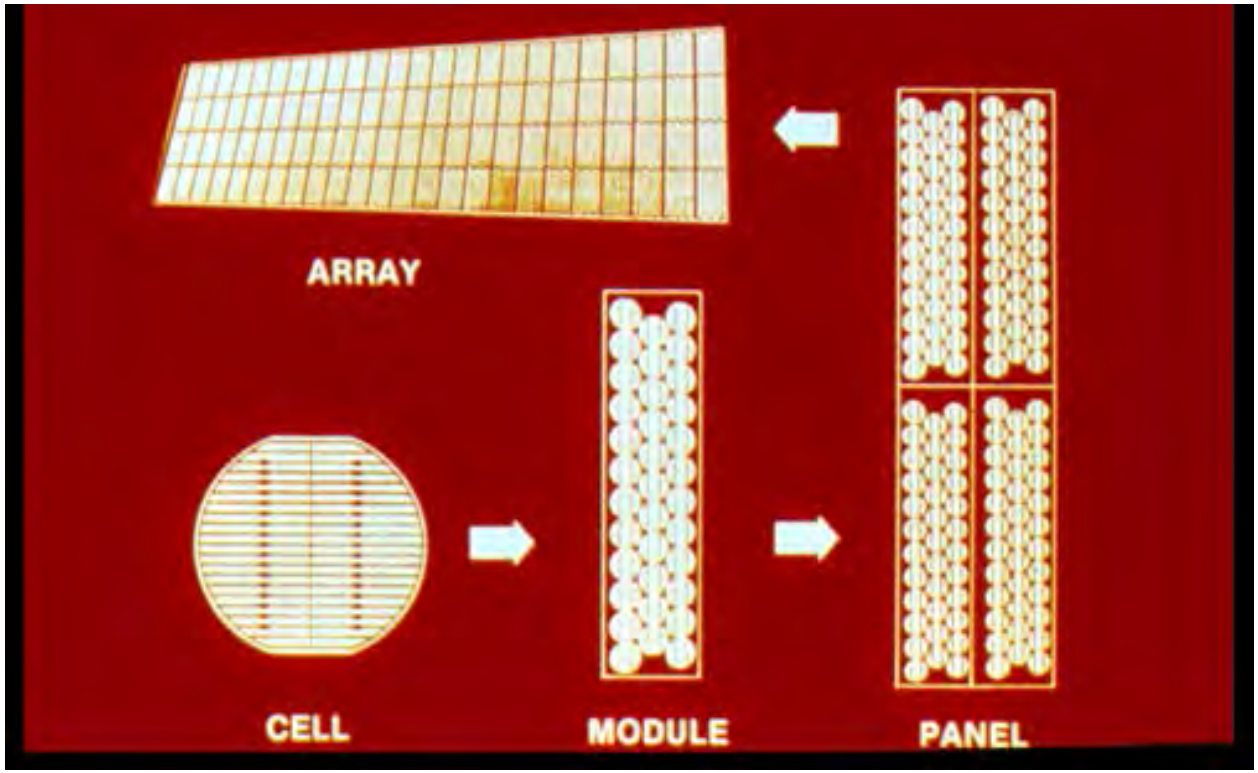




Market share of solar cell technology



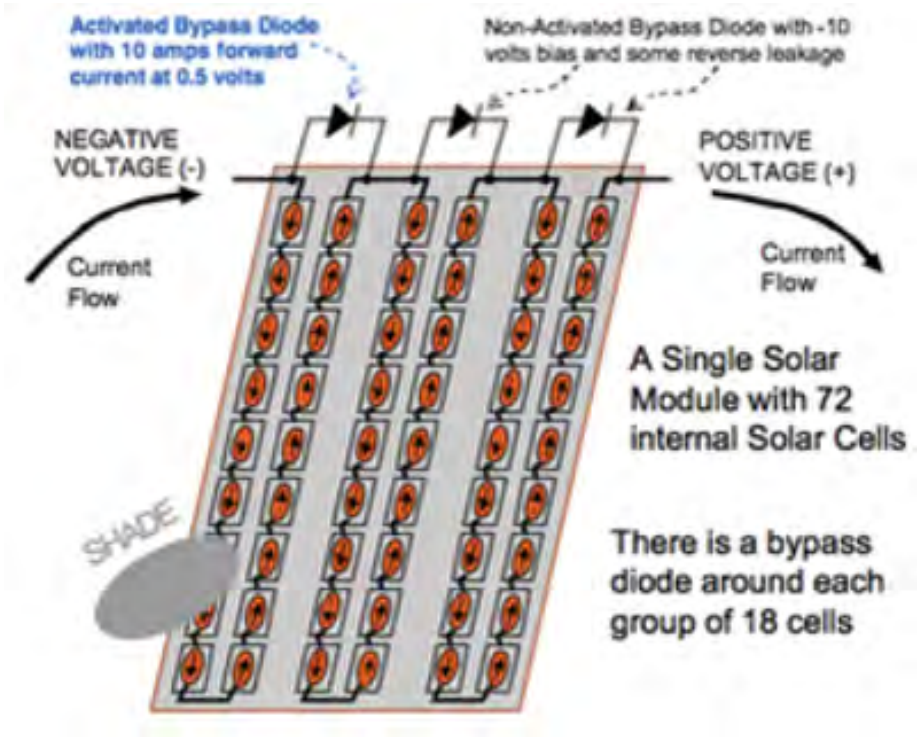
From cell to array



- The open circuit voltage of a single solar cell is approx 0.5V.
- Solar cells are connected in series to increase its voltage.
- Modules are connected in parallel to increase its current, hence the power.

From cell to array

- Number of cells per module: 36, 54, 60, 72, 96
- Most of the case :
  - 36 cells for 12 system voltage
  - 72 cells for 24 system voltage
- Bypass diode

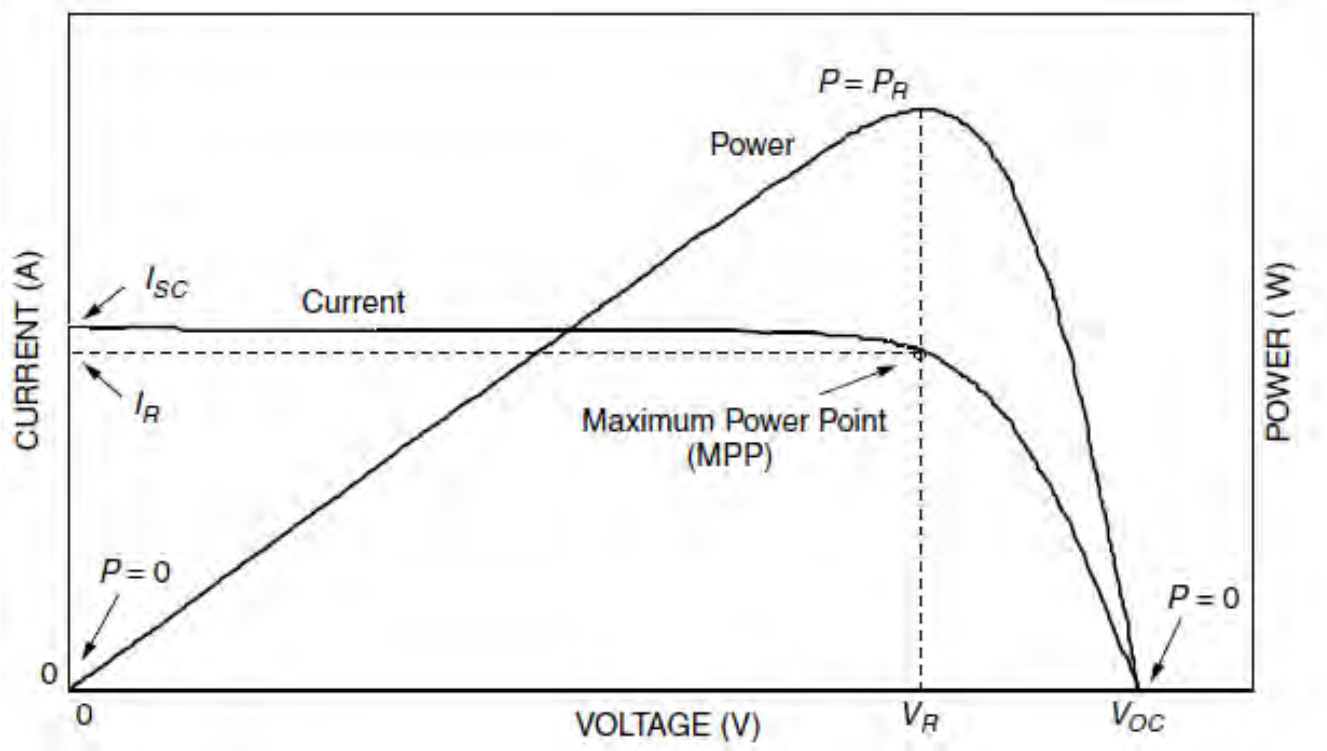


Layout

- Solar resources
- How does it works?
- Technologies
- PV characteristics and affecting parameters
- PV system types and balance of system
- Utilization of PV systems

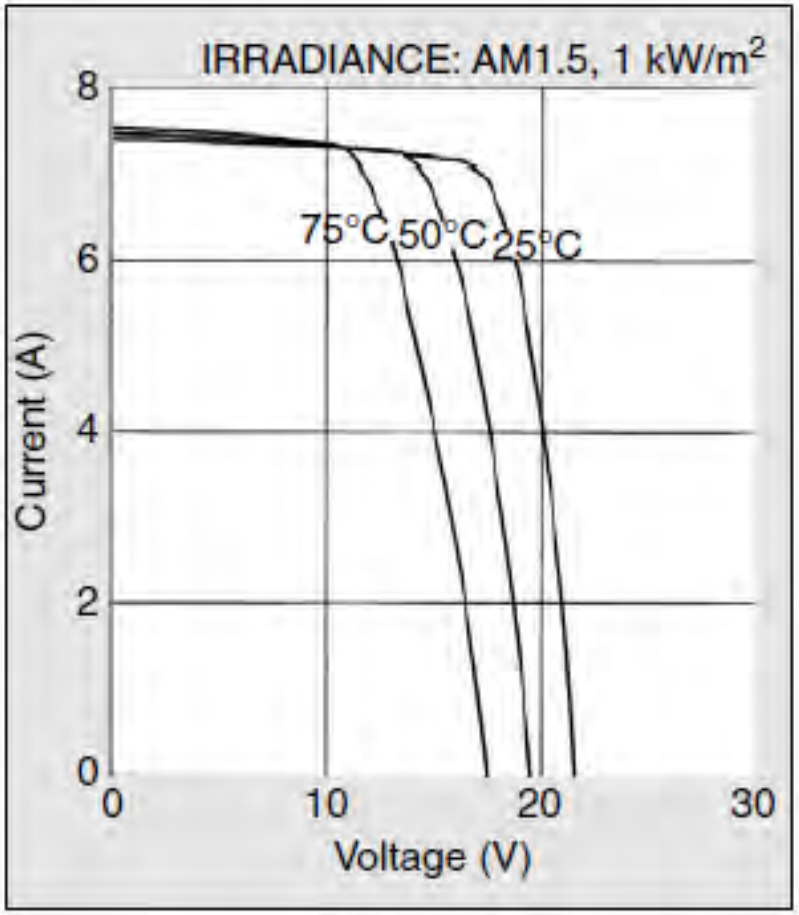
I-V CHARACTERISTIC OF PV CELL

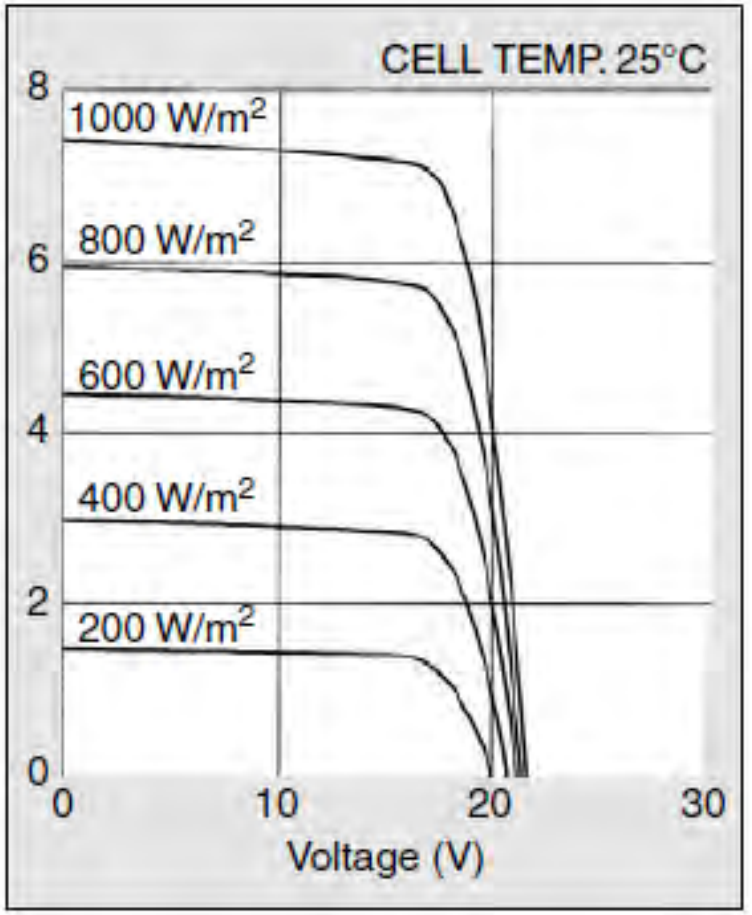
- Three main points on the I-V curve of PV cell
  - Short circuit current (Isc)
  - Open circuit voltage (Voc)
  - Maximum Power Point (MPP)



Variation of I-V characteristic of PV cell

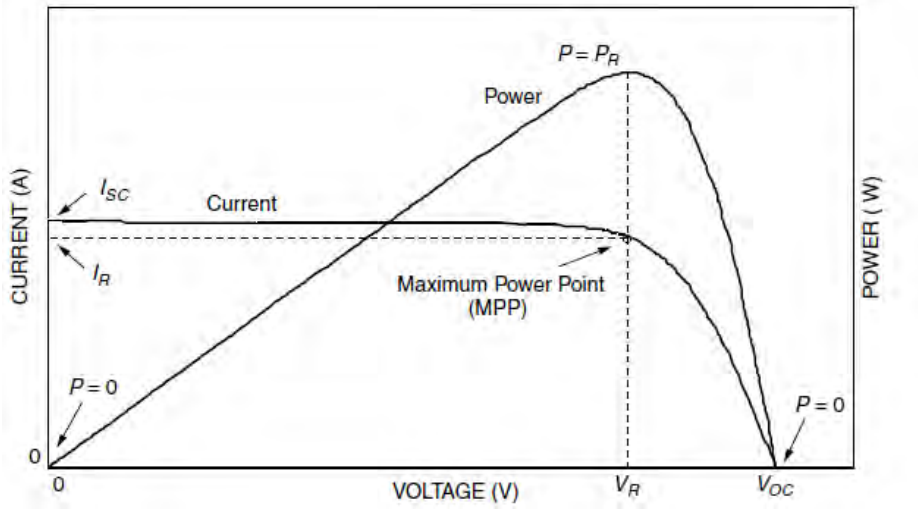
- Effect of temperature and irradiance on I-V characteristic





Standard Test Conditions (STC)

- Standard Test Conditions:
  - Solar irradiance of 1 kW/m2 (1 sun) with spectral distribution
  - Air mass ratio of 1.5 (AM 1.5).
  - The standard cell temperature for testing purposes is 25°C (it is important to note that 25°C is cell temperature, not ambient temperature).



EXAMPLES OF PV MODULE CHARACTERISTICS

Manufacturer	Kyocera	Sharp	BP	Uni-Solar	Shell
Model	KC-120-1	NE-Q5E2U	2150S	US-64	ST40
Material	Multicrystal	Polycrystal	Monocrystal	Triple junction a-Si	CIS-thin film
Number of cells n	36	72	72		42
Rated Power $P_{DC,STC}$ (W)	120	165	150	64	40
Voltage at max power (V)	16.9	34.6	34	16.5	16.6
Current at rated power (A)	7.1	4.77	4.45	3.88	2.41
Open-circuit voltage V_{OC} (V)	21.5	43.1	42.8	23.8	23.3
Short-circuit current I_{SC} (A)	7.45	5.46	4.75	4.80	2.68
Length (mm/in.)	1425/56.1	1575/62.05	1587/62.5	1366/53.78	1293/50.9
Width (mm/in.)	652/25.7	826/32.44	790/31.1	741/29.18	329/12.9
Depth (mm/in.)	52/2.0	46/1.81	50/1.97	31.8/1.25	54/2.1
Weight (kg/lb)	11.9/26.3	17/37.5	15.4/34	9.2/20.2	14.8/32.6
Module efficiency	12.9%	12.7%	12.0%	6.3%	9.4%

Fill Factor (FF)

- Fill Factor (FF) is a quantity that is often used to characterize module performance.
- *The fill factor is the ratio* of the power at the maximum power point to the product of V_{OC} *and* I_{SC}.

$$\text{Fill factor (FF)} = \frac{\text{Power at the maximum power point}}{V_{OC}\ I_{SC}} = \frac{V_R I_R}{V_{OC} I_{SC}}$$

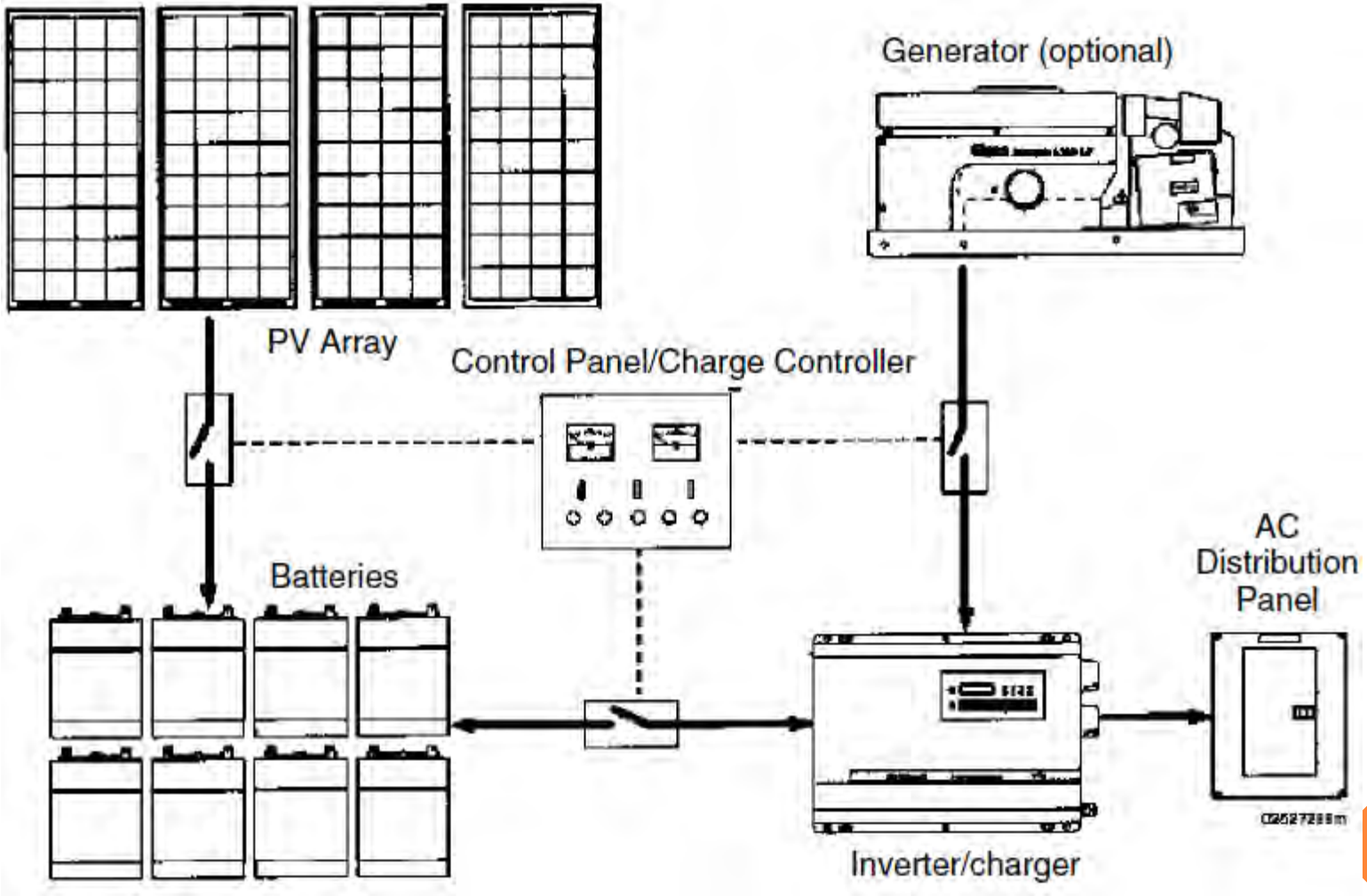
- Fill factors around 70–75% for crystalline silicon solar modules are typical, while for multi-junction amorphous-Si modules, it is closer to 50–60%.

Layout

- Solar resources
- How does it works?
- Technologies
- PV characteristics and affecting parameters
- PV system types and balance of system
- Utilization of PV systems

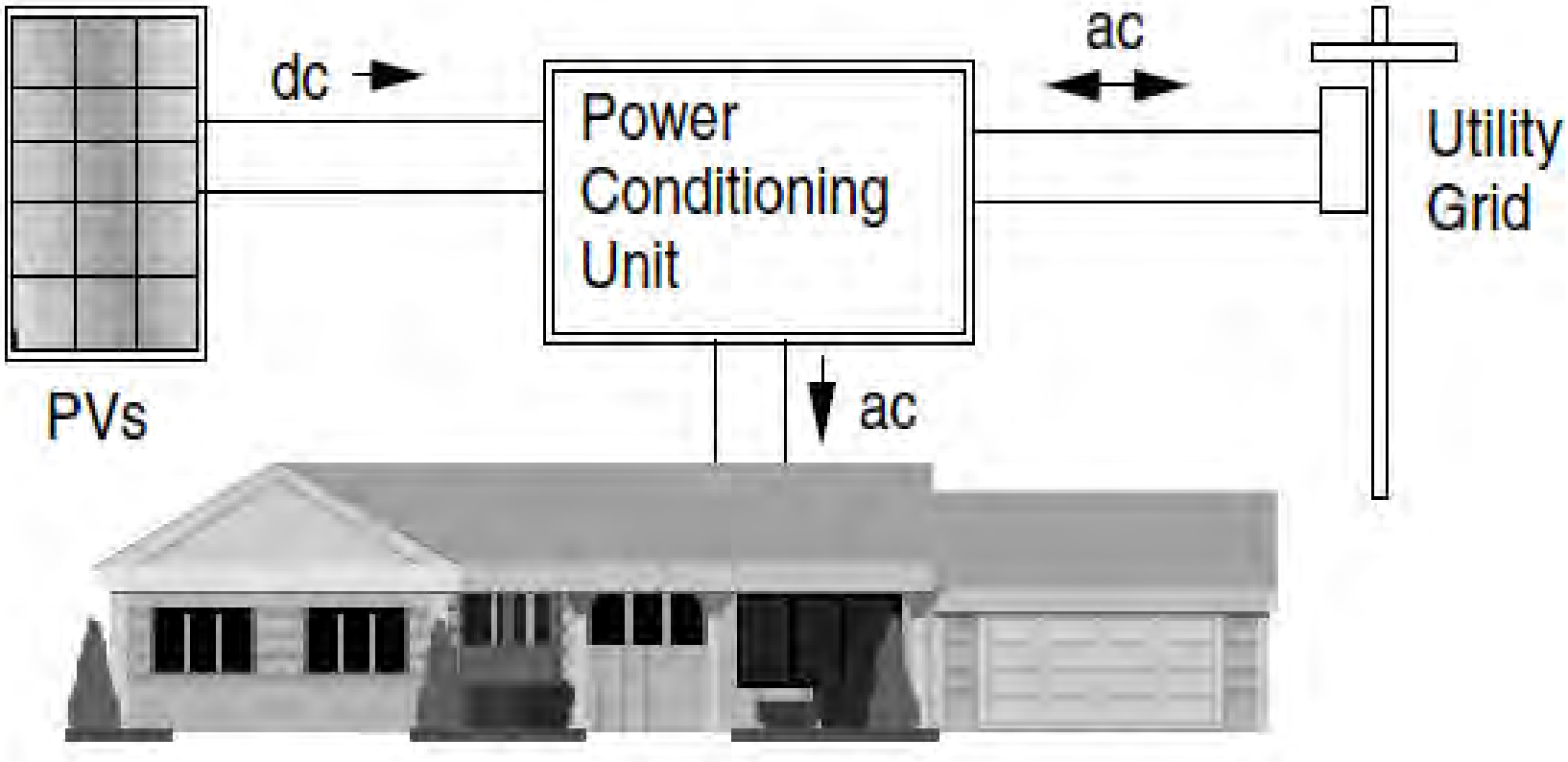
Stand alone PV systems

- An example of a stand alone PV system

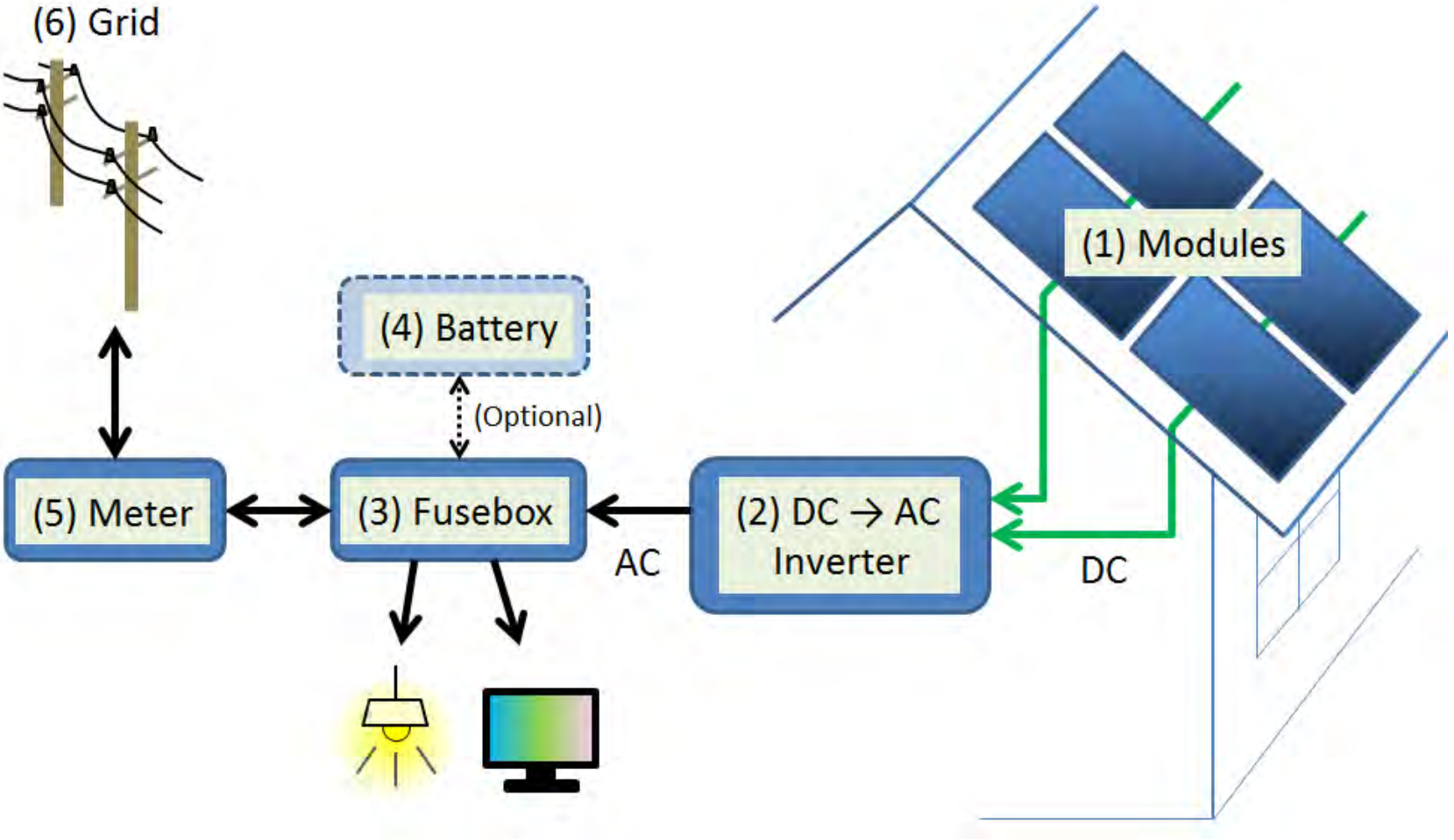


Grid connected PV systems

- An example of a grid-connected PV system



Inverter

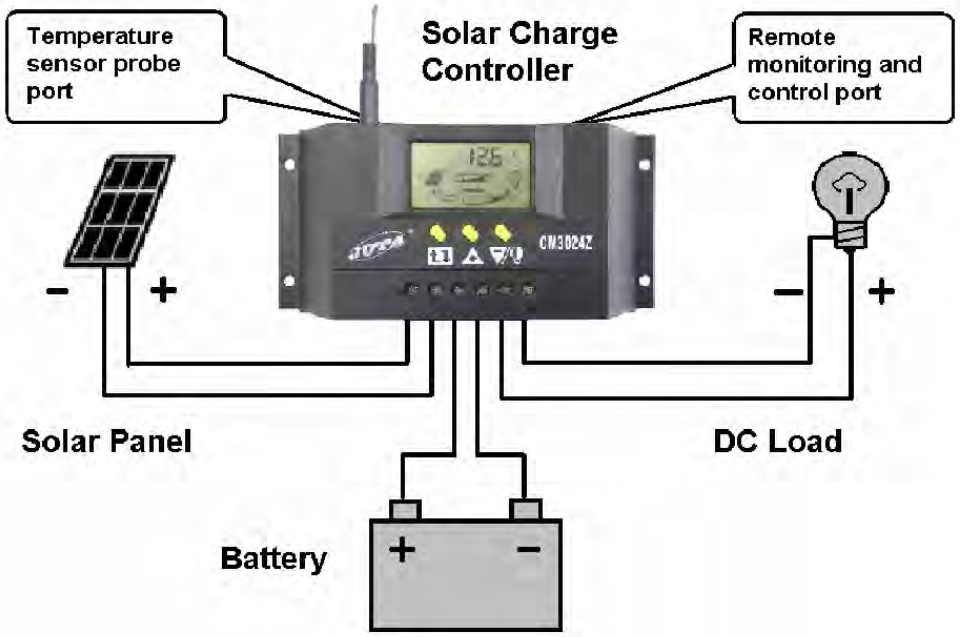

(6) Grid
(1) Modules
(4) Battery
(Optional)
(5) Meter
(3) Fusebox
(2) DC → AC Inverter
AC
DC

Inverter

- Function of inverter is to convert low voltage DC power from PV array to high voltage AC power as required by many loads.
- Characteristics of inverters
  - Power quality
    - Waveform shape
    - Total harmonic distortion
  - Input and output voltage ratings (input determined by battery voltage, output by that required by loads
  - Power and surge power rating
  - Inverter efficiency
  - Connection and interaction of inverter with other AC components
    - Other inverters
    - Grid power

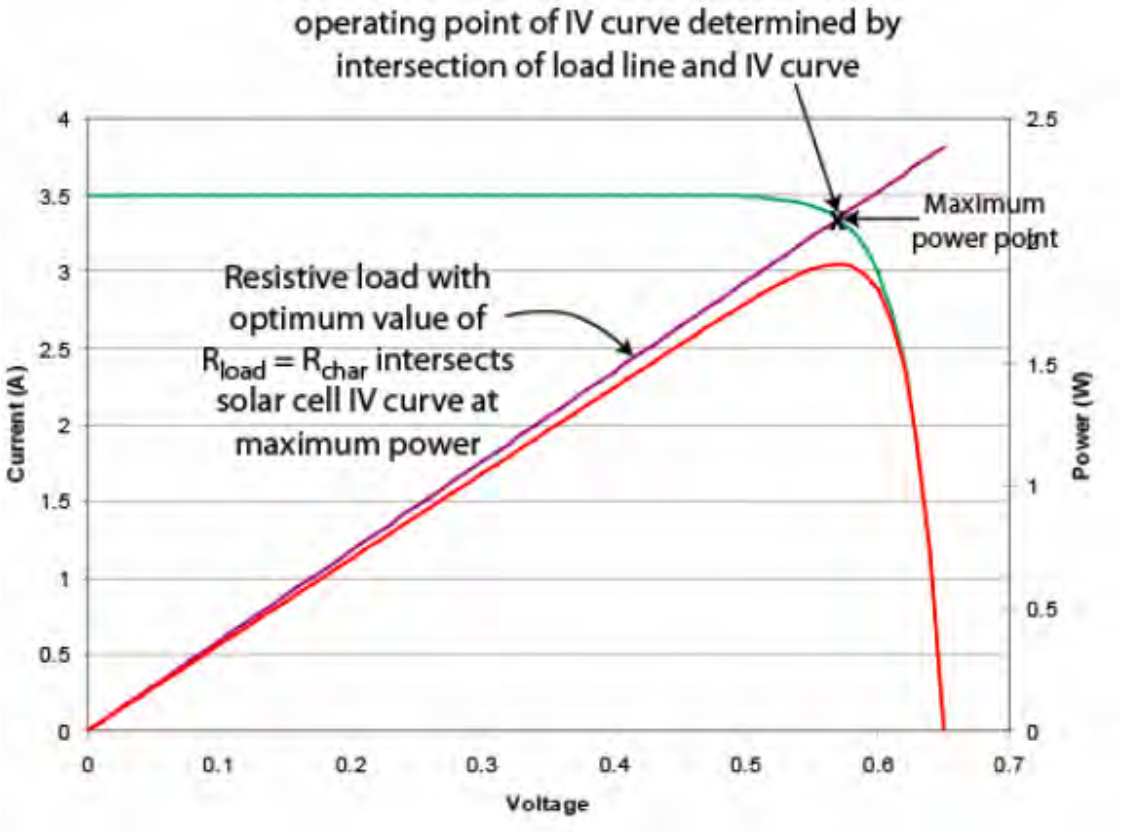
Charge controller

- A charge controller limits the rate at which electric current is added to or drawn from electric batteries.
- It prevents overcharging and may prevent against overvoltage, which can reduce battery performance or lifespan, and may pose a safety risk.
- It may also prevent completely draining ("deep discharging") a battery, or perform controlled discharges, depending on the battery technology, to protect battery life.



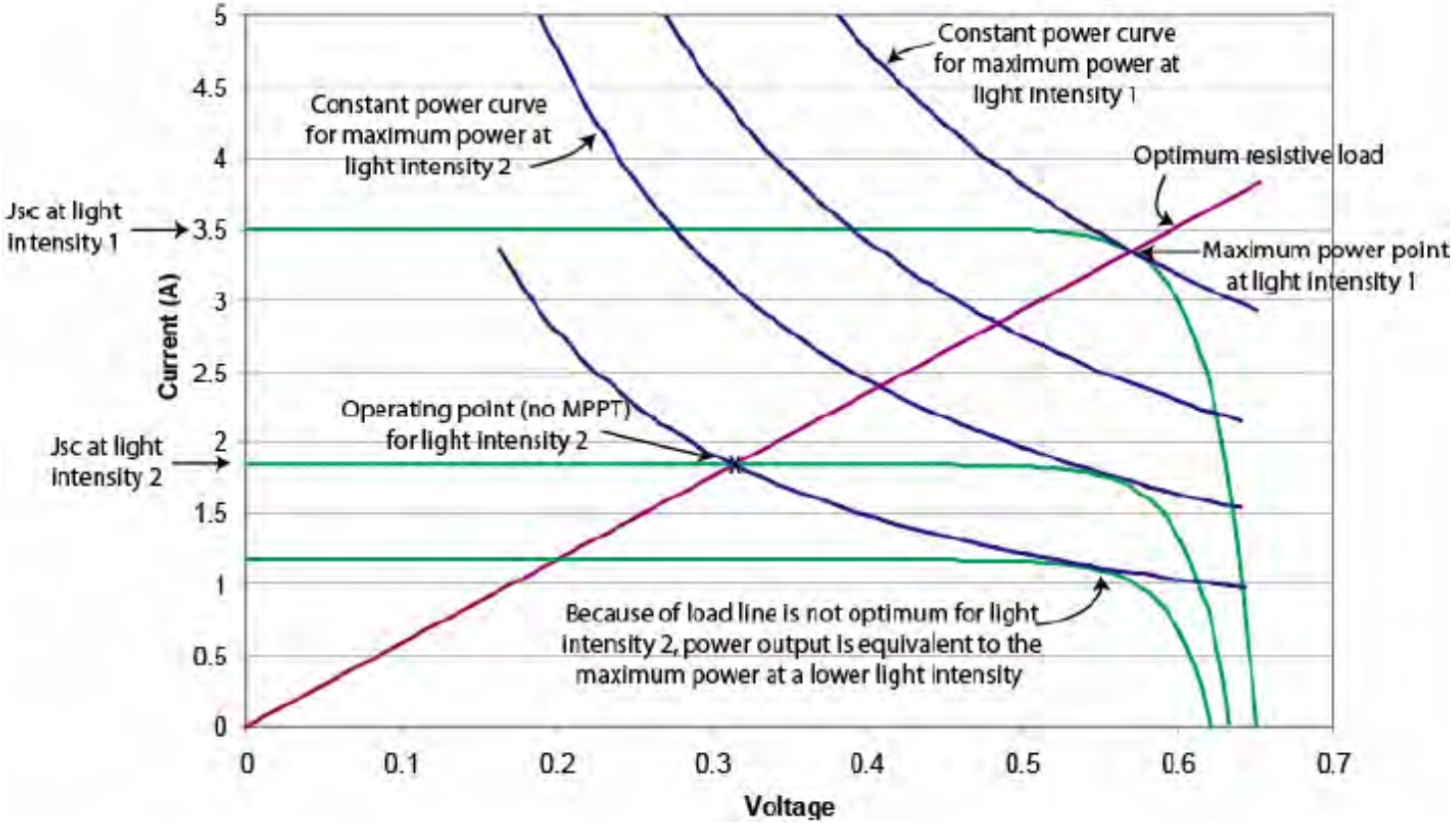
Maximum Power Point Tracker (MPPT)

- Function of MPPT is to maximize the power generated by the solar panel by ensuring it operates at its maximum power point.



Maximum Power Point Tracker (MPPT)

- MPPT allows PV module to operate at maximum power point as light intensity changes or as effective load resistance changes.

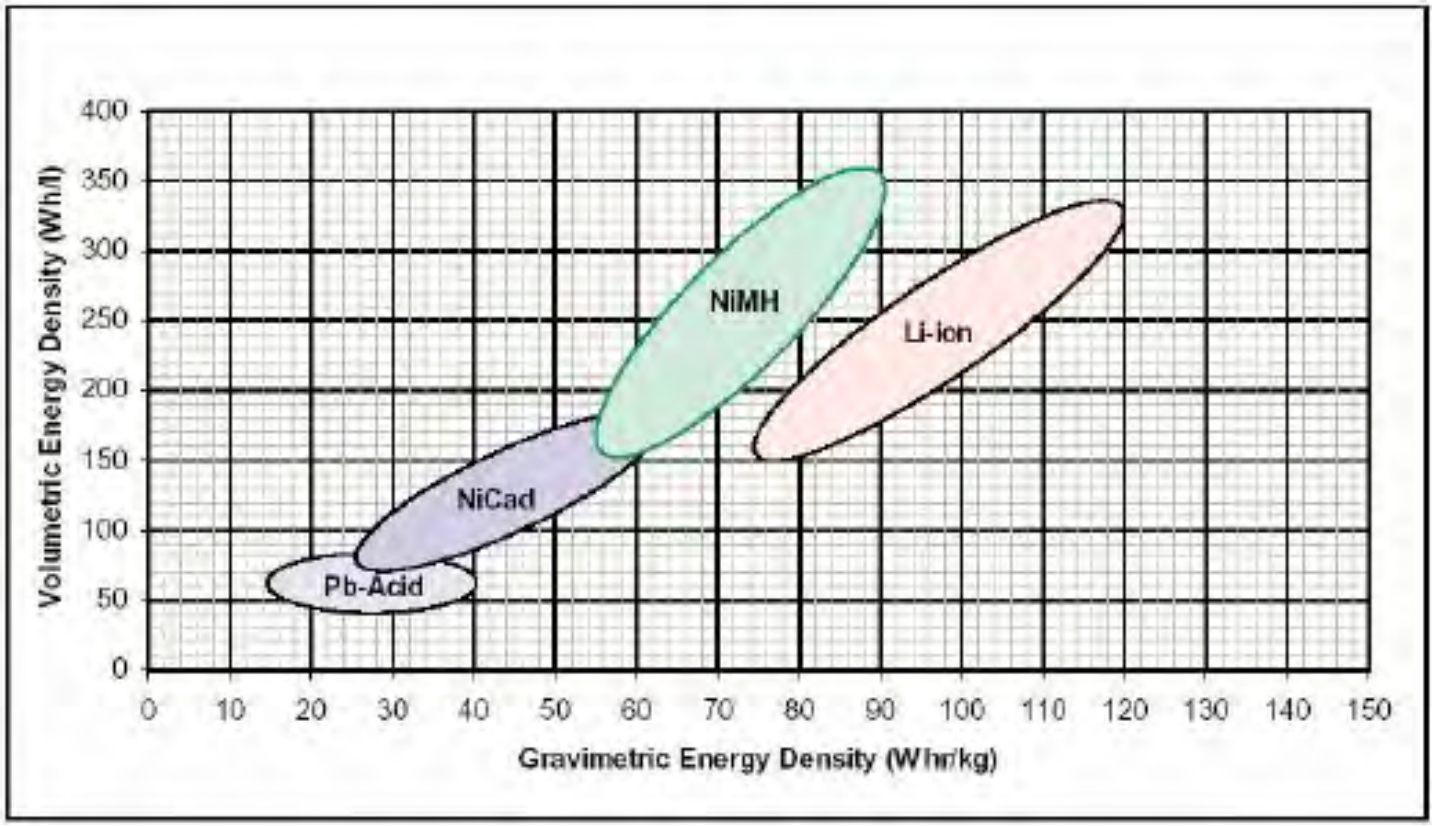


Battery

- Batteries required if (1) load profile ≠solar radiation profile and (2) to mitigate effect of variability in sunshine.
- Batteries have a major impact of PV system performance: They alter maintenance, design, are a large fraction of cost, reliability & aging, safety.
- Key issues in batteries:
  - Why and how battery voltage and capacity change with system and battery parameters.
  - Operating constraints on batteries: constraints of state-of-charge, discharge/charge rate, temperature.
  - Lifetime and safety issues with batteries

Battery characteristics

- Key characteristics of a battery: Cost, Volumetric /Gravimetric energy density, Voltage, Charging regimes, Efficiency, Depth of discharge



Battery characteristics

- Battery Capacity:
  - Measured in Amp-hours, rather than conventional Whr due to variation of battery voltage
  - Battery capacity depends on age and history of battery
- Depth of discharge
- Battery lifetime: Number of cycles
- Battery voltage and variation of voltage
- Effect of temperature

Lead acid battery

- For secondary batteries, most common system is lead acid.
- Reaction and standard potential:

Oxidation: $Pb \rightarrow Pb^{+2}(aq) + 2e^-$

takes place in sulfuric acid, so get another reaction:

$Pb^{2+} + SO_4^{2-} \rightarrow PbSO_4\ (s)$

$Pb + SO_4^{2-} \rightarrow PbSO_4(s) + 2e^-$ $\quad E^0 = 0.356\ V$

Reduction: $PbO_2(s) + 4H^+ + SO_4^{2-} + 2e^- \rightarrow PbSO_4(s)$ $E^0 = 1.685\ V$

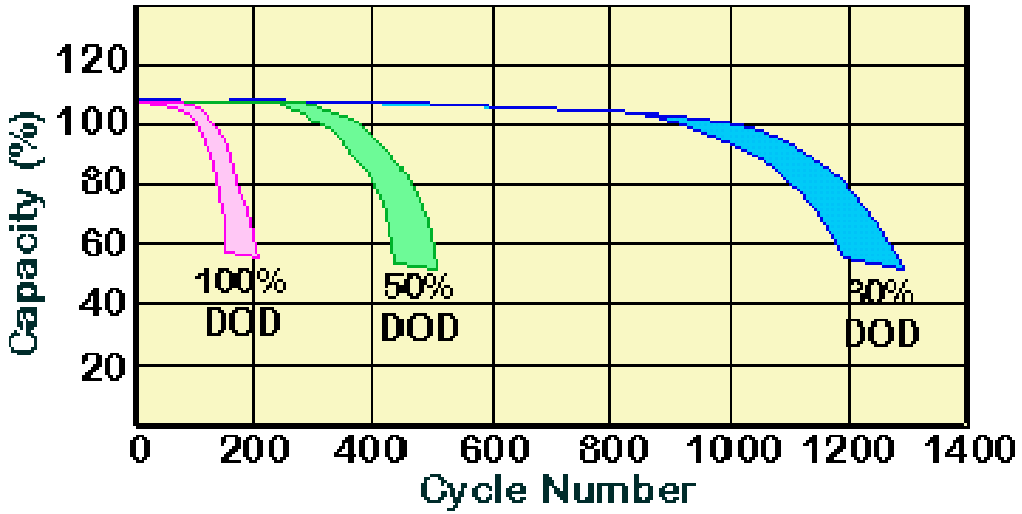
Overall:

$$PbO_2 + Pb + 2H_2SO_4 \underset{\text{charge}}{\overset{\text{discharge}}{\rightleftharpoons}} 2PbSO_4 + 2H_2O$$

- Electrodes are lead oxide and "spongy" or porous lead
- Electrolyte is sulfuric acid
- Standard potential is 2.041V

Issues in lead acid battery

- Depth of discharge, lifetime and number of cycles



- Reduced life due to sulfation of the battery and shedding of plate material.
- Gassing of battery: high voltages or fast charging leads to electrolysis of water.

Issues in lead acid battery

- Stratification of the electrolyte: electrolyte cannot be readily mixed.
- Physical damage to the electrodes due to soft electrode material
- Spillage of sulfuric acid
  - Safety issue and problems in transport
- Temperature dependence of the battery
  - Freezing of the battery at low temperatures
  - Increasing temperatures gives higher voltages, needs to be taken into account n charging and system design.

Layout

- Solar resources
- How does it works?
- Technologies
- PV characteristics and affecting parameters
- PV system types and balance of system
- Utilization of PV systems

Solar home system

Solar lantern

Remote applications

Public services

Solar battery charging station

Grid connected PV system

THANK YOU

Promotion of Energy Science Education for Sustainable Development in Cambodia

Theme 5: Renewable Energy

Theme 5-3: Solar Thermal Systems

Dr. Long Bun

Vice Head of Department of Electrical and Energy Engineering

Institute of Technology of Cambodia

Layout

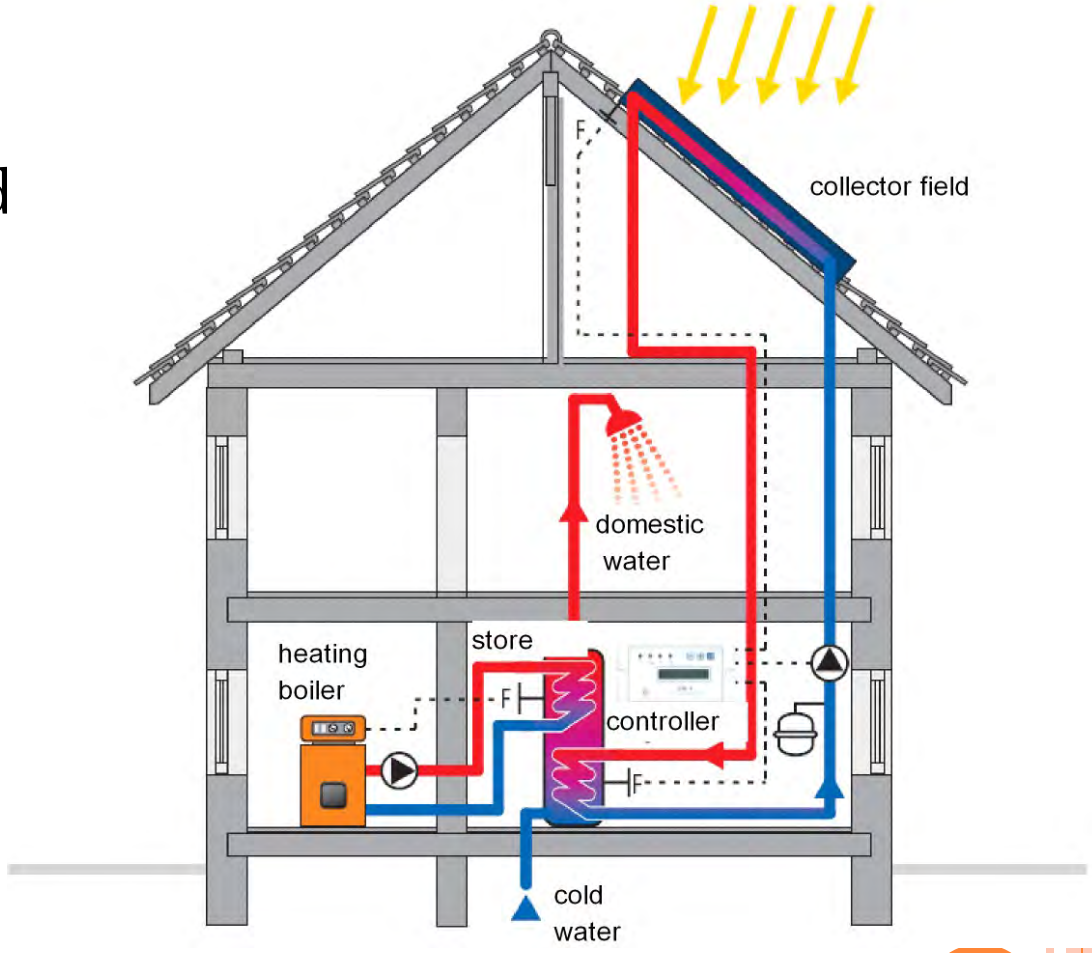
- Solar water heating
- Concentating Solar Power
- Solar drying systems
- Solar cooking

Solar water heating

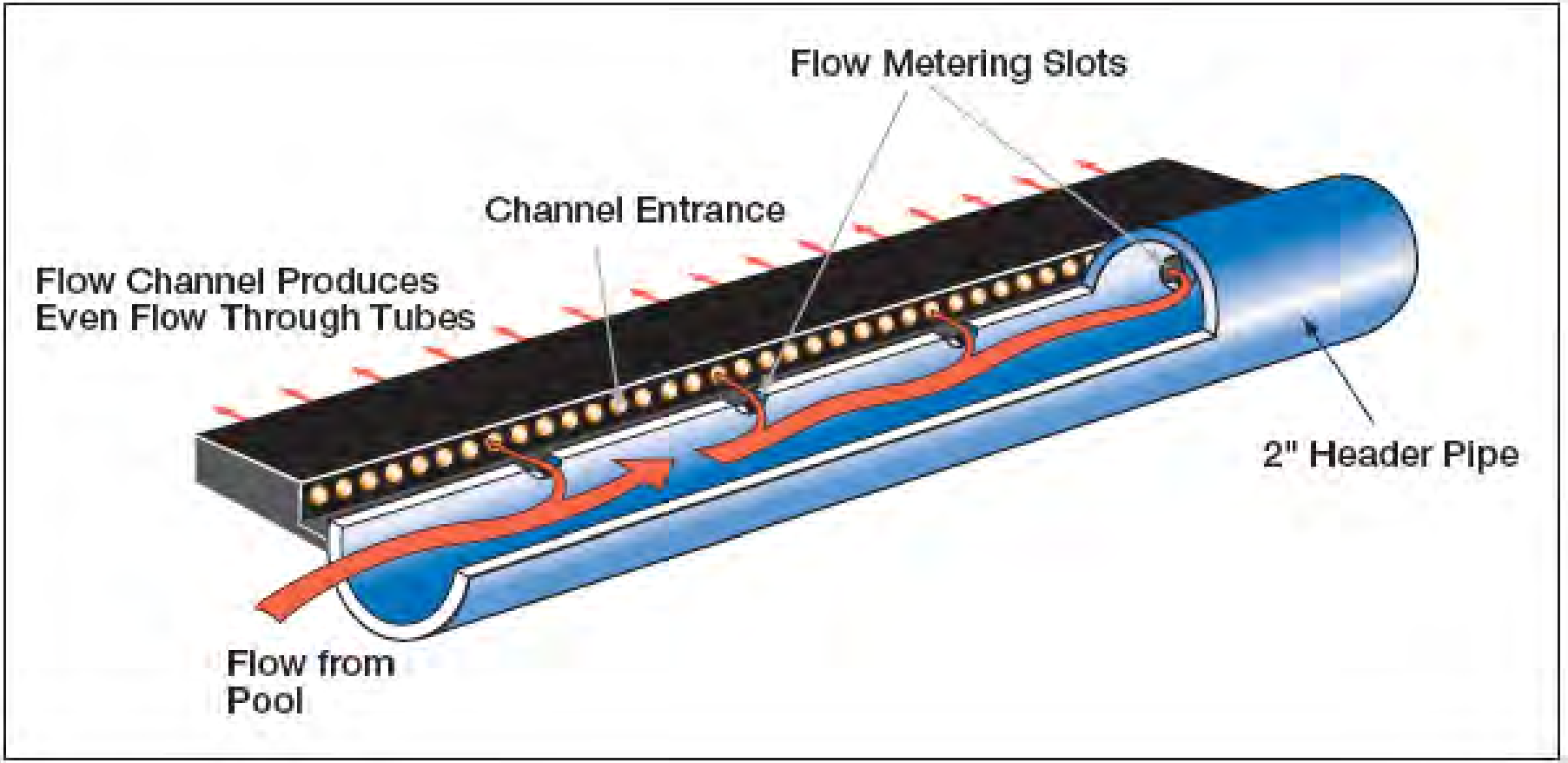
- Solar water heating system uses energy from the sun to heat water through an absorber
- The most common application of this system is :
  - Domestic hot water
  - Process hot water for commercial and institutional application
  - Small commercial and industrial applications

Solar water heating systems

- There are three basic operations performed by solar water heating systems:
  - Collection: unglazed flat plate collector, glazed flat plate collector, evacuated tube solar collector
  - Transfer: pipelines, solar liquid, solar pump, heat exchanger, fitting, safety equipment
  - Storage



Unglazed flat plate collector (1)



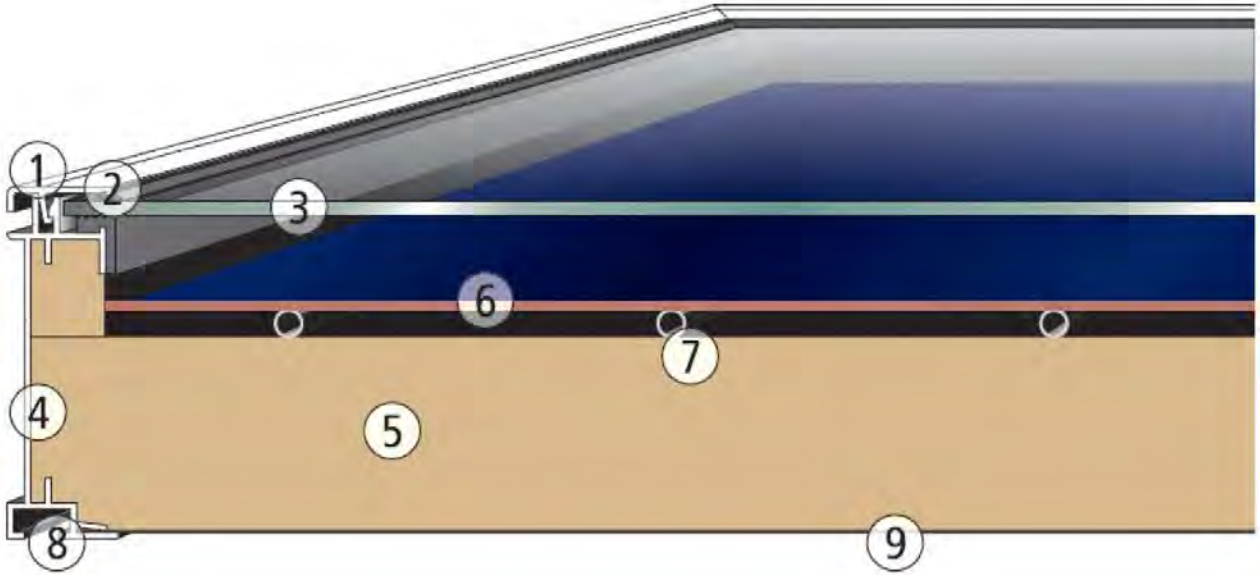
Unglazed flat plate collector (2)

- The advantages of the unglazed flat plate collector are:
  - The absorber can replace the roof skin
  - It is suitable for a diversity of roof forms
  - It can be a more aesthetic solution

- The disadvantages of the unglazed flat plate collector are:
  - Low specific performance
  - The temperature increase (above the air temperature) is limited.

Glazed flat plate collector (1)

1. *frame*
2. *seal*
3. *transparent cover*
4. *frame - side - wall profile*
5. *thermal insulation*
6. *full-surface absorber*
7. *fluid channel*
8. *fixing slot*
9. *rear wall*

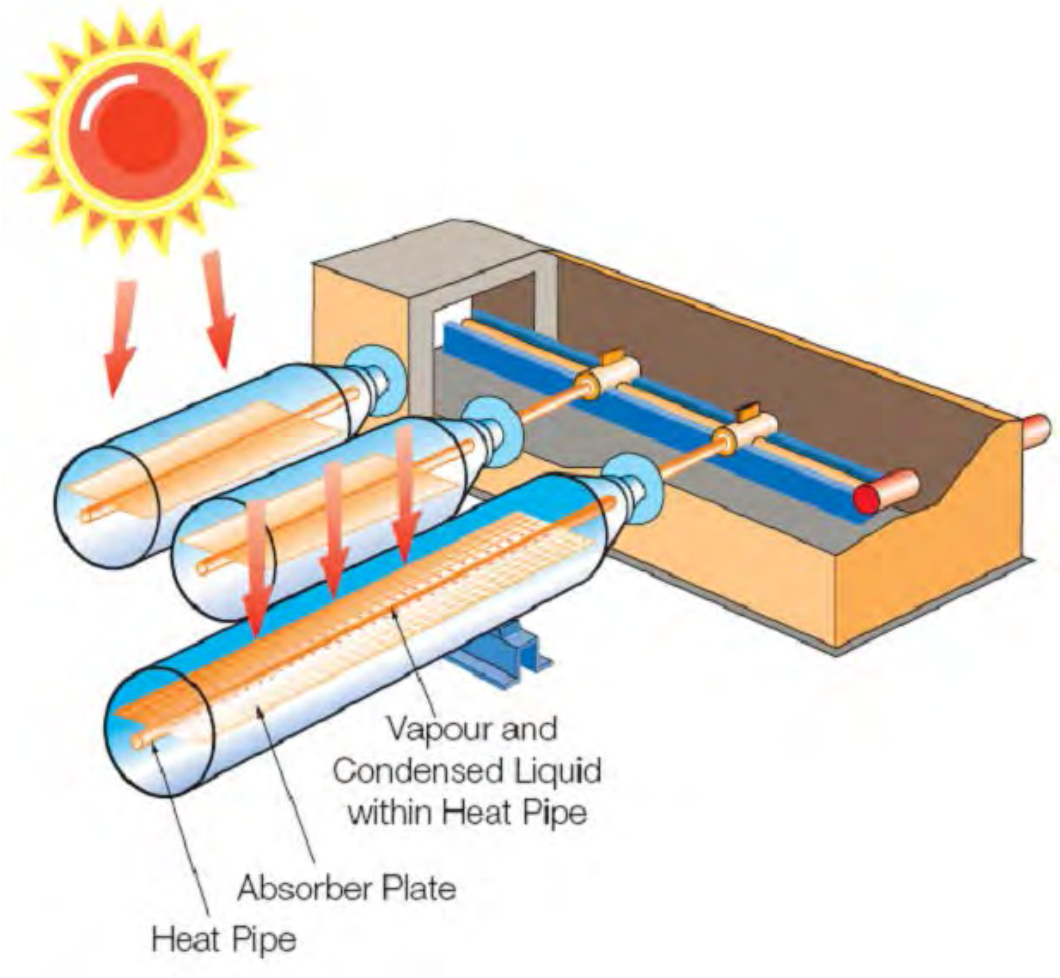


Glazed flat plate collector (2)

- The advantages of the glazed flat plate collector are:
  - Cheaper than a vacuum collector
  - Offers multiple mounting options
  - Good price/performance ratio
  - Good possibilities for do-it-yourself assembly

- The disadvantages of the glazed flat plate collector are:
  - Lower efficiency than a vacuum collectors
  - A supporting system is necessary for flat roof mounting
  - It is not suitable for generating higher temperatures
  - Requires more roof space than vacuum collectors do

Evacuated tube collector (1)



Evacuated tube collector (2)

- The advantages of the vacuum collector are:
  - High efficiency
  - High temperatures can be obtained
  - Easily transported to any installation location
  - By turning the absorber strips it can be aligned towards the sun.
  - Can be mounted horizontally on a flat roof In the form of direct through flow tubes

- The disadvantages of the vacuum collector are:
  - Expensive
  - Can not be used for in-roof installation
  - It can not be used for horizontal installation for heat pipe systems (inclination must be at least 25°).

Storage

- The times when heat is required and the energy supply by the sun is unmatched. Therefore heat must be stored.
- Heat can be stored in the tanks which could be vented or unvented.
- Tanks are offered in stainless steel, enamelled, plastic-coated steel, copper

Transfer

- The heat generated in the collector is transported to the store by means of solar circuit
  - The pipeline
  - The solar liquid (water or water + chemical substance)
  - Forced convection (need pump) or national convection (don't need pump)
  - The heat exchanger
  - The fitting
  - The safety equipments

Pipeline

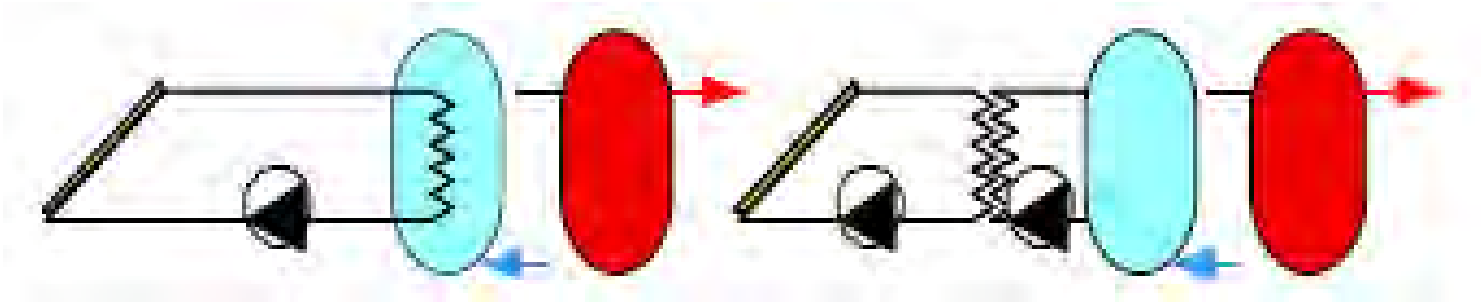
- Copper is the most frequently used material for the transport pipeline
- Steel pipes are more preferable for larger system
- Insulation of the complete piping must be made to avoid heat losses
- External pipelines must be UV, weather resistant, waterproof, able to protect from animal damage

Solar liquid

- Water is the most suitable solar liquid
  - High thermal capacity
  - High thermal conductivity
  - Low viscosity
  - noncombustible, non toxic and cheap.
- To solve the problem of frost and evaporation the addition of 40% propylene glycol is predominantly used (This is not the Cambodian case)
- But adding glycol has some negative effects
  - Increased corrosion
  - Reduced thermal capacity
  - Reduced thermal conductivity
  - Increased viscosity
  - Increased creep capacity

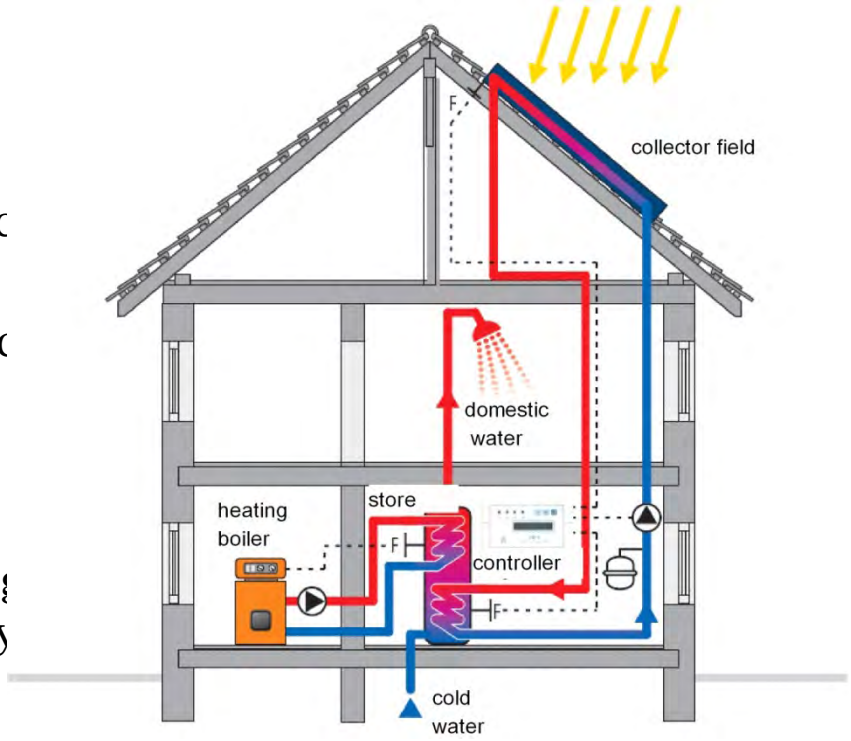
Solar pump and heat exchanger

- For pumped systems, the pump should be chosen in a manner that a difference of between 8°C and 12°C is produced between the feed and return lines.
- In case of twin circuit systems heat exchanger is needed to exchange heat between the two tank



CONTROLLER

- The task of controller is to control the circulating pump
- Two temperature sensors are required for standard temperature difference control.
- The switch-on temperature differenc varies from 5°C to 8°C.
- The switch-off temperature differenc is normally around 3°C.
- The system will be switched off as a means of over heating protection.
- Frost protection is effected by addin antifreeze to the collector fluid, or by using the drainback system.



Layout

- Solar water heating
- Concentating Solar Power
- Solar drying systems
- Solar cooking

Concentrating Solar Power (CSP)

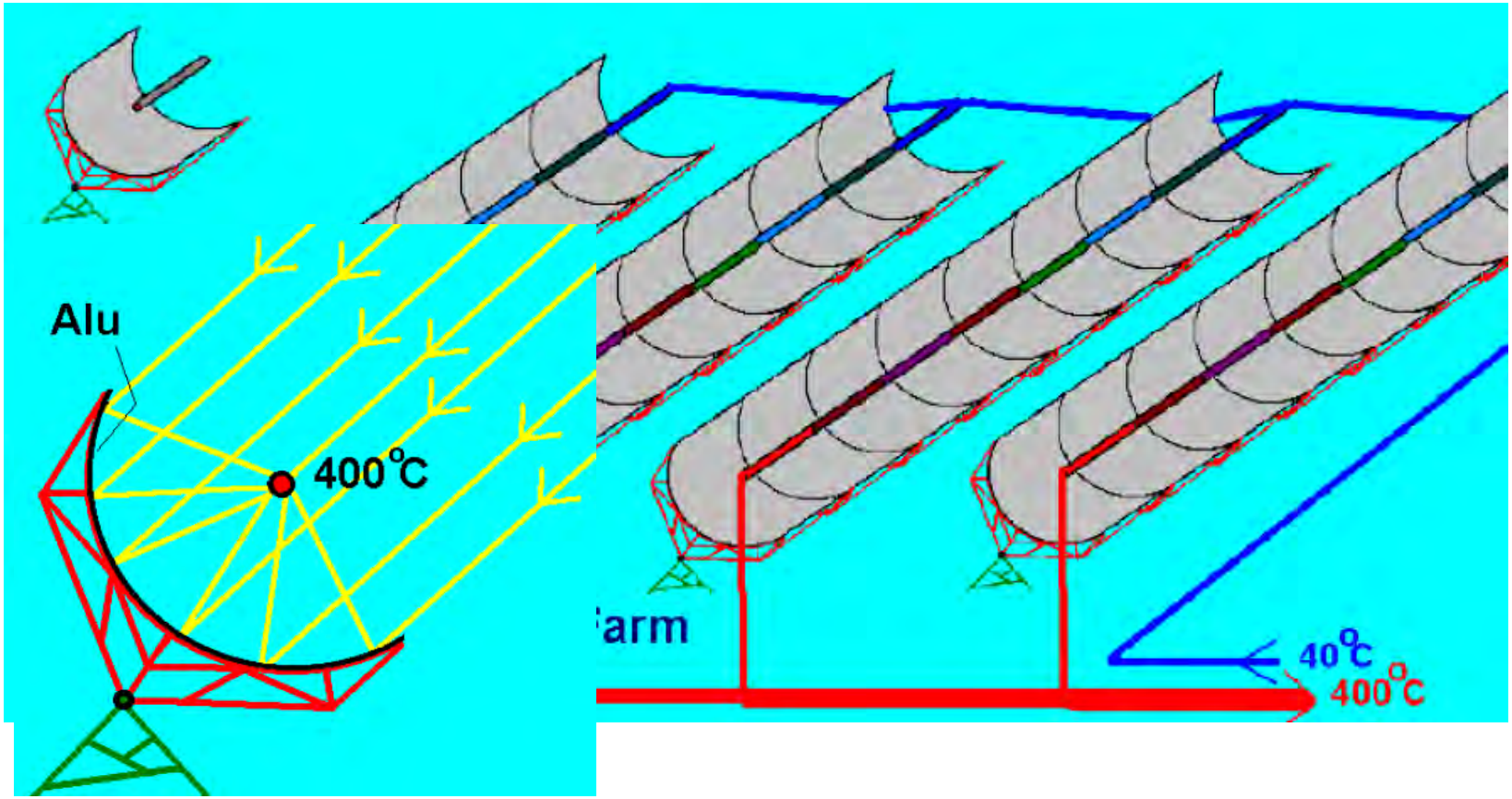
- Concentrate solar energy through use of mirrors or lenses.
- Concentration factor ("number of suns") may be greater than 10,000.
- Systems may be small:
  - Eg. Solar cooker
- Systems may be large:
  - Utility scale electricity generation
  - Furnace temperature up to 3800°C

Concentrating Solar Power Application

- Power Generation:
  - Utility Scale: 64 MW Nevada Solar One (2007)
  - Buildings: 200 kW “Power Roof”
- Thermal Needs:
  - Hot Water and Steam (Industrial & Commercial Uses)
  - Air Conditioning – Absorption Chillers
  - Desalination of seawater by evaporation
  - Waste incineration
- “Solar Chemistry”
  - Manufacture of metals and semiconductors
  - Hydrogen production (e.g. water splitting)

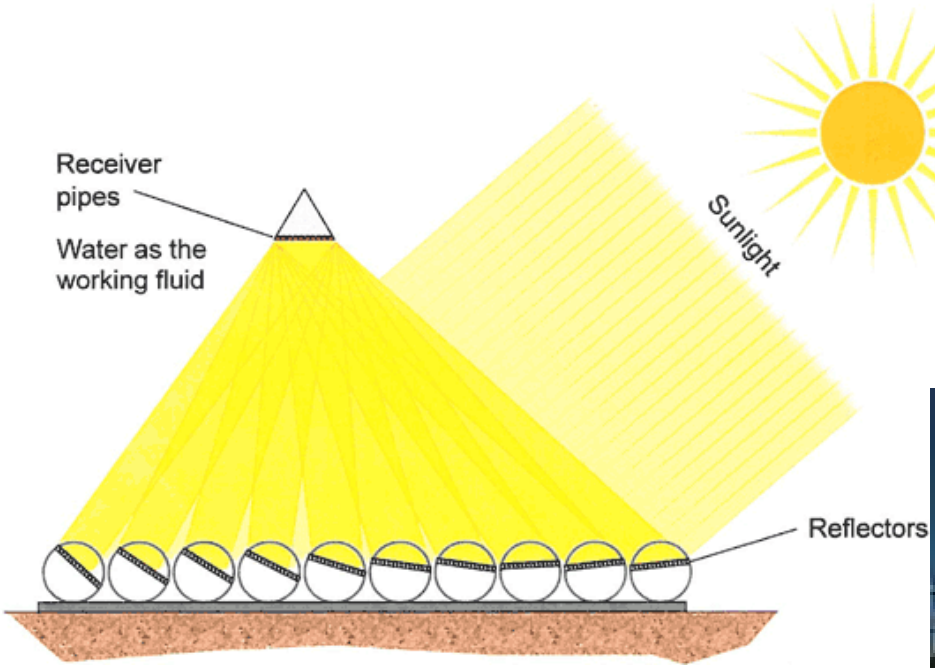
Parabolic trough

Parabolic trough



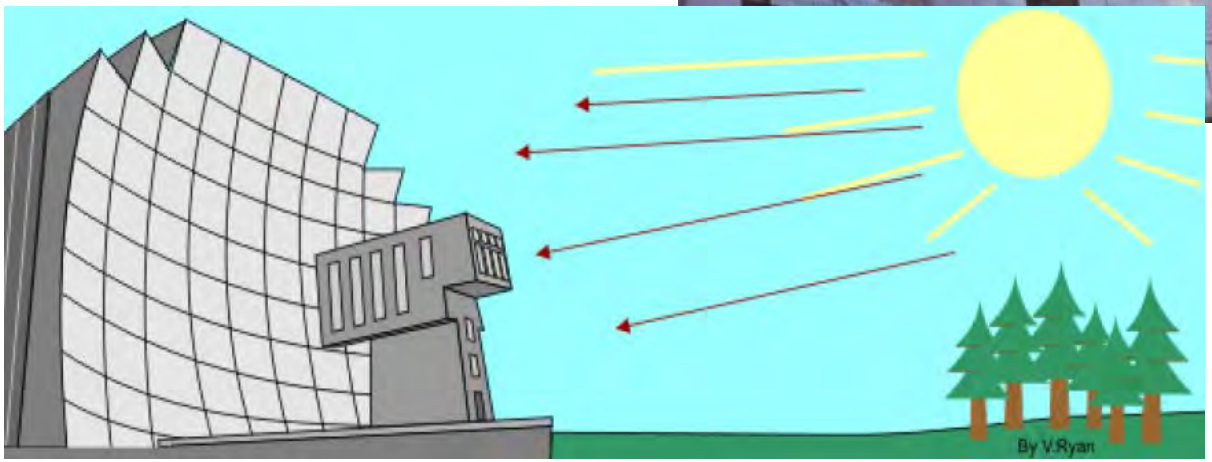
Dish parabolic

Fresnel reflector

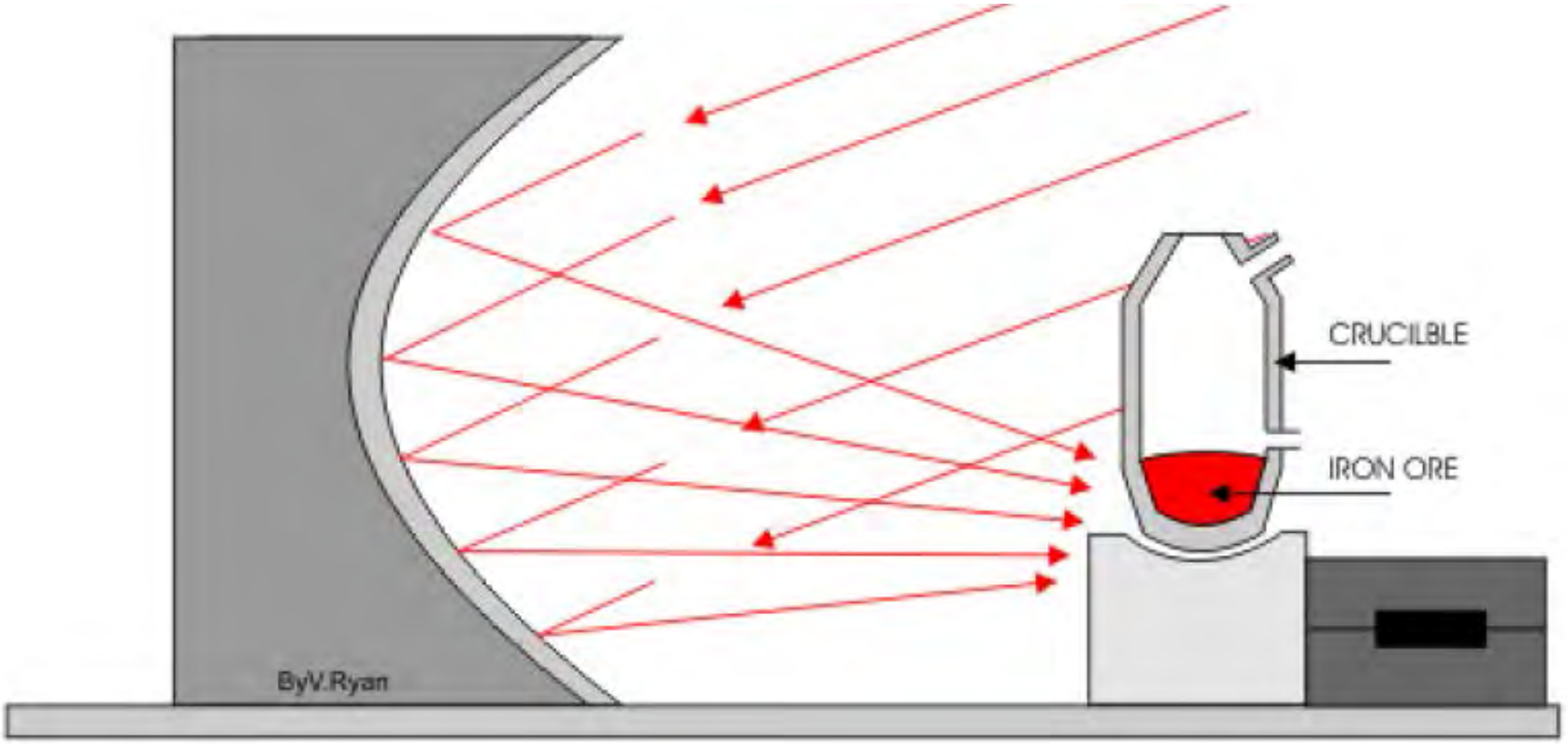


Central receiver

Solar furnace



An example of application of solar furnace



Layout

- Solar water heating
- Concentating Solar Power
- Solar drying systems
- Solar cooking

WHY SOLAR DRYING?

- Drying is a traditional method for preserving food (crops and meat).
- For meat :
  - Preservation
  - Special taste
- For crops :
  - Early harvesting and hence reducing the field losses of the products,
  - Reducing the risk of field losses caused by wild animals,
  - Better planning of harvesting season,
  - Improving the quality of the product
  - Facilitating transportation (dried product is easier to transport)

Basics of solar drying

- Drying or dehydration of material means removal of moisture from the interior of the material to the surface and then to this moisture from the surface of the drying material.
- The drying of product is a complex heat and mass transfer process which depends on :
  - External parameters : temperature, humidity and velocity of the air stream;
  - Internal parameters : surface characteristics (rough or smooth surface), chemical composition (sugar, starches, etc), physical structure (porosity. density. etc.); size and shape of the product.

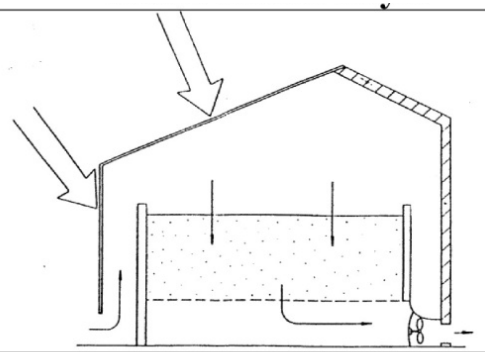
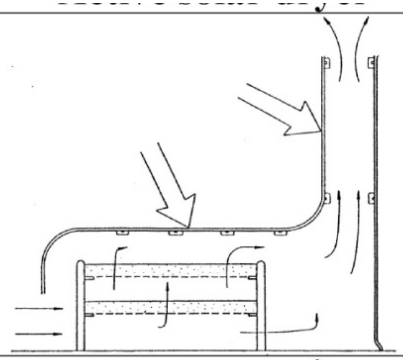
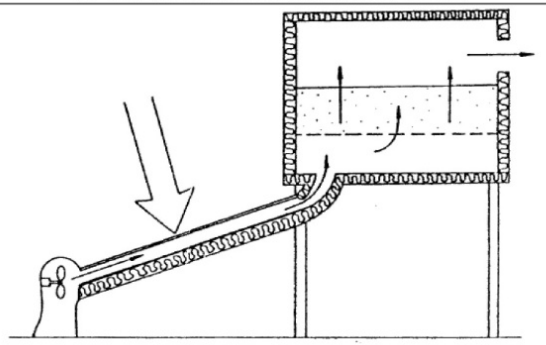
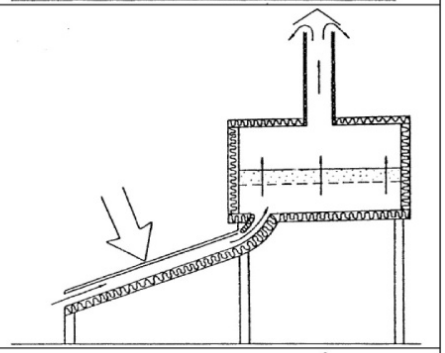
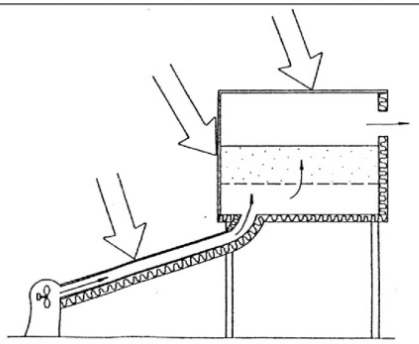
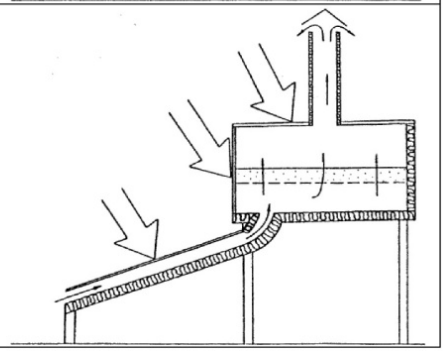
Open sun drying VS solar dryers

- Open sun drying is the simplest method of drying used in most developing countries.

- Advantages
  - No technology involved
  - Very low cost (cost of labor only)

- Disadvantages product due to dirt and insects.
  - Wastage by birds / mice.
  - Spoilage due to sudden and unpredicted
  - Contamination of the rain.
  - There is no control of temperature over crop drying.
  - Over drying may cause loss of germination power, nutritional changes, sometimes complete damage.

SOLAR DRYER

	Active solar dryer	Passive solar dryer
Integral (Direct) type		
Distributed (Indirect) type		
Mixed mode type		

Solar cabinet dryer

Solar tunnel dryer

Solar box and cabinet dryer

Layout

- Solar water heating
- Concentating Solar Power
- Solar drying systems
- Solar cooking

Solar cooker

- Cooking using firewood causes several problems: poor efficiency of energy conversion, time spent on collecting firewood, indoors pollution etc
- Advantages of using solar cooker: free and inexhaustible source of energy, relieves the workload on women and children, reduce harmful effect on health, stopping deforestation
- There are several types of solar cooker: Parabolic cooker, Butterfly or Papillon cooker, Flat plate collector cooker, Solar box cooker, Scheffler cooker

Parabolic cooker

Butterfly or Papillon cooker

Solar box cooker

Scheffler cooker

THANK YOU

Promotion of Energy Science Education for Sustainable Development in Cambodia

Theme 5: Renewable Energy

Theme 5-4: Micro Hydropower

Dr. Long Bun

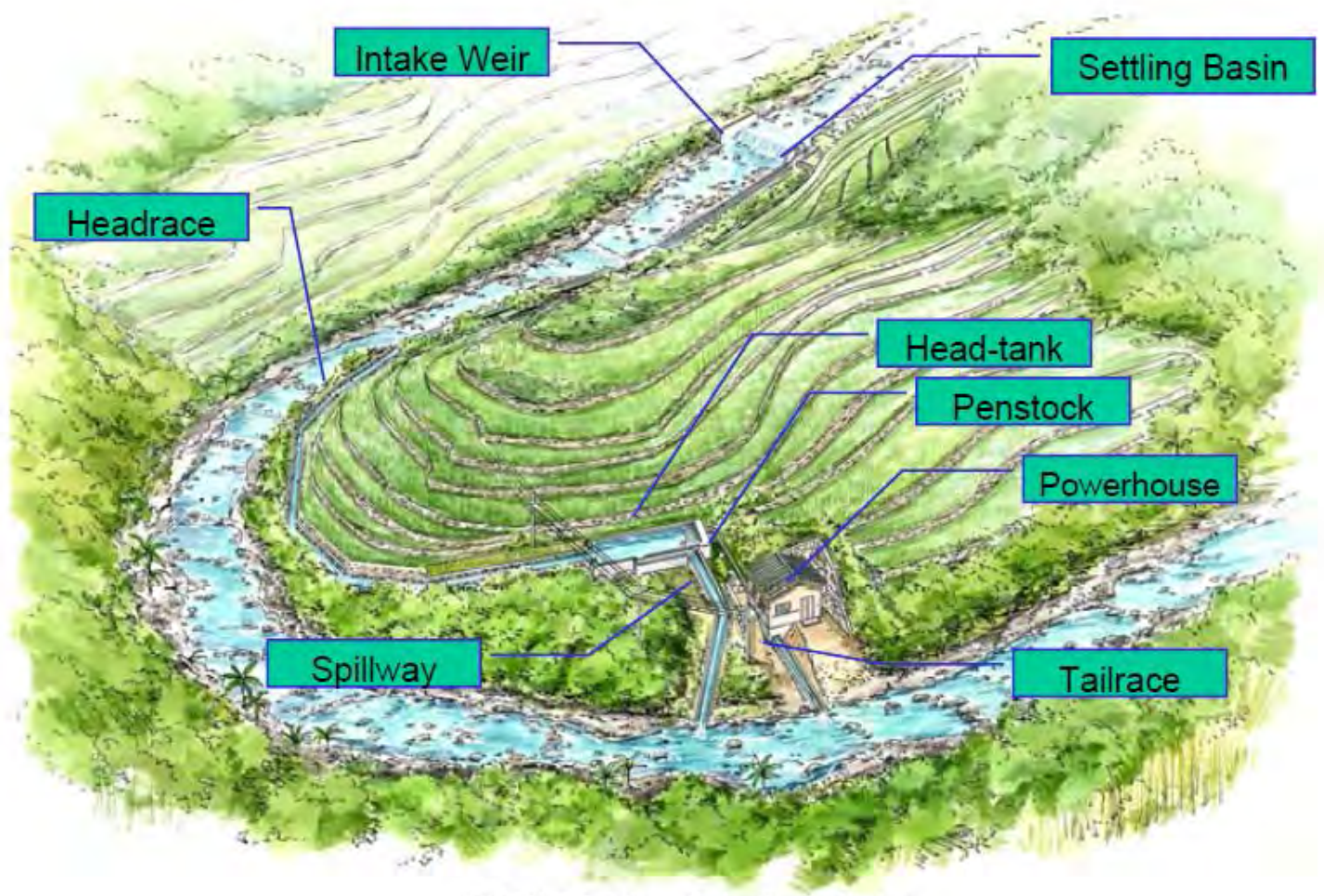
Vice Head of Department of Electrical and Energy Engineering

Institute of Technology of Cambodia

Layout

- Components of micro/mini hydropower plant
- Hydropower potential
- Types of turbines
- Types of generator
- Hydropower status in Cambodia

Components of hydropower plant



CAMBULO Micro-Hydro Power Project

Intake weir

- The Intake weir – a barrier built across the river used to divert water through an opening in the riverside (the 'Intake' opening) into a settling basin.
- The functions of intake weir :
  - to divert the river flow into the Intake
  - to prevent the Sediment/silts to pass through

SETTELING BASSIN

- Settling Basin-The settling basin is used to trap sand or suspend the silt from the water before entering the penstock.
- Function of setteling bassin : to trap sand or suspend the silt from the water

Headrace

- Headrace – A channel leading the water to a head tank. The headrace follows the contour of the hillside so as to preserve the elevation of the diverted water.