Local Chemical Industries

Energy and Fuels

Renewable Sources of Energy

GEOTHERMAL ENERGY
SOLAR ENERGY
FUEL CELLS

Note: These slides were prepared by students

PART 1

Geothermal Energy

Alternative Power Sources are New Ideas !!

"PEOPLE who seem to have a new idea, have often just stopped having an old idea !"

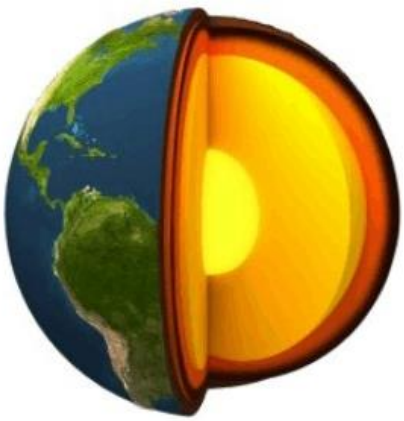
EDWIN LAND

3

What is Geothermal?

4

- The word **geothermal** literally means ***Heat* from within the *Earth*.**
- Or "Earth" +"Heat"



* Graph from : http://www.erdwaerme-bodensee.de/

What is Geothermal Energy?

- It is an alternative energy source characterized by being:
  - Renewable
  - Economical
  - Environmentally friendly
- Geothermal production of energy is 3rd highest among renewable energies.
  1. Hydro
  2. Biomass
  3. Gethermal
  4. Solar
  5. Wind

5

Geothermal Energy in Numbers

- 10,715 (MW) of geothermal power in 24 countries generates 67,246 GWh of electricity in 2010.
- This represents 20% increase in geothermal power online capacity since 2005.
- In 2010, the United States led the world in geothermal electricity production with 3,086 MW of installed capacity from 77 power plants.

(Reported By : The IGA)
International Geothermal Association

6

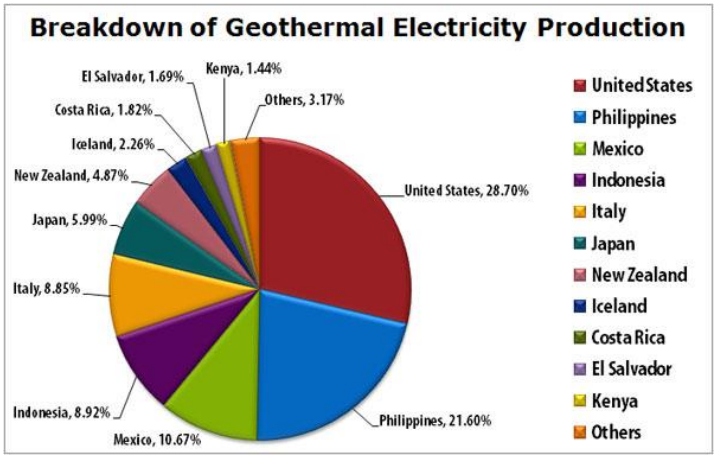
Geothermal Energy in Numbers

- The **Philippines** follows the US as the second highest producer of geothermal power in the world, with 1,904 MW of capacity in 2010.
- Geothermal power makes up approximately 18% of the country's electricity generation.

(Reported By : The IGA)
International Geothermal Association

7

Geothermal Energy in Numbers



http://www.google.jo/imgres?imgurl=http://static.seekingalpha.com/uploads/2009/3/1/saupload_18574506breakdown geothermalelectricityproduction.jpg&imgrefurl=http://seekingalpha.com/article/123371

8

You should know that

- The largest group of geothermal power plants in the world is located at The Geysers, a geothermal field in California.

9

Mantle, Magma… Money!

- The Earth is layered chemically.
- The temperature of the inner core has been estimated at values of nearly 7,000 °C (or 12,000 °F).
- Geothermal energy is power extracted from heat within the earth's crust. Very deep within the earth is a layer of molten rock known as magma.

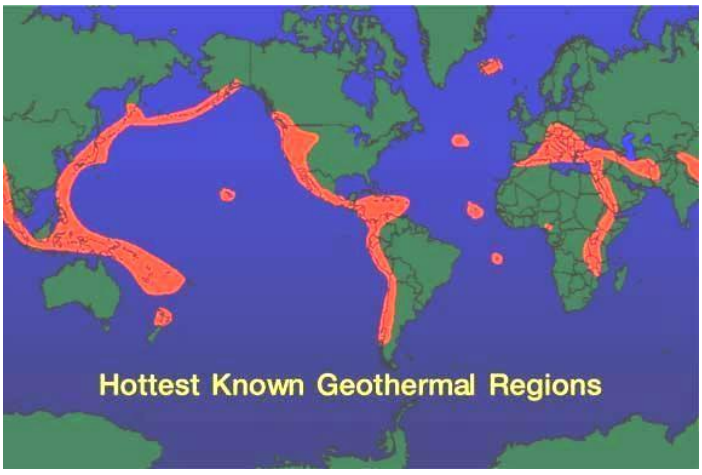
10

Mantle, Magma… Money!

- **Magma**, is the layer from which heat is continually produced through the natural decay of uranium, potassium and other radioactive materials.
- The layers of rock surrounding this magma are super-heated, gradually declining in temperature as you move farther from the molten core and toward the relatively chilly surface.

11

Hottest known areas



* Graph from Geothermal Education Office, California

12

Where to Find Geothermal Energy

- **Geothermal resources are best where heat has an easy path to the surface.**
- The easiest paths lie along plate edges, especially around active volcanoes. The Pacific Rim, running through California, Oregon and up to Alaska, is a prime example.

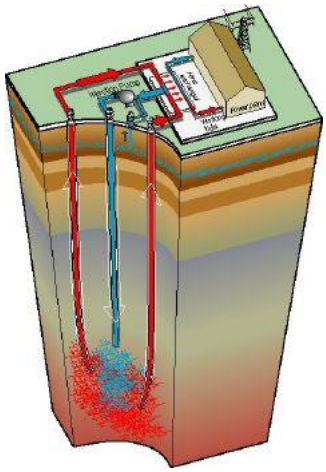
13

The General Idea of Collecting GE

- Direct Sources function by sending water down a well to be heated by the Earth's warmth.
- Then a heat pump is used to take the heat from the underground water to the substance that heats.
- Then after the water is cooled, it is injected back into the Earth.

14

Hot Dry Rocks



16

Hot Dry Rocks

- In some areas, the rocks are plenty hot enough, but water doesn't flow through them and back to the surface.
- Scientists came up with a method of "wetting" down these rocks to increase the geothermal potential.
- In a Hot Dry Rock scenario, rocks are broken up by pumping super high-pressure water into them.
- Then, cool water is circulated through the broken rocks, where it can be heated and used to create steam.

17

PART 2

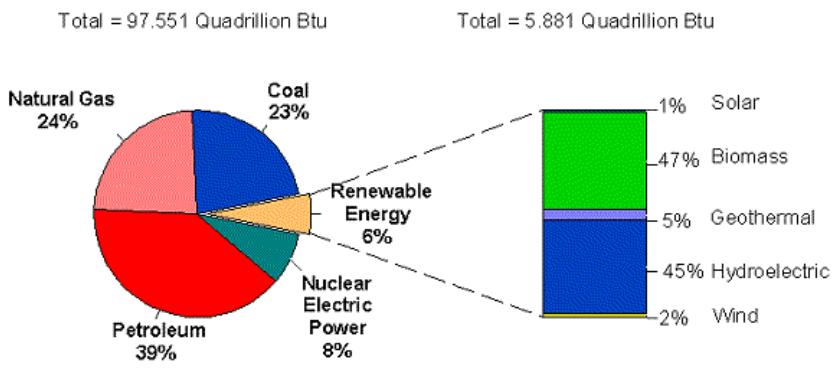
Solar Energy

Solar Energy

- Solar energy is an alternative energy source that involves harnessing the radiant light energy emitted by the sun and converting it into electrical current.
- Every second, 600 million tons of protons are converted into helium atoms in the Sun to be released as energy. Humankind only needs, on average, about 1/10,000 that amount of energy for its total consumption.

http://sun http://solarenergyfactsblog.com/interesting-facts-about-solar-energy/energyfacts.com/2008/02/solar-energy-fact-6/ http://www.wisegeek.com/what-is-solar-energy.htm

Solar Energy



21

Advantages

- You can produce your own energy
- You'll get energy without noise
- No more air pollution
- No moving parts
- Almost maintenance free
- You're using a clean and renewable resource that will "always be there".
- You'll never run out of fuel
- You'll be doing your part to decrease the amount of greenhouse gases.

http://www.solarenergysavvy.com/

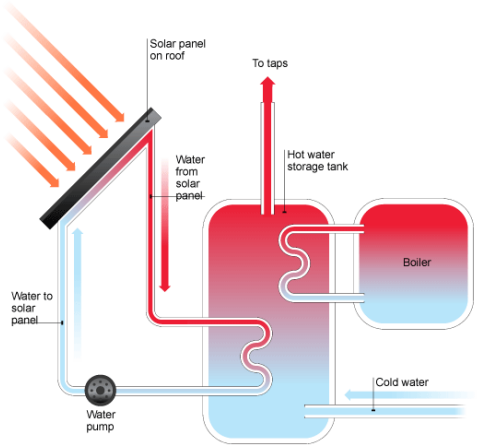
Residential Solar Energy

- Solar Photovoltaic (PV) is a method of generating electrical power by converting solar radiation into direct current electricity using semiconductors that exhibit the photovoltaic effect.
- Photovoltaic power generation employs solar panels composed of a number of cells containing a photovoltaic material.
  - Solar Home Lighting
  - Solar Heating System

http://www.solarenergysavvy.com/

Residential Solar Energy

Solar Heating System



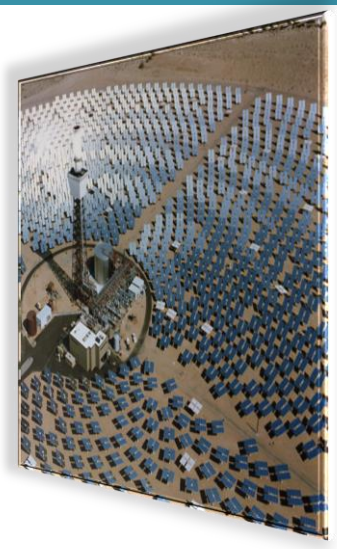
Solar Energy Cost

- Only 20 Years ago, solar energy cost 7 times as much. Advanced technologies have contributed to the enormous decrease in price, but it is mainly due to the increase in manufacturing volumes, as more and more people realize the benefits of solar energy.
- There is more good news. Solar energy cost will continue to decline as the market continues to grow, making it even more affordable.

http://www.facts-about-solar-energy.com/solar-energy-cost.html

Disadvantages

- One of the main disadvantages is the initial cost of the equipment used to harness the suns energy.
- Solar energy installation requires large area for the system to be efficient in providing a source of electricity. This may be a disadvantage in areas where space is short, or expensive (such as inner cities).



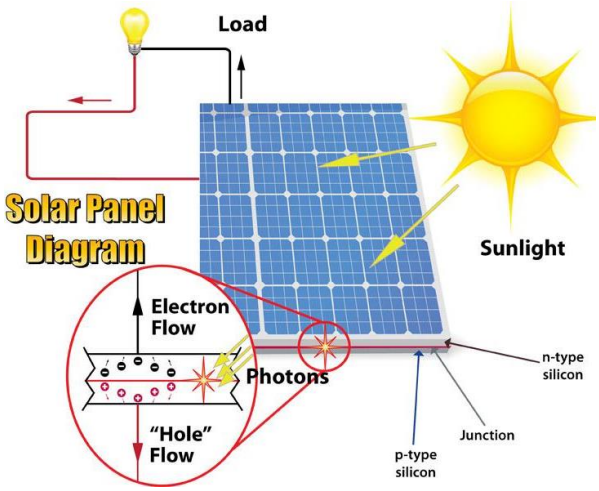
Photovoltaic Cells

- Pollution can be a disadvantage to solar panels, as pollution can degrade the efficiency of photovoltaic cells. Clouds also provide the same effect, as they can reduce the energy of the suns rays.
- Solar energy is only useful when the sun is shining. During the night, your expensive solar equipment will be useless.
- However, the use of solar battery chargers can help to reduce the effects of this disadvantage.

http://www.clean-energy-ideas.com/articles/disadvantages_of_solar_energy.html

Photovoltaic Cells

- The location of solar panels can affect performance, due to possible obstructions from the surrounding buildings or landscape.



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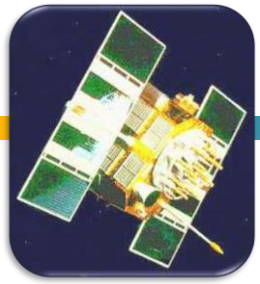


Solar panels power satellites in space

Solar cells to charge mobile and laptop

This solar panel tracks the sun, so captures more energy

Solar Cars

Fact

- The Sun will exhaust its supply of hydrogen in about 5 billion years, at which time it will collapse under it's own weight and become very hot.

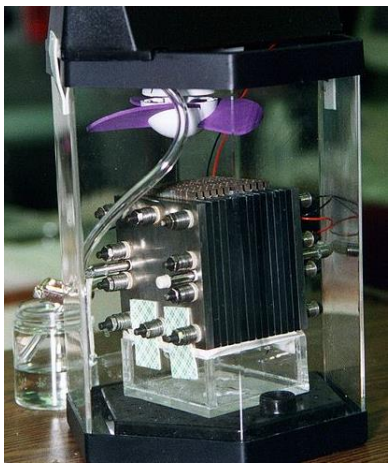
PART 3

FUEL CELLS

FUEL CELL

33

- Is an electrochemical cell that converts energy from fuel (hydrogen, natural gas, methanol, propane) into electrical energy.
- Electricity is generated from the reaction between a fuel supply and an oxidizing agent.
- Battery is another electrochemical device that we are all familiar with.

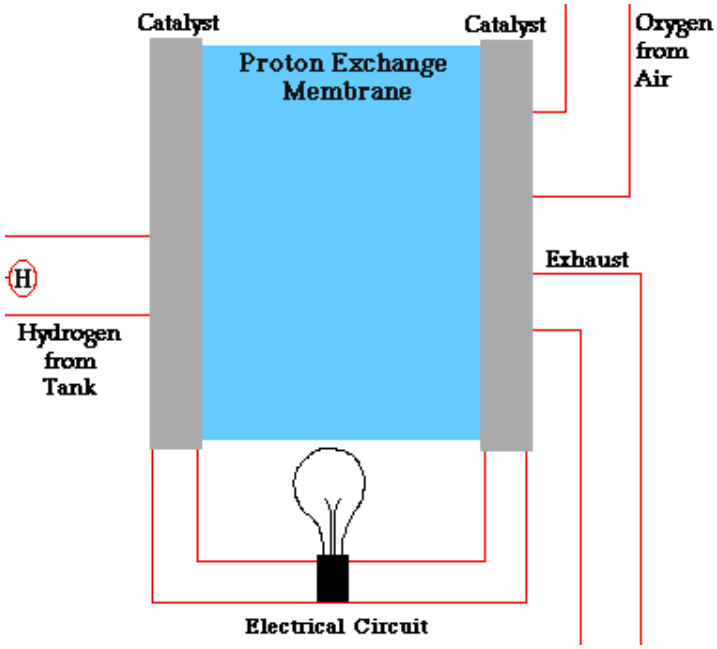


Source : Wikipedia

Fuel Cells vs. Electrochemical Cell Batteries

Fuel cells	Batteries
• Its gaseous or liquid fuel and oxidizer are led in from outside	• Stores its solid fuel and oxidizer on plates
• Chemicals constantly flow into the cell so it never goes dead	• A battery eventually "goes dead"
• Electrical energy is generated without combusting fuel (do not need to recharge)	• Electrical energy is generated by combusting fuel (needs recharging)
• Environmentally-friendly power source	• Have environmental impacts

34



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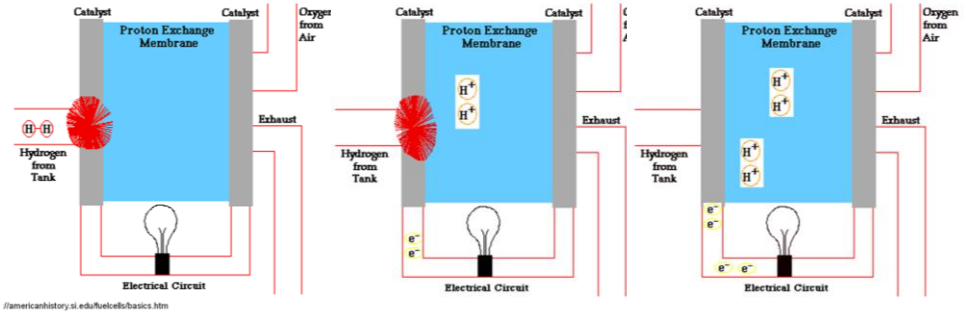
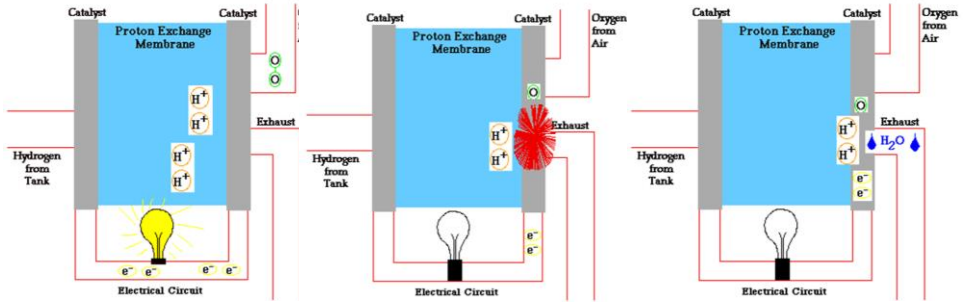
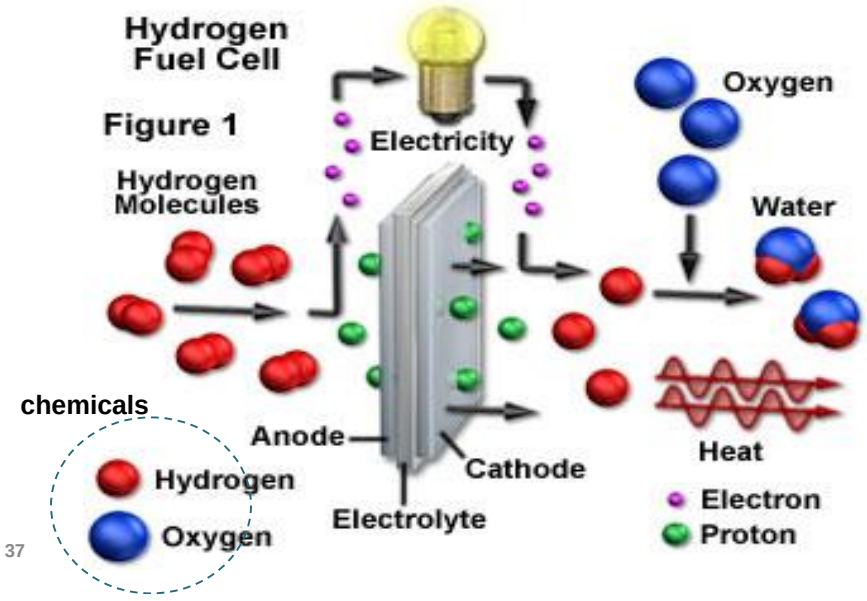
See: http://americanhistory.si.edu/fuelcells/basics.htm





Basic Principle of Fuel Cells



37

Attractive Characteristics of Fuel Cell

- High energy conversion efficiency
- Modular design
- Very low chemical pollution
- Rapid load response

Most fuel cells in use today employ hydrogen and oxygen as the chemicals.

38

Basic Elements of fuel cells

1. Anode: positively charged post of the fuel cell

- ⇨ It conducts the electrons that are freed from the hydrogen molecules, so that they can be used in an external circuit .
- ⇨ It has channels etched into it that disperse the hydrogen gas equally over the surface of the catalyst .

2. Cathode: negatively charged post of the fuel cell

- ⇨ Has channels etched into it that distribute the oxygen to the surface of the catalyst.
- ⇨ It also conducts the electrons back from the external circuit to the catalyst, where they can recombine with the hydrogen ions and oxygen to form water .

39

Basic Elements of fuel cells

3. Electrolyte: such as the proton exchange membrane

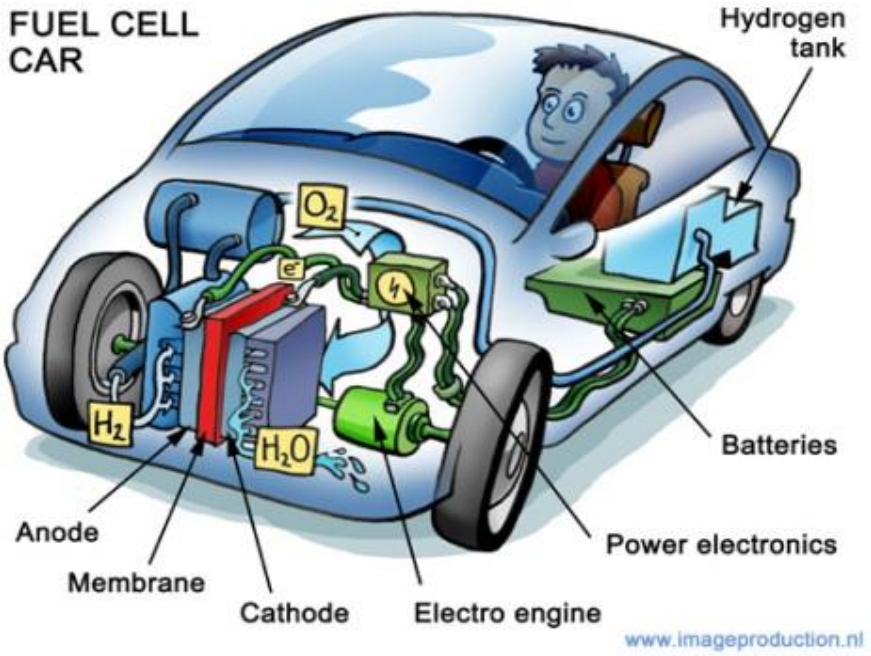
- ⇨A specially treated material (KOH, H_2SO_4) .
- ⇨Only conducts positively charged ions or protons (H^+)
- ⇨It blocks electrons

4. Catalyst

Special material that facilitates the splitting of H_2 on the anode side of fuel cell or facilitates reaction of oxygen and hydrogen at the cathode side

- ⇨ Usually made of platinum powder very thinly coated onto carbon paper or cloth.
- ⇨ It is rough and porous so that the maximum surface area of the platinum can be exposed to the hydrogen or oxygen.

40



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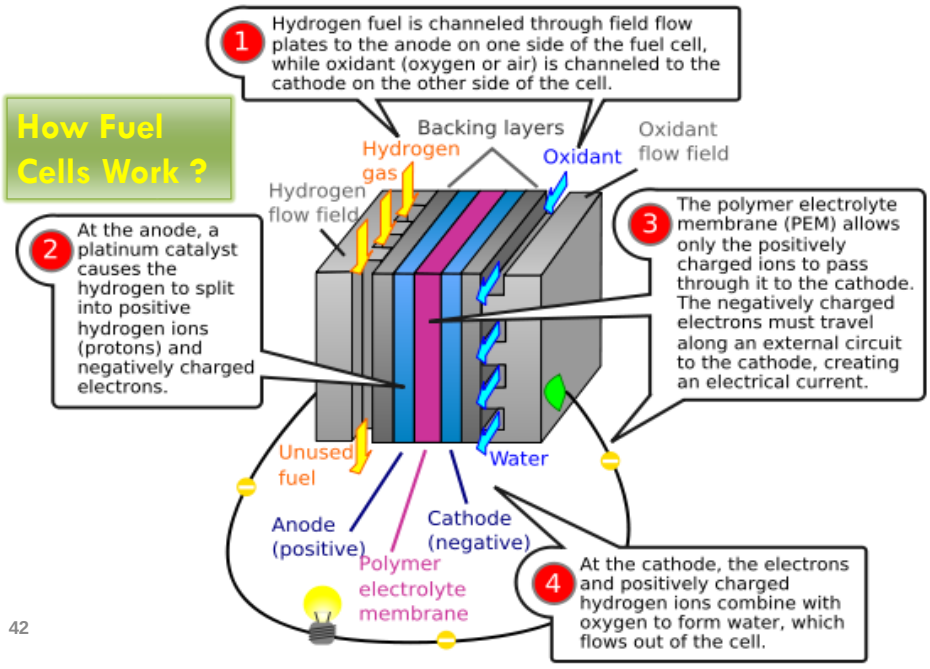
Proton exchange membrane fuel cell



42

How Fuel Cells Work ?

1. The pressurized hydrogen gas (H_2) enters the fuel cell on the anode side.
2. This gas is forced through the catalyst by the pressure. When a H_2 molecule comes in contact with the platinum catalyst, it splits into two H^+ ions and two electrons (e^-):

$$\mathbf{H_2 \Rightarrow 2H^+ + 2}\boldsymbol{e}^-$$

3. The electrons are conducted through the anode, where they make their way through the external circuit (doing useful work such as turning a motor) and return to the cathode side of the fuel cell.

43

How Fuel Cells Work ?

4. Oxygen enters the cathode and combines there with electrons returning from the electrical circuit and hydrogen ions that have traveled through the electrolyte from the anode to form water (H_2O)

$$\mathbf{O_2 + 4H^+ + 4}\boldsymbol{e}^- \mathbf{\Rightarrow 2H_2O}$$

5. This reaction in a single fuel cell produces only about 0.7 volts.
6. To get this voltage up to a reasonable level, many separate fuel cells must be combined to form a fuel-cell stack .

44

Types of Fuel Cells

- There are 4 primary types of fuel cells based on the type of electrolyte employed:
  1. Alkali
  2. Phosphoric acid
  3. Molten carbonate
  4. Solid oxide
  5. Proton exchange membrane (PEM)

See: http://americanhistory.si.edu/fuelcells/basics.htm

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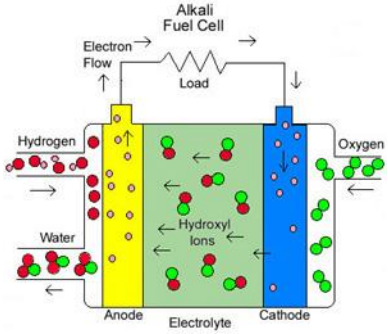

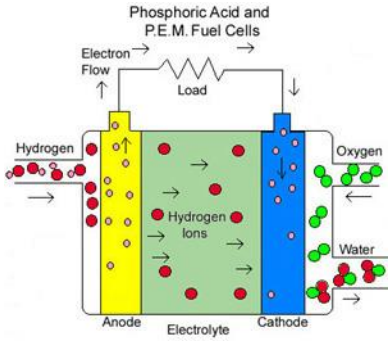

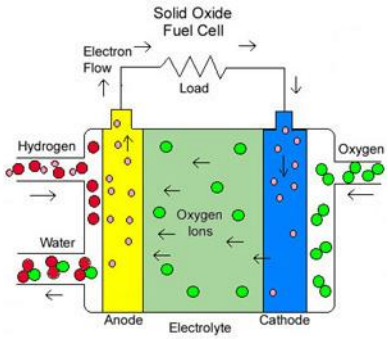

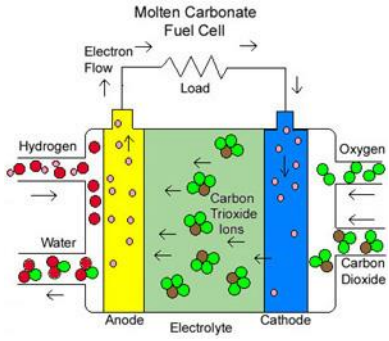

46

Types of Fuel Cells

Fuel Cell	Alkali	Molten Carbonate (MCFC)	Phosphoric Acid (PAFC)	Proton Exchange Membrane (PEM)	Solid Oxide (SOFC)
Electrolyte	Aqueous KOH solution	high-temperature compounds of salt (like $NaCO_3$ or $MgCO_3$)	phosphoric acid	polymer electrolyte in the form of thin permeable sheet.	hard, ceramic compound of metal (e.g. CaO or ZrO_2)
Efficiency	~ 70%	60 – 80%	60 – 80%	40 – 50%	~60%
Operating Temperature	300 – 400 °C	650 °C	150 – 200 °C	~80 °C	1,000 °C
Cell Output	300 W – 5 kW	2 – 100 MW	200 kW – 11 MW	50 – 250 kW	Up to 100 kW
Electrode catalyst	Platinum (Expensive)	Nickel (Inexpensive)	Platinum	Platinum is used on both sides of the membrane	

47

Types of Fuel Cells

Fuel Cell	Alkali	Molten Carbonate (MCFC)	Phosphoric Acid (PAFC)	Proton Exchange Membrane (PEM)	Solid Oxide (SOFC)
Fuel	Pure H_2	H_2	Can tolerate CO concentration of about 1.5%, which broadens the choice of fuels they can use. If gasoline is used, sulfur must be removed.	H_2	H_2
Uses	in Apollo spacecraft to provide both electricity and drinking water.			cells operate at a low enough temperature to make them suitable for homes and cars.	

48

Expected Problems/ Challenges/ Disadvantages of Fuel Cells

1. **Alkali**
   - Can leak
2. **Phosphoric acid**
   - Internal parts must be able to withstand the corrosive acid
3. **Solid oxide**
   - high temperature limits applications of SOFC units and they tend to be rather large
4. **Molten carbonate**
   - high temperature limits materials and safe uses of MCFCs–too hot for home use.
   - carbonate ions from the electrolyte are used up in the reactions, making it necessary to inject carbon dioxide to compensate.
5. **Proton exchange membrane (PEM)**
   - fuels must be purified

49

Problems with Fuel Cells

1. Hydrogen is not so readily available
2. Hydrogen is difficult to store and distribute

50