Solar Energy

Introduction to the lecture

- Solar energy is used for direct conversion of sunlight to electricity with advantages of minimum maintenance.
- Lecture on solar energy has 3 parts.
- Part 1 of solar energy introduces the concept of solar energy, fundamentals of solar energy, radiant energy, quantity of solar energy and advantages and disadvantages of solar energy.
- Part 2 of this lecture provides an on solar cell principles and cell manufacture.

Introduction to the lecture

- This lecture discusses the photovoltaic cell (PV), principles of solar electric system, cross section of PV cell, principles of PV cell and solar cell manufacture.
- Part 3 provides information on solar PV facts & trends i.e. world solar power production, solar cell production volume in the world and photovoltaic market.

Aim and Learning outcomes

- The aim is to introduce students to the concept of renewable solar energy system and its global production and describe the procedure to manufacture solar cell.
- After completing of this lecture students will be able to:
  - Explain the principles that underlie various natural phenomena for the production of solar energy.
  - Develop a comprehensive technological understanding of solar PV system.

Aim and Learning outcomes

- After completing of this lecture students will be able to:
  - Provide in-depth understanding of PV cell design.
  - Design a basic photovoltaic system to meet energy.
  - Compare the advantages and disadvantages of solar energy production.
  - Understand the present scenario of global solar energy production and consumption.

Talk outline

- **Part-I**
- **Introduction – Solar Energy**
  - **Fundamentals of Solar Energy**

Talk outline

- Part-II
  - Solar Cell Principles
  - Cell Manufacture

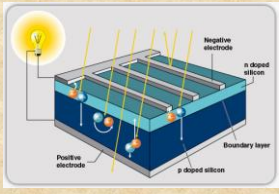
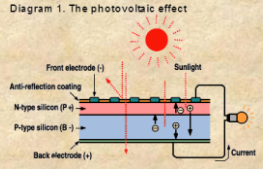


Diagram 1. The photovoltaic effect

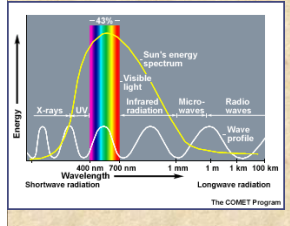


Talk outline

- Part-III
  - Photovoltaic system, Facts and Trends

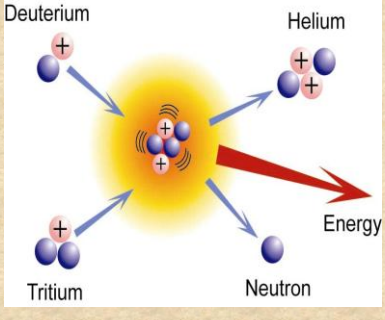
Solar Energy

What is Solar Energy?

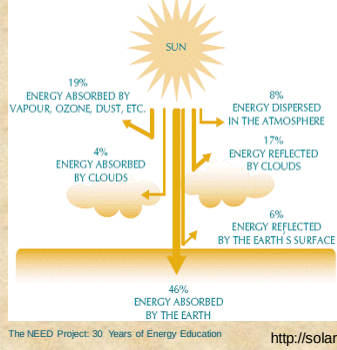


- Originates with the thermonuclear fusion reactions occurring in the sun
- Represents the entire electromagnetic radiation (visible light, infrared, ultraviolet, x-rays, and radio waves).

Radiant Energy



How much solar energy?



- The surface receives about 46% of the total solar energy that reaches the Earth. Only this amount is usable.

http://solarenergybeginning.wordpress.com/

Advantages and Disadvantages

Advantages

- All chemical and radioactive polluting byproducts of the thermonuclear reactions remain behind on the sun
- While only pure radiant energy reaches the Earth
- Energy reaching the earth is incredible.
- By one calculation, 30 days of sunshine striking the Earth have the energy equivalent of the total of all the planet's fossil fuels, both used and unused!

Advantages and Disadvantages

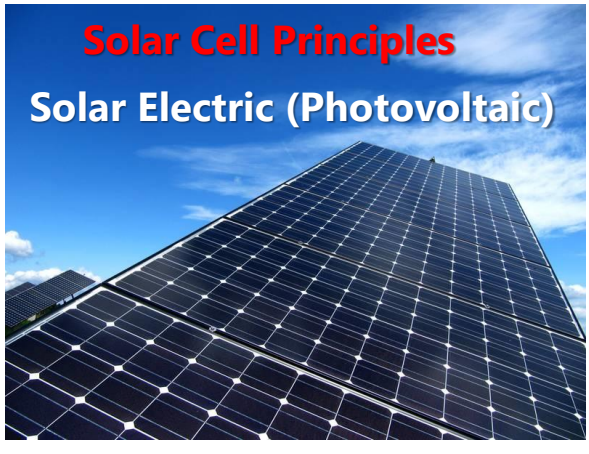
Disadvantages

- Sun does not shine consistently
- Solar energy is a diffuse source. To harness it, we must concentrate it into an amount and form that we can use, such as heat and electricity

- Addressed by approaching the problem through:
  1) collection, 2) conversion, 3) storage

Solar Cell Principles

Solar Electric (Photovoltaic)



Definitions: PV Cell

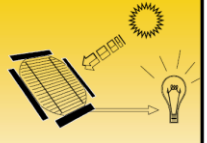
- Cell: The basic photovoltaic device that is the building block for PV *modules*.

PV Cells have efficiencies approaching 21.5%

Florida Solar Energy Center

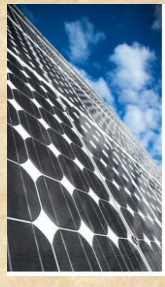
What Are Solar Cells?

- Thin wafers of silicon
  - Similar to computer chips
  - much bigger
  - much cheaper!
- Silicon is abundant (sand)
  - Non-toxic, safe
- Light carries energy into cell
- Cells convert sunlight energy into electric current-they do not store energy
- Sunlight is the "fuel"



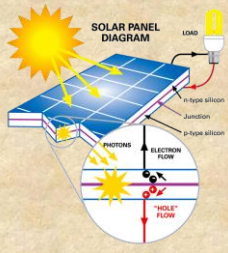
Florida Solar Energy Center

Solar Electric Systems



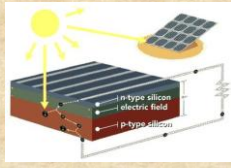
- Photovoltaic (PV) systems convert light energy directly into electricity
- Commonly known as "solar cells."
- The simplest systems power the small calculators we use every day
- More complicated systems will provide a large portion of the electricity in the near future
- PV represents one of the most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

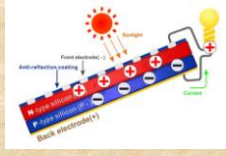
How Does it Work - Principles



- The principles behind the direct use of sun's energy for the production of electricity was discovered in 1887 by Heinrich Hertz
- 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)

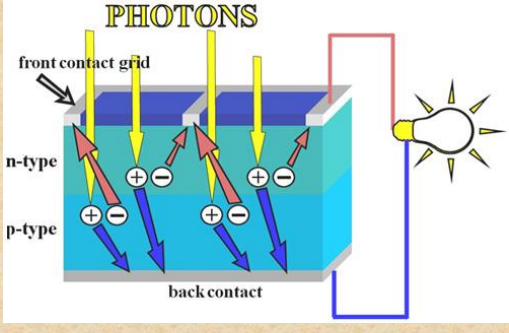
How Does it Work - Principles





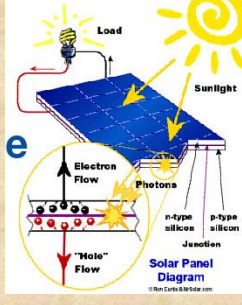
- When absorbed on negative plate, electron are emitted with an amount of kinetic energy is known as photoelectric effects
- Only the absorbed photons generate electricity
- An electron in a metal atom is able to capture a photon and obtain the energy necessary to escape

Cross Section of PV Cell



http://en.wikipedia.org/wiki/Solar_cells

How Does it Work - Principles

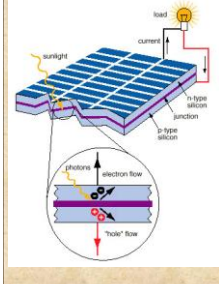


- If the energy of the incoming photon exceeds the binding energy of the electron in the metal
- When the photons are absorbed, the energy of the photons is transferred to electrons in the atoms of the solar cell

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.

How Does it Work?

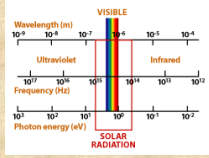


- The other piece of silicon has a small amount of phosphorous added to it, giving it an excess of free electrons
- This is called the **n-layer** because it has a tendency to give up negatively charged electrons

Best Place For Solar Panels?

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

Light & the Photovoltaic Effect



- Certain semiconductor materials absorb certain wavelengths
- The shorter the wavelength the greater the energy
- Ultraviolet light has more energy than infrared light
- Crystalline silicon, utilizes all the visible spectrum plus some infrared radiation

How Solar Cells are Made ??

Cooking ?????

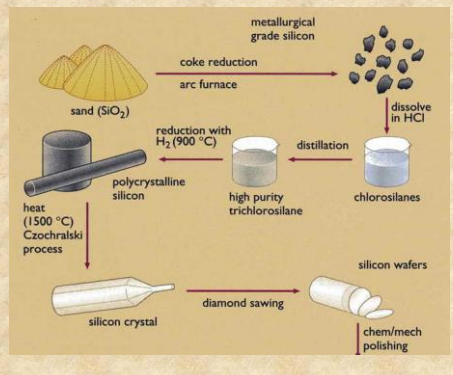
Solar Cell Manufacture

- To make a solar cell, silica (SiO_2) is first refined and purified
- Then melted and solidified in such a way that the silicon atoms are arranged into perfect lattice
- To introduce a seed crystalline silicon into a molten mass of pure silicon and slowly draw it out
- Known as Czochralski process

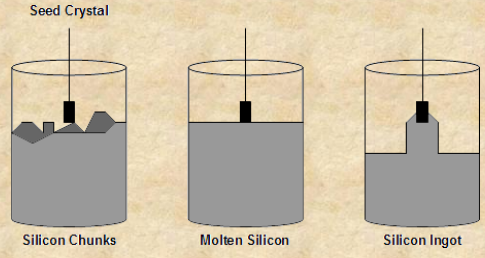
Solar Cell Manufacture

- The cylindrical ingot is formed
- Then sliced into wafers about 0.5 mm thick
- Doped with impurities of phosphorus to create negative layer
- Also doped with boron to form the positive layer

Creating Silicon Wafers



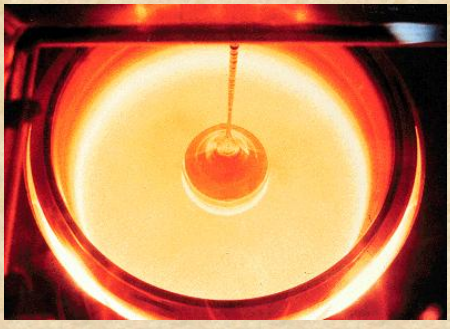
Growing Silicon Ingots



Czochralski Process

http://en.wikipedia.org/wiki/Czochralski_process

Drawing a Silicon Ingot



http://www.answers.com/topic/silicon

Silicon Ingots & Wafers

http://www.sumcosi.com/english/products/products2.html

Silicon Solar Cell

http://en.wikipedia.org/wiki/Image:Solar_cell.png

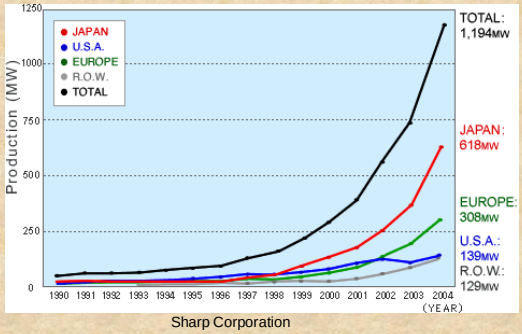
Solar PV Facts & Trends

World Solar Power Production

Country	PV Capacity				
	Cumulative			Installed in 2004	
	Off-grid PV [kW]	Grid-connected [kW]	Total [kW]	Total [kW]	Grid-tied [kW]
Australia	48,640	6,760	52,300	6,670	780
Austria	2,687	16,493	19,180	2,347	1,833
Canada	13,372	512	13,884	2,054	107
France	18,300	8,000	26,300	5,228	4,183
Germany	26,000	768,000	794,000	363,000	360,000
Italy	12,000	18,700	30,700	4,700	4,400
Japan	**84,245**	**1,047,746**	**1,131,991**	**272,368**	**267,016**
Korea	5,359	4,533	9,892	3,454	3,106
Mexico	18,172	10	18,182	1,041	0
Netherlands	4,769	44,310	49,079	3,162	3,071
Norway	6,813	75	6,888	273	0
Spain	14,000	23,000	37,000	10,000	8,460
Switzerland	3,100	20,000	23,100	2,100	2,000
United Kingdom	776	7,386	8,164	2,261	2,197
United States	189,600	175,600	365,200	90,000	62,000

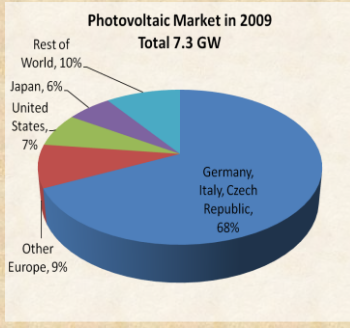
http://en.wikipedia.org/wiki/Solar_panel

Solar Cell Production Volume



Sharp Corporation

http://sharp-world.com/solar/generation/images/graph_2004.gif



Source: Solarbuzz, a part of The NPD Group