CAN WE GET UNLIMITED POWER FROM WIND OR SUN?

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OUTLINE

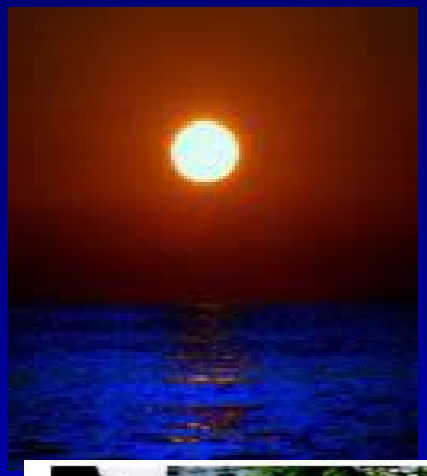


Photo credit: California Fuel Cell Partnership

- Energy, Power and Electricity
- Fun with Sun
- Sun Gods & Wind Gods
- Sun Catchers & Wind Farms
- Chemistry & Energy
- Element Number 1: Hydrogen Economy
- Nuclear Energy
- Fuel Cells & Batteries
- Our Energy Future

WHAT IS ENERGY & HOW MUCH ?

"the ability to do work like climbing a mountain, play foot ball, ride a cycle ...."
LAW OF CONSERVATION OF ENERGY

WORK IS ENERGY TRANSFORMED TO OR FROM AN OBJECT BY MEANS OF A FORCE ACTING ON THE OBJECT

1 kg bird flying 2 m/s velocity –> 2 Joule

Power = rate at which work is done by a force -> Joule/sec = Watt
1 hp = 746 W
Work = power multiplied by time
= kWh = 3.6×10^6 Joule = 3.6 MJ
If you pick up a book and place on a table - 4×10^{-6} kWh = 4 mWh

260 Kg. -> 2 m = 5100 J

WHERE DOES EACH OF THESE GET ITS ENERGY?

Solids, Liquids and Gases (Kinetic Energy)

Solids (Military Unit)

- Rigid
- No Disorder
- No Random motion
- Small Distances Between Molecules

- Diffusion
- Much Disorder
- Much Random motion
- Large Distances Between Molecules

Liquids (Reunion Party)

- Flowing
- Much Disorder
- Some Random motion
- Medium Distances Between Molecules

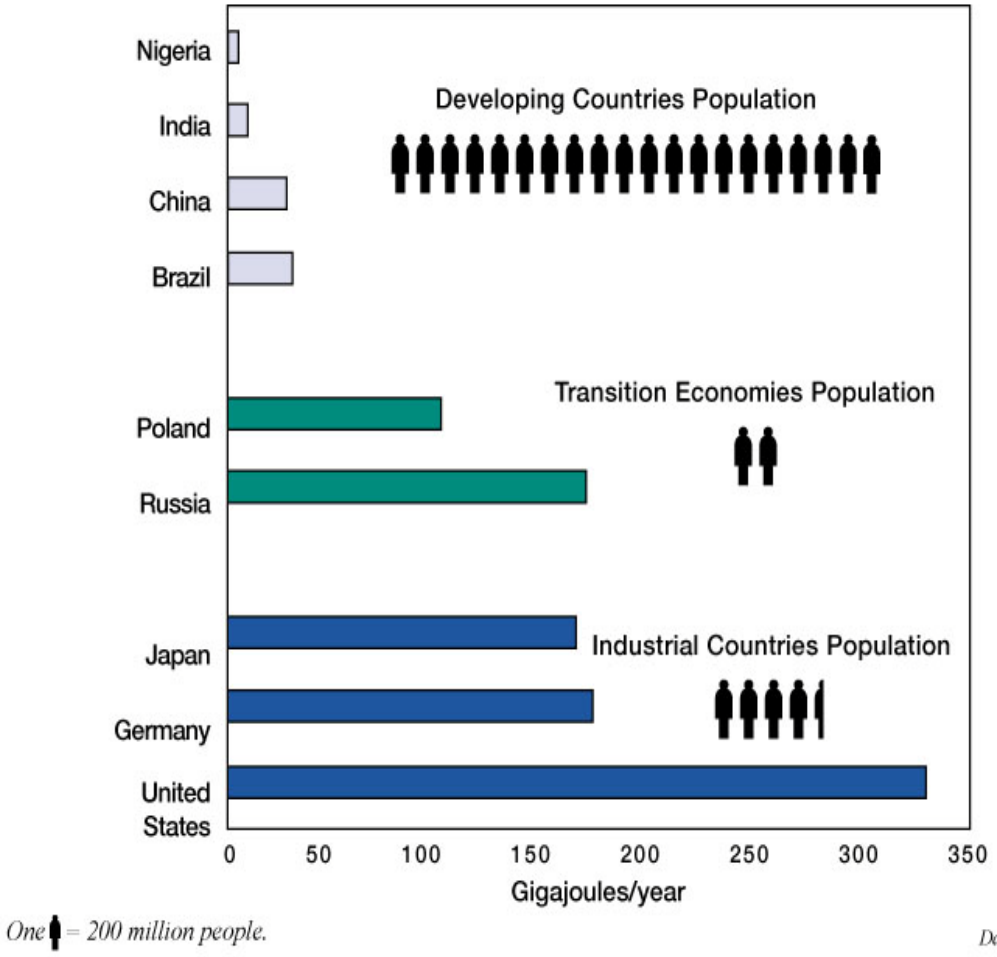
Gases (Soccer Game)

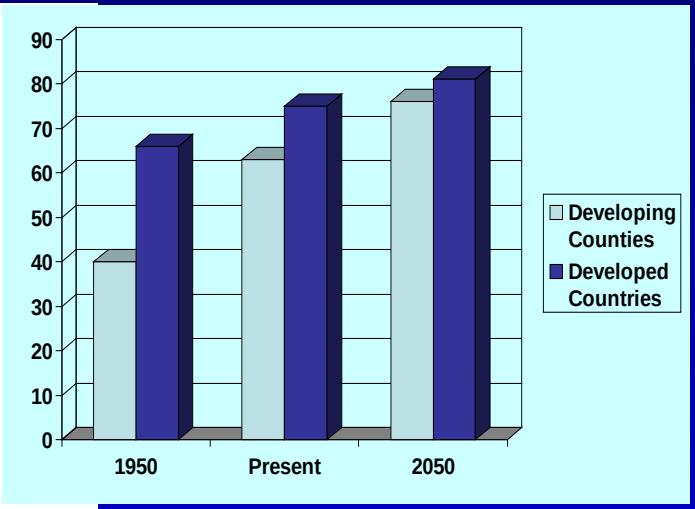
Energy densities of various energy sources

Watt Hour/kg

10^{10}		1.2X 10^{10} Fast breeder reactors
10^{9}		
10^{8}		1.7 x 10^{8} Uranium-235
10^{7}		
10^{6}		
10^{5}		
10^{4}		3.3 x 10^{4} Hydrogen 1.3 x 10^{4} Petrol/Gasoline
10^{3}		8.5 x 10^{3} Coal
10^{2}		3.8 x 10^{2}
10^{1}		0.2 x 10^{2}
10^{0}		Primary and secondary Batteries, Fuel cells
1		

Population and Energy Use per Capita



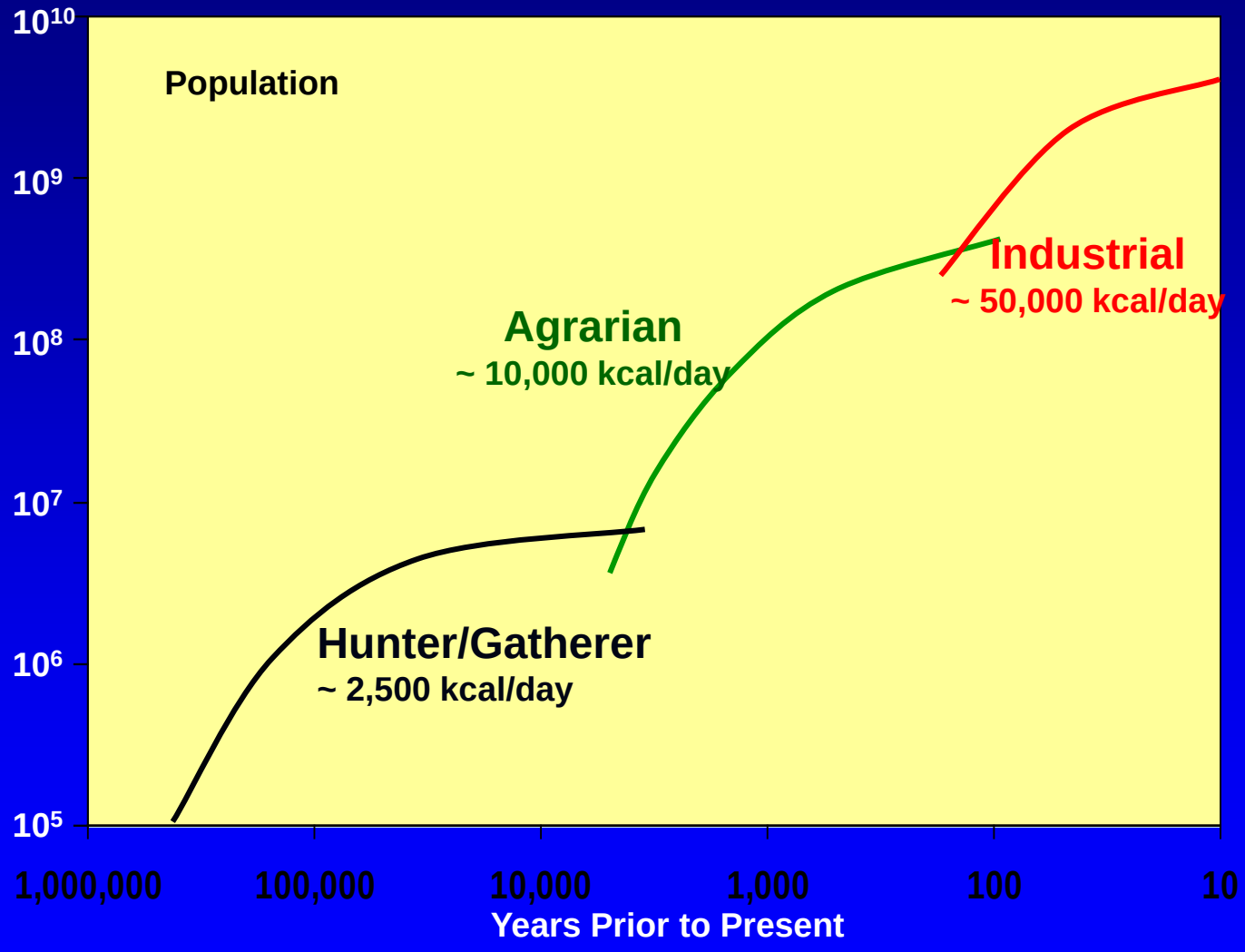


LIFE EXPECTANCY

ECONOMIC GROWTH

Energy-related GHG emissions projected to triple by 2030!
US with 4.8% of population uses 21% of world energy production
while India with 16% population uses 3.5% only!

Cycles of Demographic Growth



20 % OF 6.7 BILLION LIVE WITH OUT ELECTRICITY!

TOKYO

SEOUL

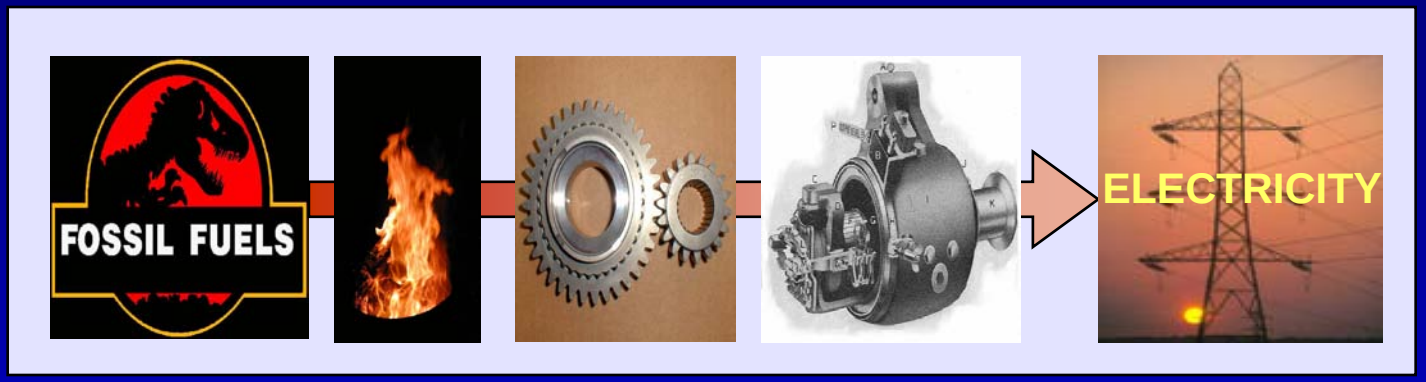

HOLLYWOOD

JAKARTHA

Great-pacific-garbage

NEW YORK

Conventional energy flow



- Direct green house gas emission
- High temperature operation
- Lower efficiency
- Lower efficiency at partial load
- Loud operation
- Low investment cost
- Well established technology

THERMAL POWER STATIONS

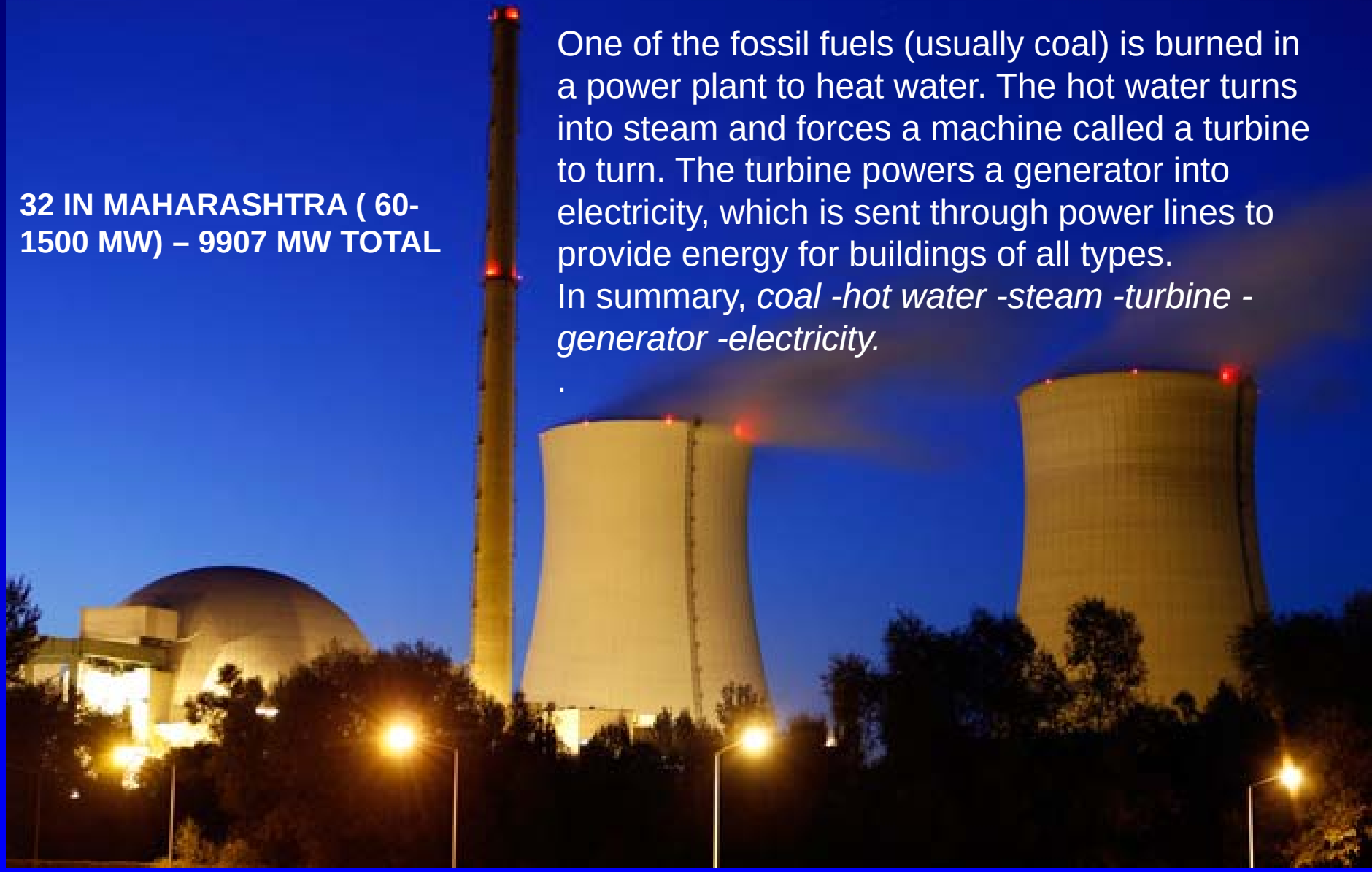
Photo credit: California Energy Commission

Photo credit:
American Coal Foundation

Photo credit: corbisimages.com

32 IN MAHARASHTRA (60-1500 MW) – 9907 MW TOTAL

One of the fossil fuels (usually coal) is burned in a power plant to heat water. The hot water turns into steam and forces a machine called a turbine to turn. The turbine powers a generator into electricity, which is sent through power lines to provide energy for buildings of all types.
In summary, *coal -hot water -steam -turbine -generator -electricity.*
.



HYDROELECTRIC POWER

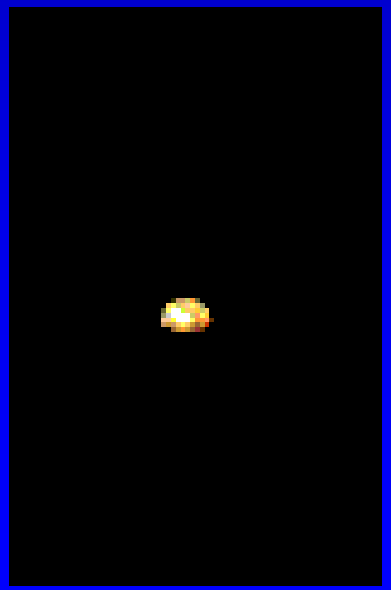
36 IN MAHARASHTRA – 3000 MW

7 UNDER CONSTRUCTION – 660 MW

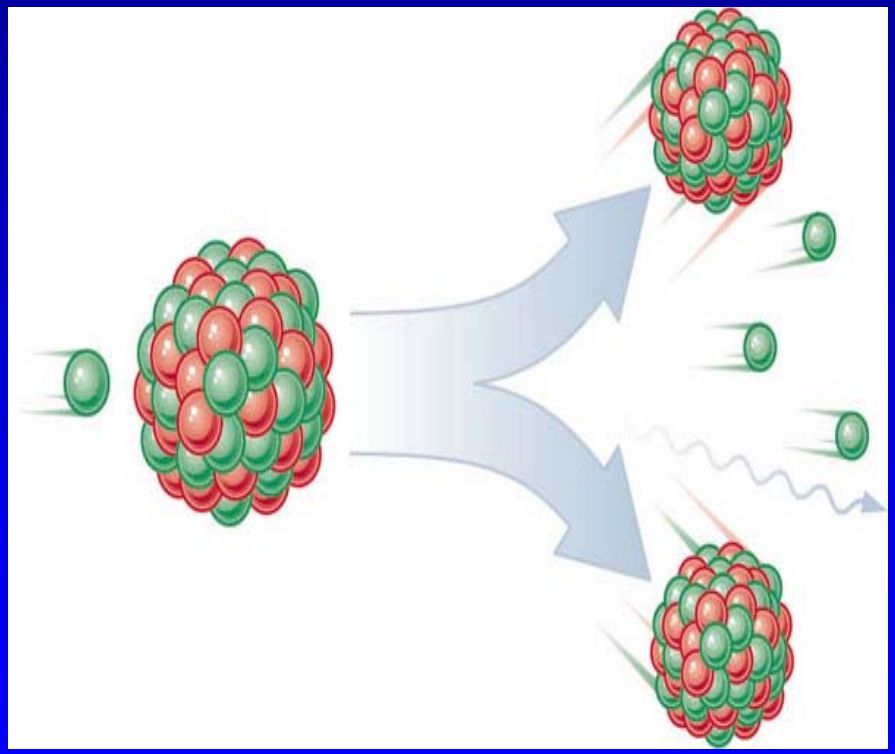
Electricity can also be made from windmills or from water behind a dam. Falling water or rotating windmill blades will cause turbines to generate electricity

INDIA AS AN EMERGING ECONOMY

Nuclear Energy

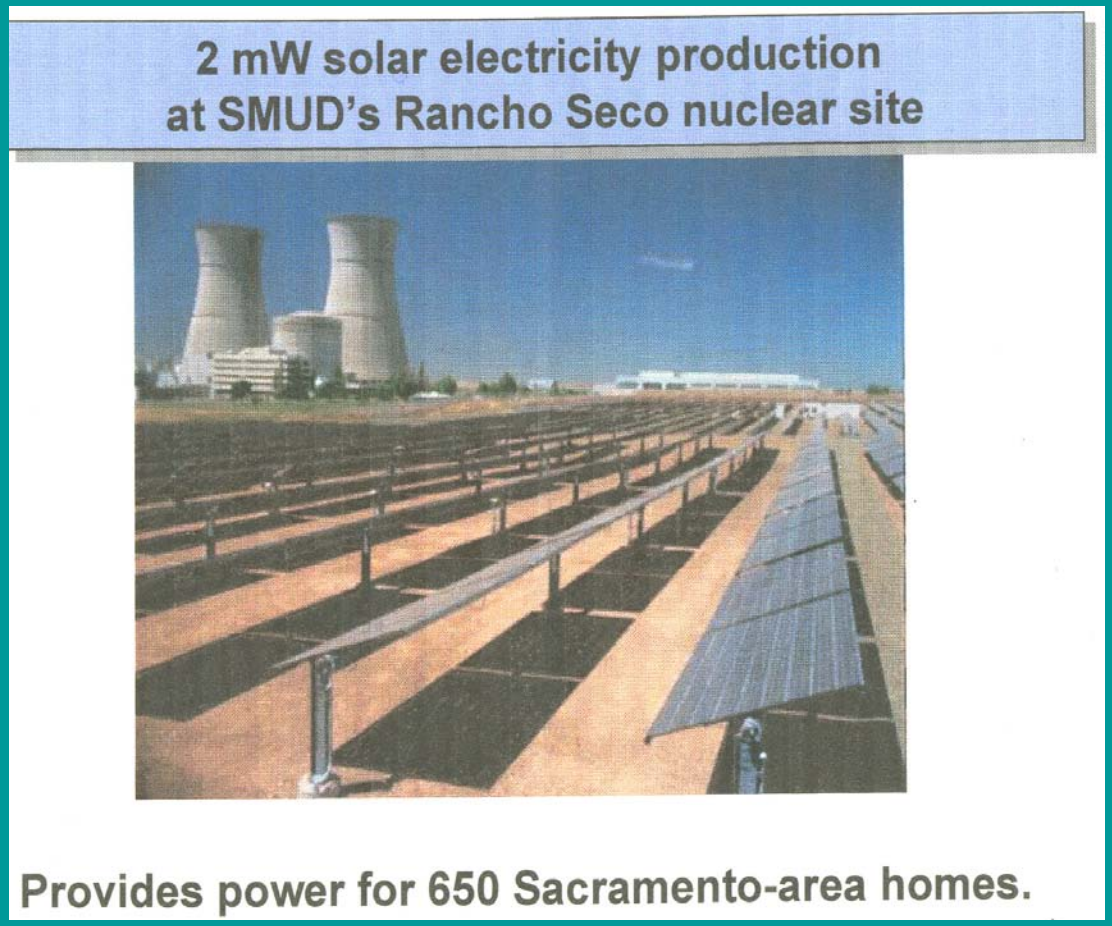


Fission: History and Overview



- Discovered 1938: Otto Hahn and Frittz Strassmann
- Presented 1939: Lise Meitner and Otto Frisch
- Research of Nuclear Fission began U.S. Weapons Program
- 1942 First Controlled self sustaining fission reaction, Enrico Fermi
- Nuclear Fission Creates electricity
- Three types of nuclear energy: Fission reactions, Fusion reactions, and Radioactive decay

NUCLEAR POWER



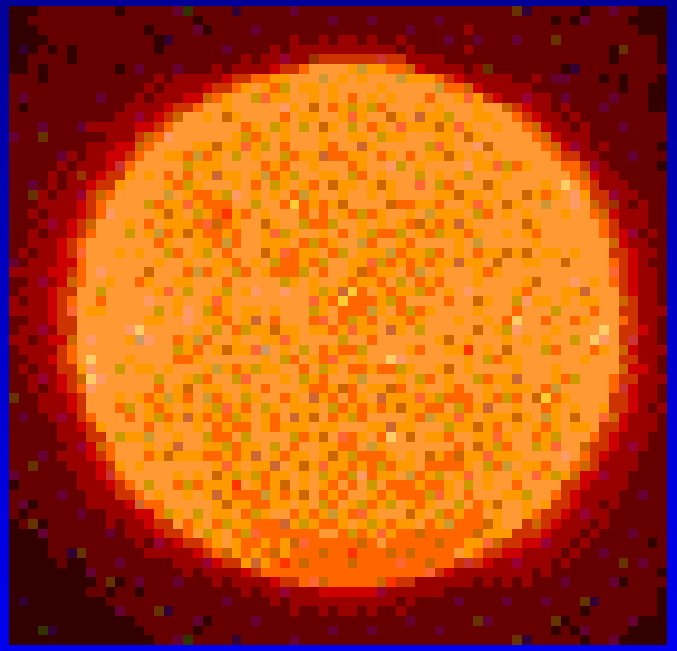
100 nuclear submarines; 440 commercial nuclear reactors; -> 15% power - France 76%, Belgium 56%, South Korea 36%, Switzerland 40%, Sweden 47%, Finland; 30%, Japan 33%, United Kingdom 25%, Bulgaria 46%, Hungry 42%, United States 20%
17 in India itself

Nuclear Waste

- - Two types of nuclear waste
  - o Low level
  - o High level
- Two types of high level wastes
  + Spent
  + Waste materials

- Storage Methods
  + Pools
  + Above ground storage casts

- Transportation of Spent nuclear Fuel
  + Shipped throughout the US to storage facilities

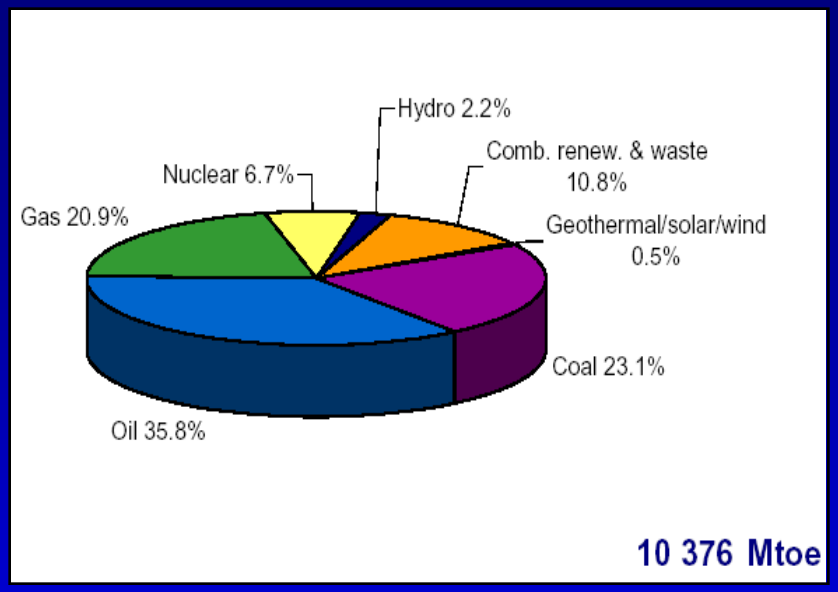


TOO MANY VEHICLES!

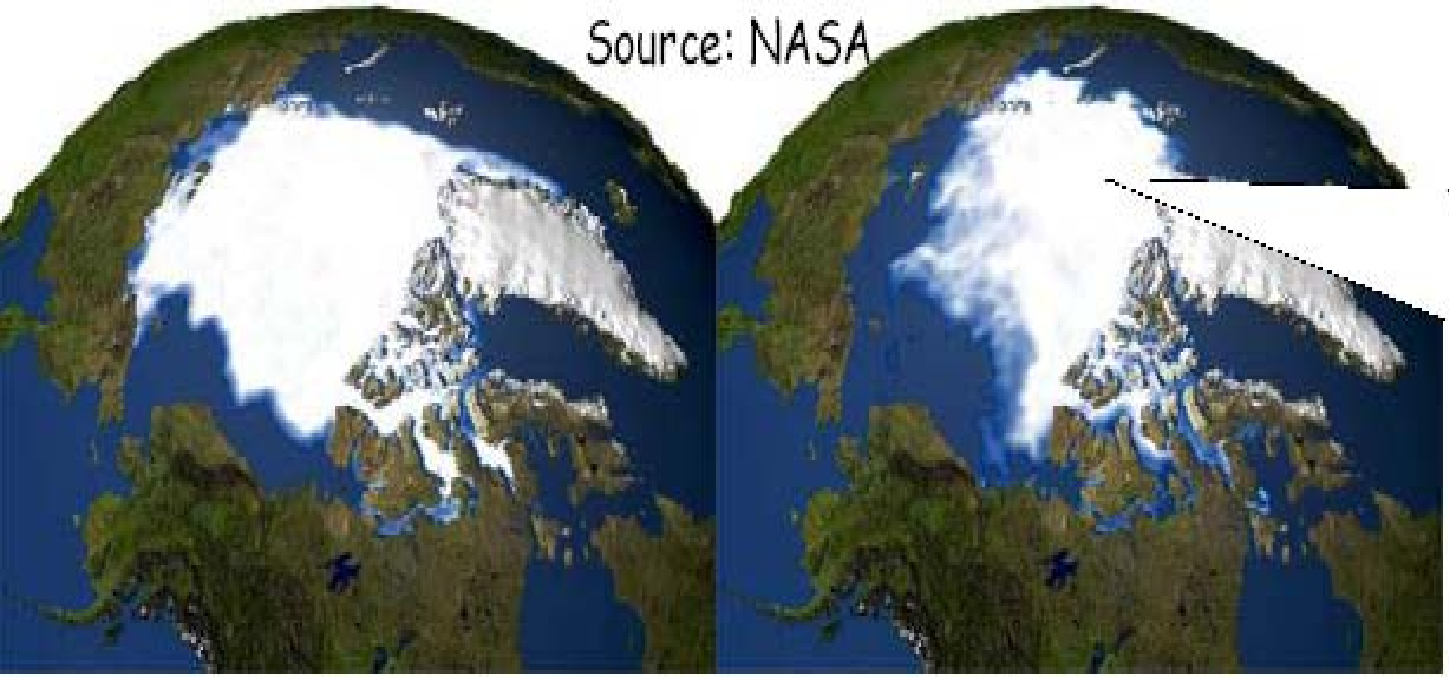
Nature of global energy problem

FACTS	ACTIONS NEEDED
Population growth	Limit of growth of populations
Increasing Energy demand	Increasing efficiency
Limited re-served energy	Exploring all energy options
Environmental degradation	New clean technology

Global temperature rise



Global temperature rise: fingerprint



Arctic sea ice, 1979

Arctic sea ice, 2003

Why Hydrogen Economy

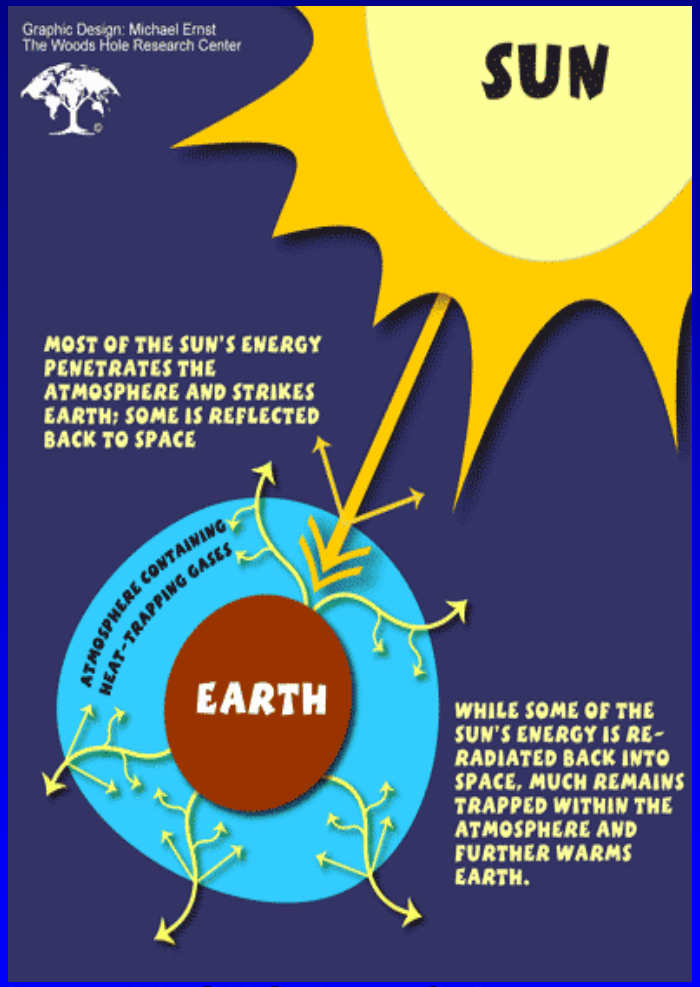
Global war

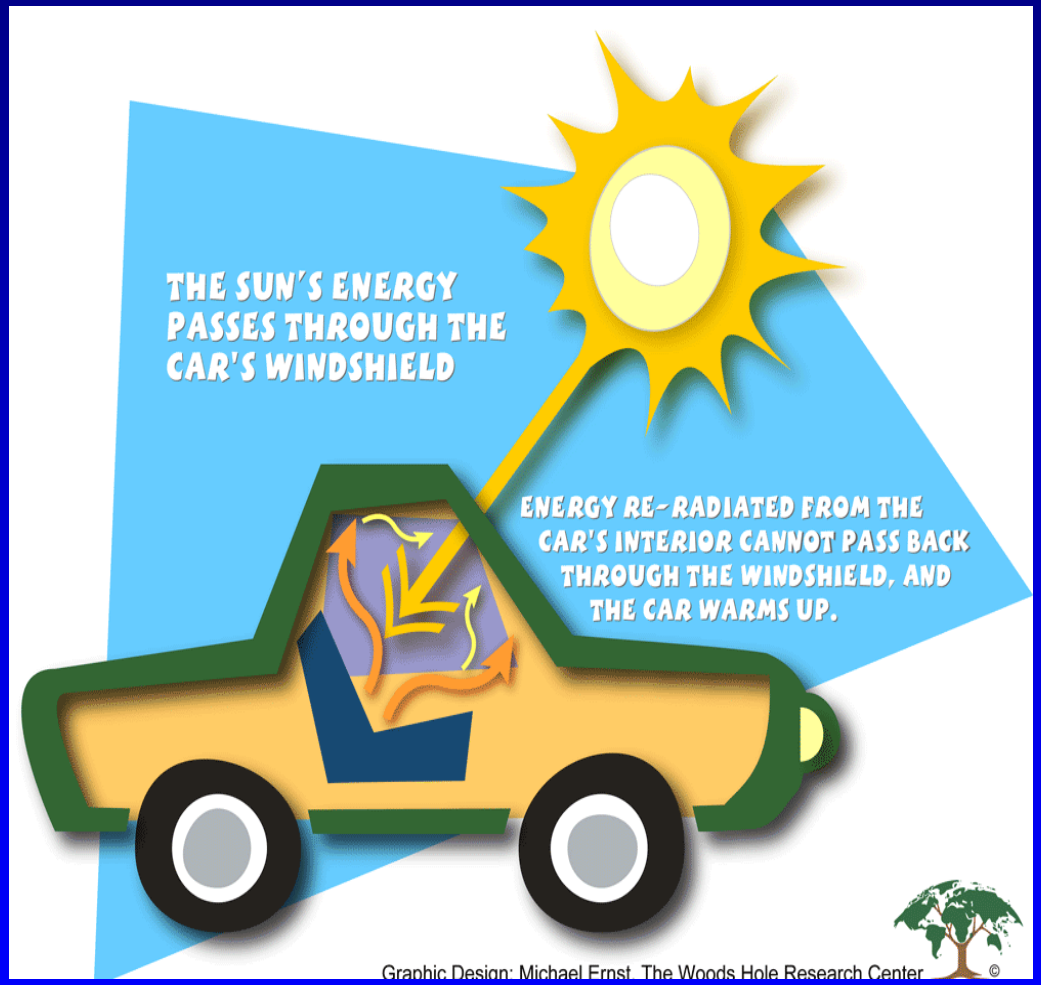
Global warn ing

Global warming

- Solar energy -using the sun
- Wind energy -using wind to turn a windmill
- Nuclear energy -splitting uranium atoms to create heat energy
- Geothermal energy -harnessing heat and steam generated below Earth's surface
- Waves and Tides -using the force of ocean waves and tides

Green house effect





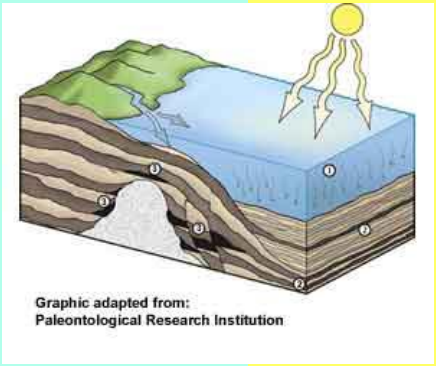
Source: Wood Hole Research Centre

Threats & Consequences

THREAT

ON

BY



CONSEQUENCES

- **Reserved fossil fuel is limited**
- **Depletion of fossil fuel**
  - Coal 300 Years
  - Petroleum 40 years
- **Future energy crisis**

Acid rain

Global warming

Effects on Ecosystems

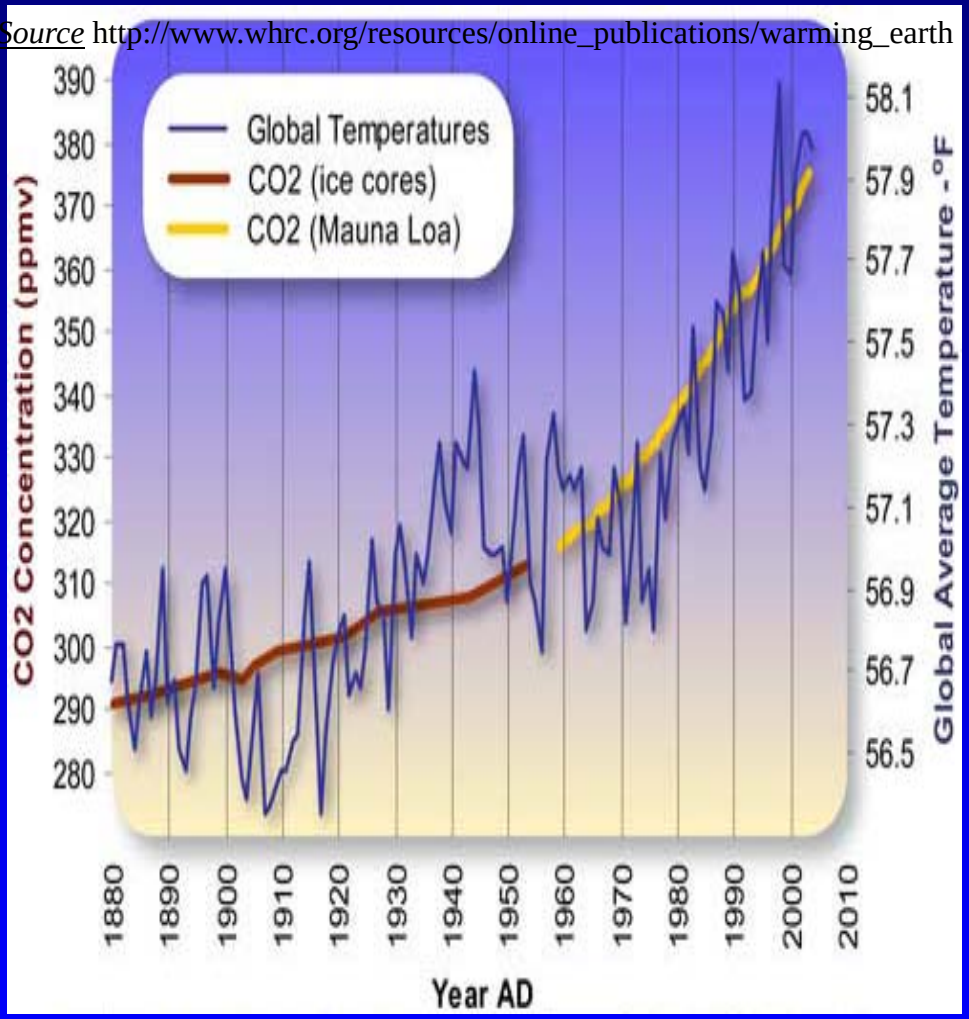
Glaciers melting

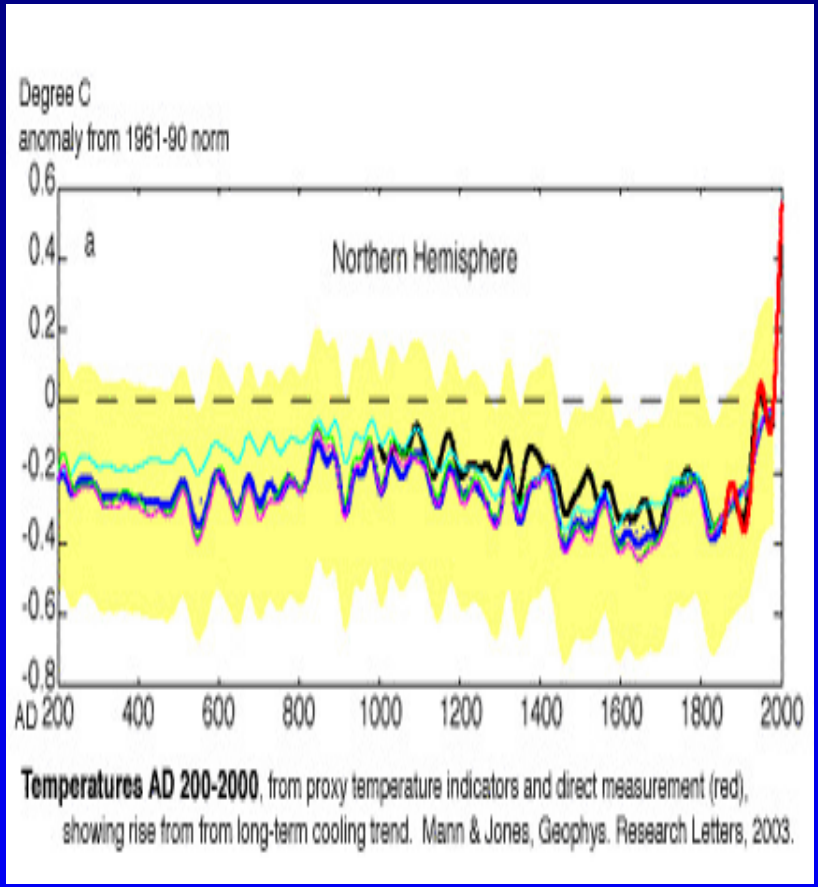
Heat waves, tropical storm and warm weather

Ocean warming, sea-level rise and coastal flooding

Global average temperature rise

Source http://www.whrc.org/resources/online_publications/warming_earth





Temperatures AD 200-2000, from proxy temperature indicators and direct measurement (red), showing rise from from long-term cooling trend. Mann & Jones, Geophys. Research Letters, 2003.

CO_2 by major industries (Global)

	CO_2 emissions Million tonnes/year
Iron and steel production	1440
Cement manufacture	1130
Oil refining	690
Petrochemicals	520
Other industry	1320
Overall industry	5100
Power generation	7660

ENERGY SOURCES

Non Renewable Energy

Coal, Natural Gas, Petroleum, Nuclear Energy

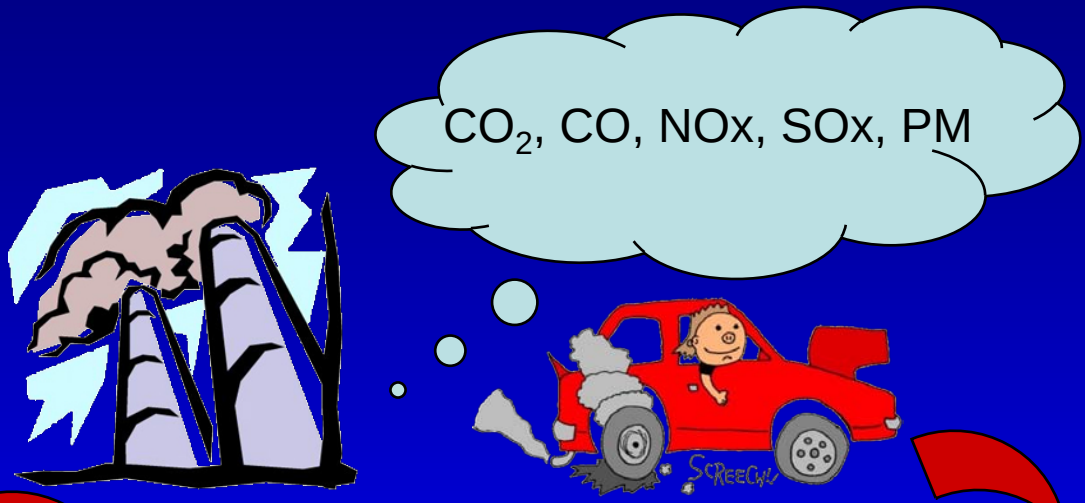
Alternate Energy (Renewable Energy)

- Wind Energy
- Solar Energy
- Oceanic Energy (wave, tide, ocean thermal)
- Hydro Power
- Geothermal
- Biomass

Hydrogen and fuel cells ???

Nuclear Fusion ???

How can we have the Energy, Vehicles and Comfort by not polluting or with less pollution?



Solutions

Long term

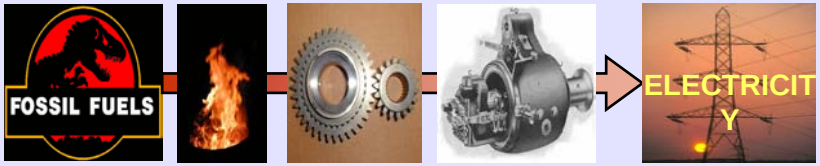
Short term

Alternate fuels

Clean up of exhaust

Comparison: Conventional converters & Fuel cells

Conventional energy converter

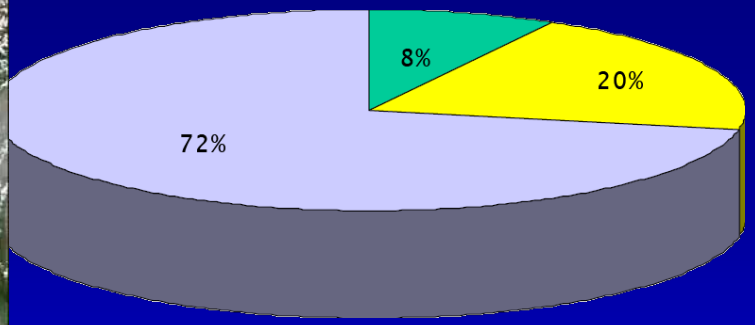


- Direct green house gas emission
- High temperature operation
- Lower efficiency
- Lower efficiency at partial load
- Loud operation
- Low investment cost
- Well established technology

Fuel cell

- Indirect/lower emission
- High and low temp. operation
- Higher efficiency
- Higher efficiency at partial load
- Quiet operation
- High investment cost at present
- Under R&D

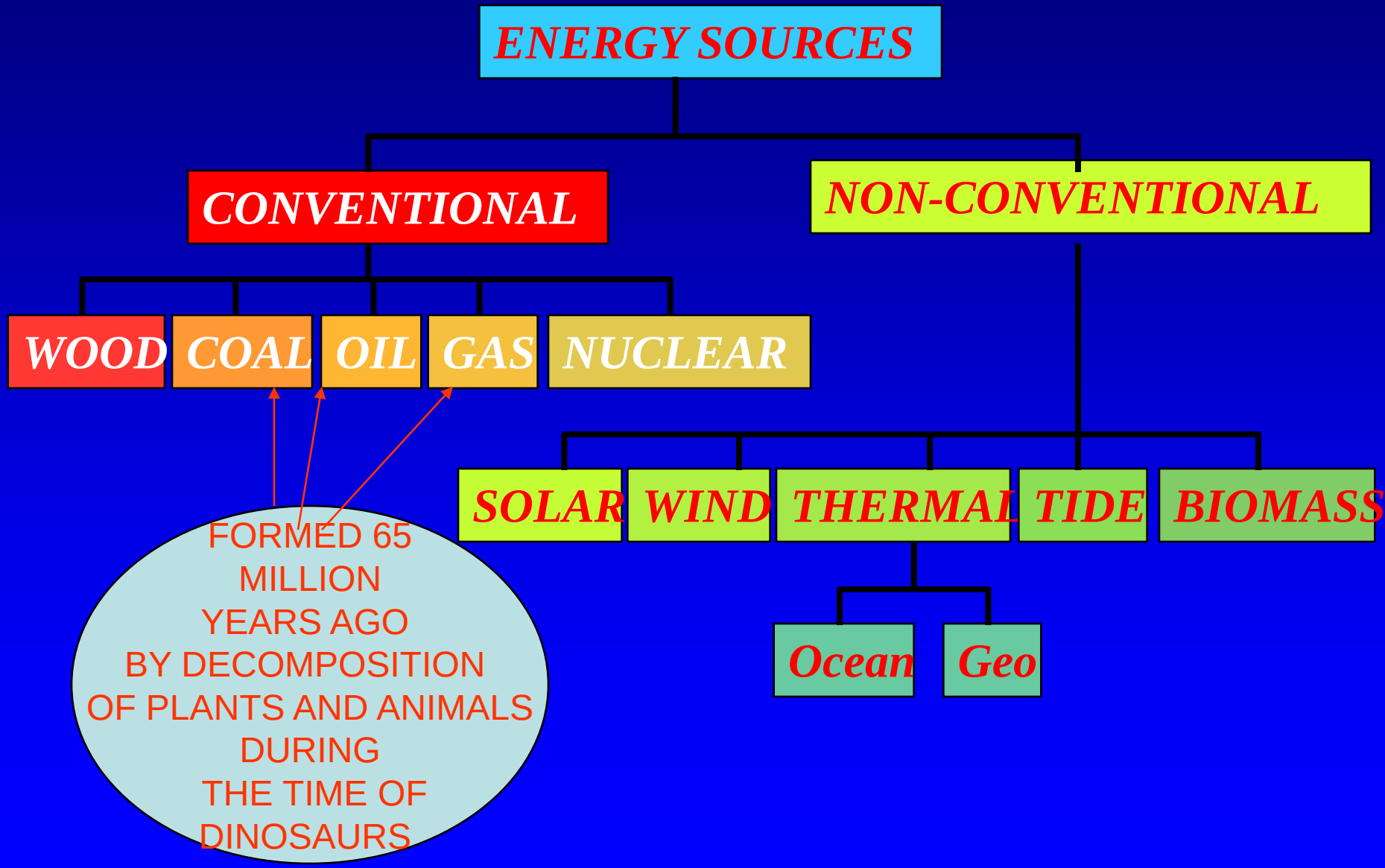
Air pollution in major Indian cities



FUELLS FROM HELL!

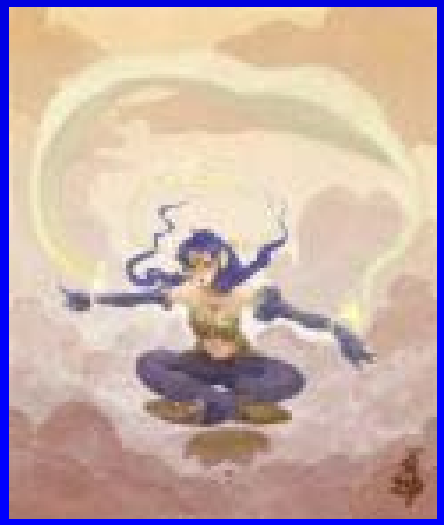
Innovative Solutions

Global energy resources



SUN GODS & WIND GODS

Ya Poncha



What is biomass?

Wood

Seeds

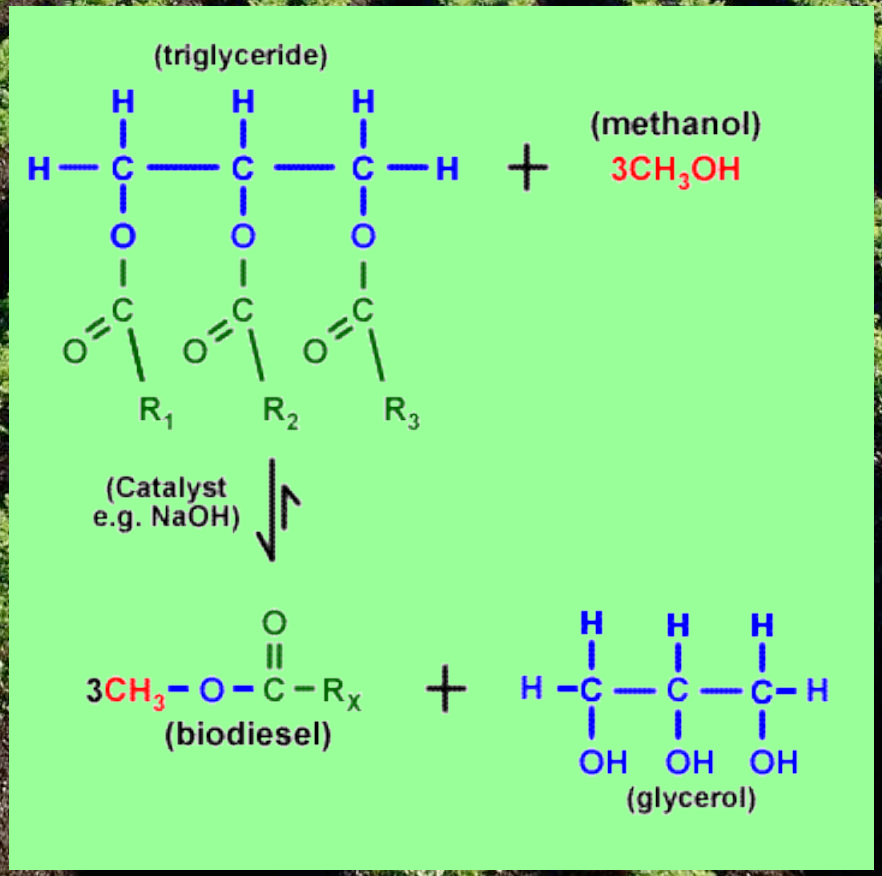
Crops

Garbage

Alcohol fuels/fruits

Manure

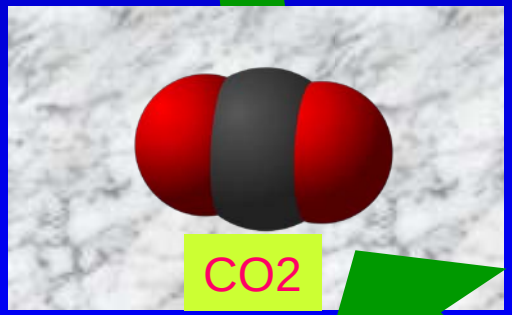
Biodiesel: A next generation fuel?



Oil extraction

Farming

Biodiesel production



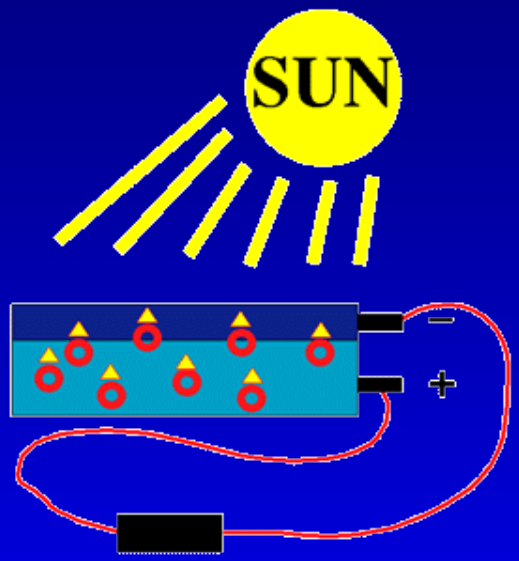
CO2

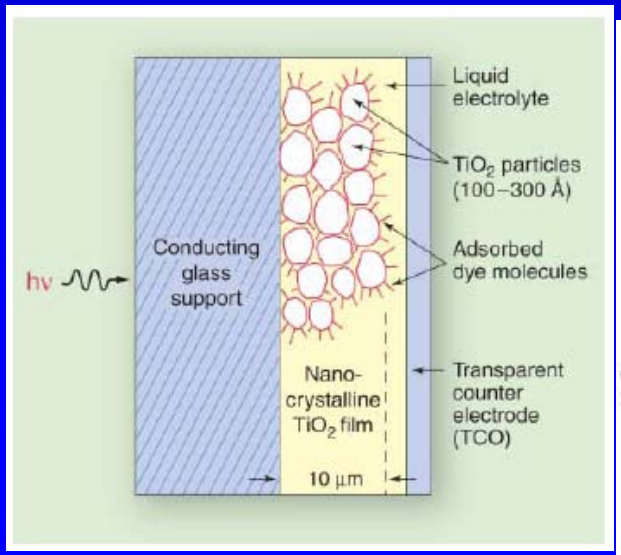
Distribution

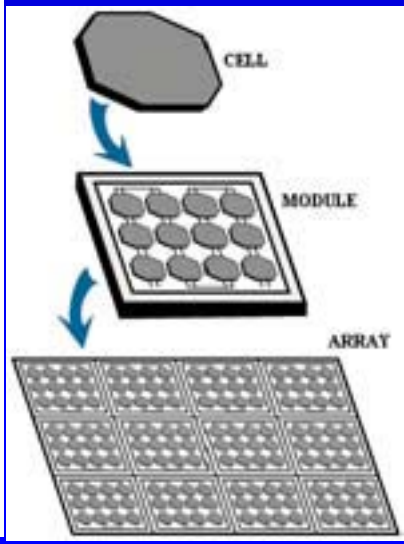
Use

FUN WITH THE SUN

- Scientists first got the idea of nuclear fusion from the sun and the stars.
- The sun is the solar system's biggest fusion reactor. Formed about 4.6 billion years ago, it has a surface temperature approaching 6000^0C while inside it could be 15 million ^{0}C
- About a million of earth could fit in it easily!
- Sun is composed of 75% Hydrogen,23% He and 2% others
- The sun turns hydrogen to helium in its core. This process is called nucleosynthesis. The released energy creates both heat and (sun) light.







WILL SUN EVER RUN OUT OF ITS FUEL?

SOLAR FLARES & WINDS

SUN'S OUTPUT 386 BILLION BILLION MW

- **YES, EVENTUALLY THE HYDROGEN IN SUN'S CORE WILL RUN OUT.ONCE THIS HAPPENS THE STAR WILL DIE**
- **THE SUN HAS USED ABOUT HALF OF ITS HYDROGEN RESERVES ALREADY, BUT DON'T WORRY THE SUN STILL HAS A GOOD 5 BILLION YEARS LEFT**
- **SUN CONSUMES 4 MILLION TONNES OF HYDROGEN EVERY SECOND, EXPANDS OUTWARD , MERCURY WILL BE ENGULFED, OCEANS WILL EVAPORATE AND CORE WILL COLLAPSE UNDER GRAVITY**
- **FEW BILLION YEARS FOR PLANNING OUR ESCAPE!**

http://www.astronomy.ohio-state.edu/~pogge/Lectures/vistas97.html

SOLAR SPAIN

HOW TO BRING SOLAR ENERGY TO 7 BILLION PEOPLE ON EARTH

SOLAR THERMAL

PHOTOVOLTAIC

HOW FAST?

HOW CHEAP?

CSP Potential: squares indicate the size of land that, if covered by CSP plants, could generate as much electricity as currently consumed by the world (biggest square), the Europen Union (middle), and Germany (smallest)

WIND ENERGY

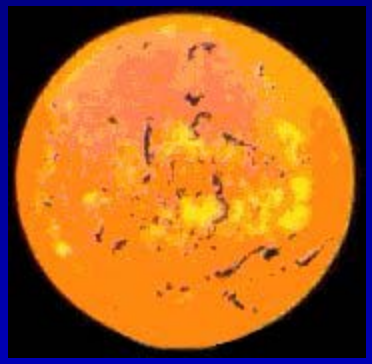
- Early in the twentieth century, windmills were commonly used across the Great Plains to pump water and to generate electricity
- Ancient ships.
- Modern wind Turbanes

The Nevada Solar One CSP power plant near Las Vegas, Nevada. The 400-acre, 64 MW CSP plant produces enough energy to power about 14,000 homes

Covered by concentrating solar power plants, less than one percent of the world's deserts could produce all of our electricity by 2050. So what is stopping us from doing it?

About 500 years ago, Leonardo da Vinci scribbled a few sketches into his notebook showing how to concentrate and use solar energy. Going back even further, soldiers in ancient Greece are said to have set enemy ships ablaze by using their shields to concentrate reflected sunlight on sails. A few thousand years later, concentrating solar power (CSP) could become the world's most promising renewable energy technology.

The Search for Intelligent Life in the Universe

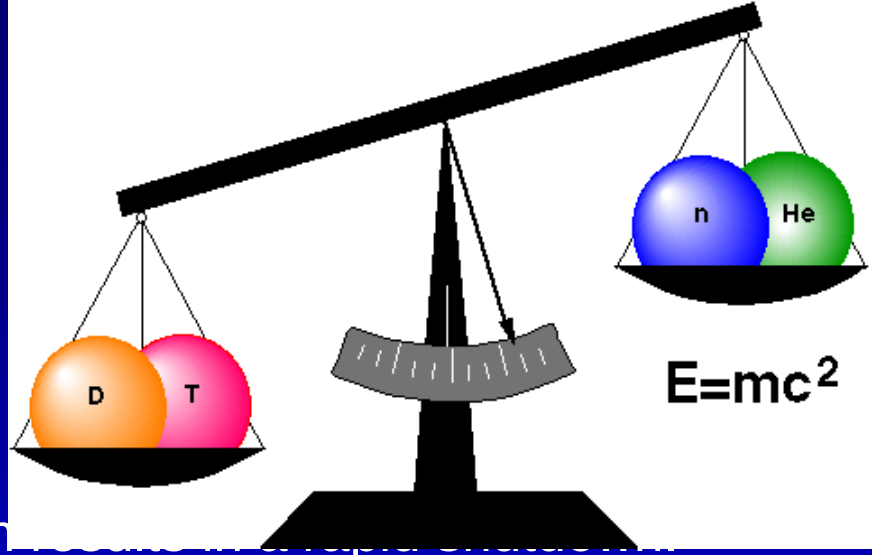


Our sun with its nine planets is only one of several hundred *billion* stars in the Milky Way galaxy.

Our galaxy in turn is but one of hundreds of billions of galaxies in the visible universe.

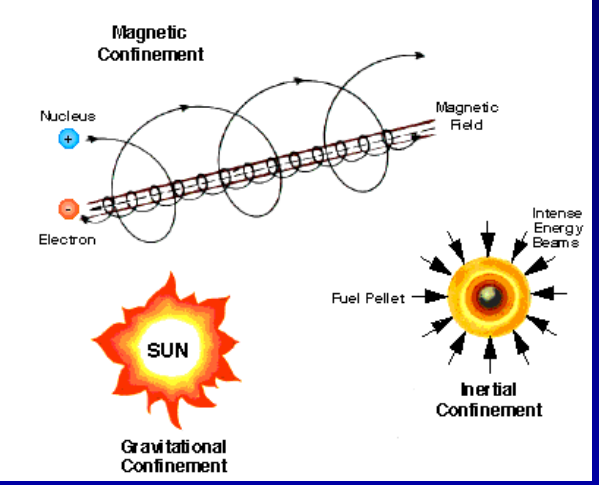
How many millions of solar systems are out there, somewhere, with planets sustaining life, and thinking beings who, like us, gaze up at the skies, and wonder?

The sun is about 4.5 billion years old, and will probably look a lot like it does now for another five billion years or so, until its supply of hydrogen runs out. Then it will swell to red giant size for about 500 million years, collapse to a white dwarf, and slowly begin to cool off over the next thousand billion years or so.
The sun is made up primarily of hydrogen (71%) and helium (27%), the major components of the interstellar gases from which the sun originally formed. The remaining 2% is composed of elements such as oxygen, carbon, nitrogen, neon, iron, silicon, magnesium, and sulphur



- A vast, new source of energy.
- Fuels are plentiful.
- Inherently safe since any malfunction
- No atmospheric pollution leading to acid rain or "greenhouse" effect.
- Radioactivity of the reactor structure, caused by the neutrons, decays rapidly and can be minimized by careful selection of low-activation materials. Provision for geological time-span disposal is not needed.
- Sunlight is energy released from fusion reactions in the sun.
- Complete fusion reactions produce no long-life products
- The fusion bomb, developed and first exploded in the early 1950's, was the first use of nuclear fusion.

The only waste products are helium, and toxic waste that is contained within the chamber and is not long-term.
Fusion produces no climate-changing or atmosphere-polluting emissions.



The Future is Fusion

The Sun is our Greatest source of Energy- uses fusion

The source of fusion is vastly abundant in our oceans (an isotope of hydrogen in water)

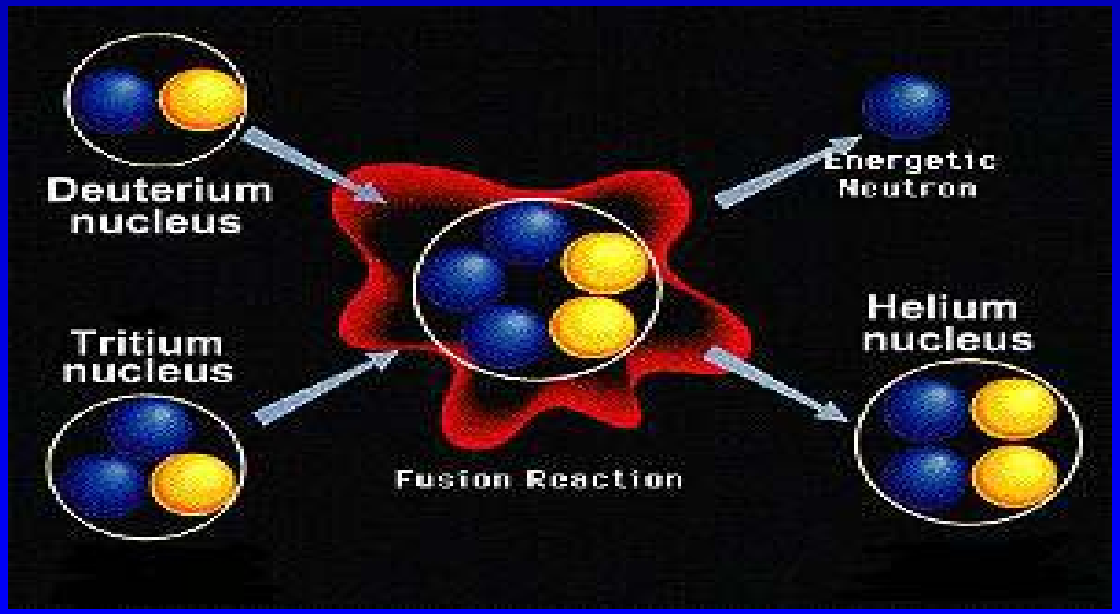
The waste of fusion is helium, and there is no pollution of long term extent.

Nuclear fusion --> $E = mc^2$

Fusion can give us energy for millions of years

Fusion: Overview and History

- **British Physicists in the 1940s and 50s housed in a hangar at Harwell a device called ZETA - Zero Energy Toroidal Assembly which was the first fusion based operating system.**
- **Masked in the secrecy of the Cold War**
- **Fusion is the production of a thermonuclear reaction in a gas discharge**



Called 'fusion' because it is based on fusing light nuclei such as hydrogen isotopes to release energy, similar to that which powers the sun and other stars.

What is Hydrogen Economy!

- Hydrogen economy is different from the world we see today
- Imagine! Hydrogen is available everywhere from kitchen to fuel station
- Its really different world
- This different world will not be realized in a day, year or decade.
- However, initiative has to be taken immediately!!!
- There are many many challenges ahead for the transition
- But it has to overcome for the existence of the future civilization

PRODUCTION

Biomass
Microbial
Pyrolysis
Fossil Fuels
Coal gasification
Electrolysis
of water
Biophotocatalysis
Photolystics

STORAGE

Compressed
Gas
Liquid H_2
Solid State Storage
Alloys, Hydrides, organic solids
Carbon nanotubes

HYDROGEN ENERGY

CONVERSION

Combustion

Fuel Cells

PEFCs
SOFCs
DMFCs
DBFCs

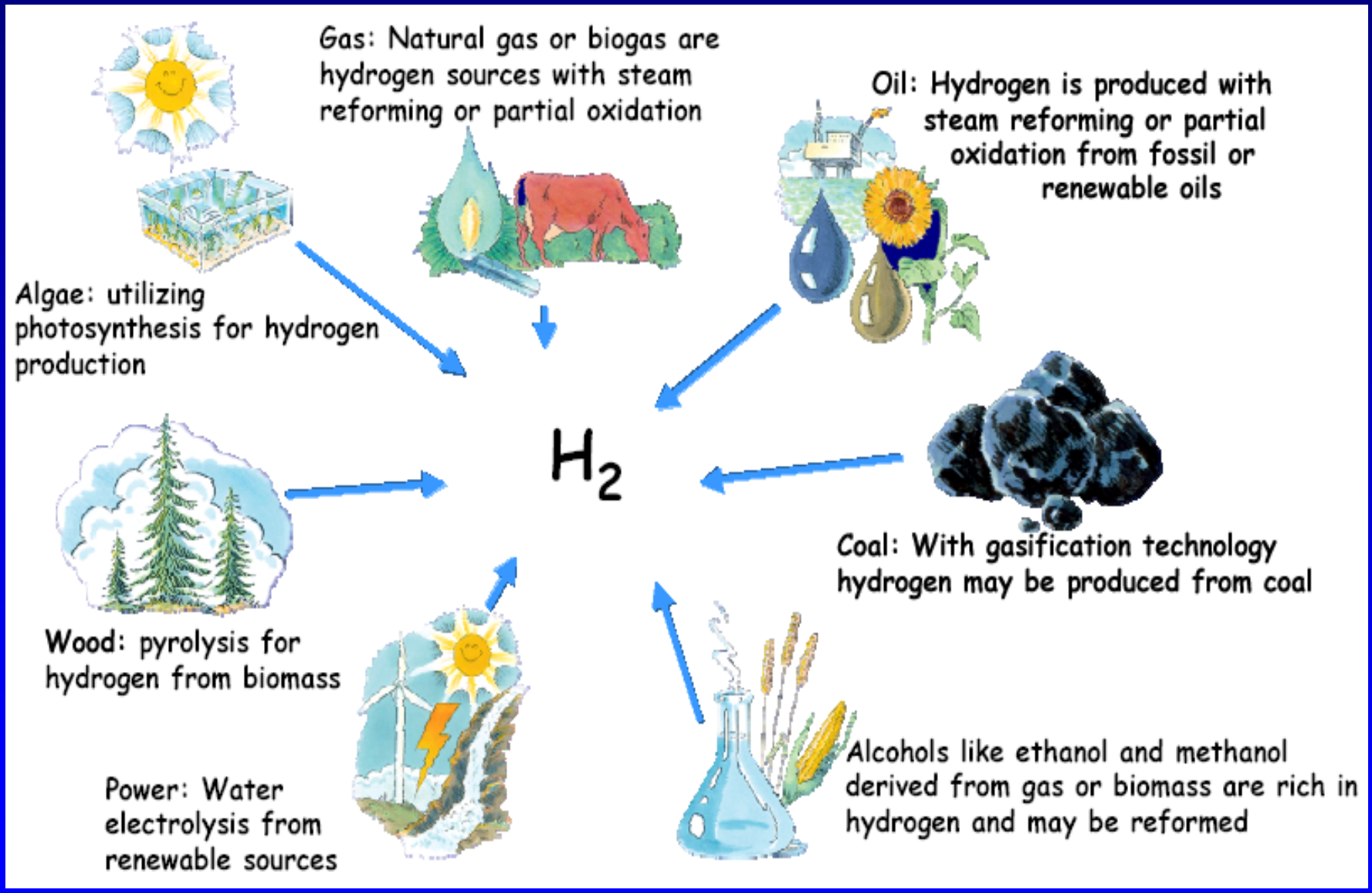
THEORY & MODELLING

Flow pattern
Simulation of mass-transfer
Power characteristics

Hydrogen as a primary energy carrier: concept of hydrogen energy

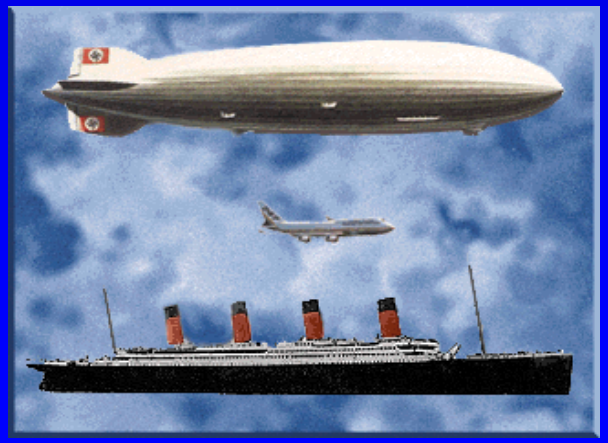
H_2: Source

H_2 is available everywhere! However needs to be generated



Hindenburg Disaster

- Explosion of the luxury airship Hindenburg at Lakehurst, NJ, on May 6, 1937
- Paralyzing the development of widespread H_2 use as a fuel
- Actually hydrogen was not the culprit

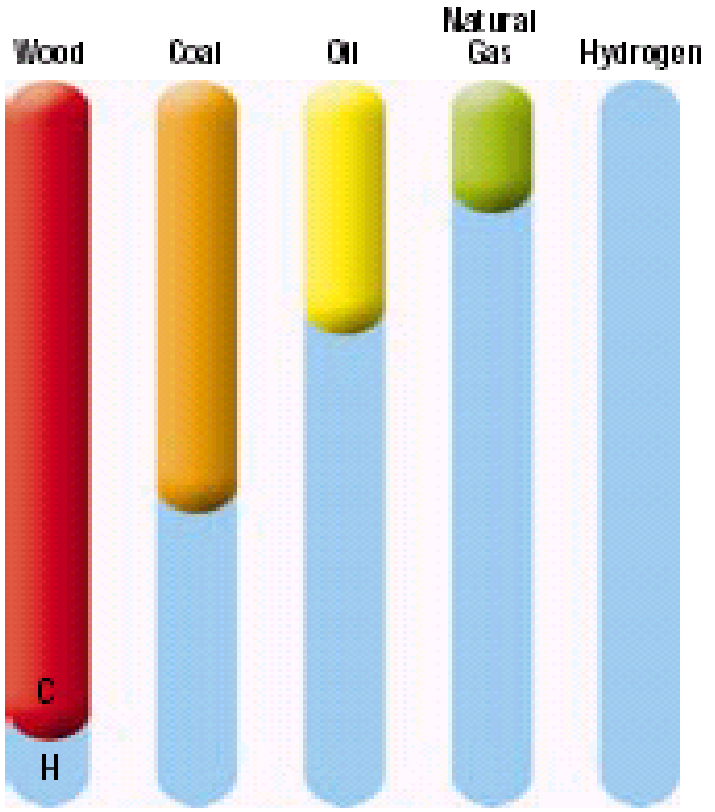


- Hindenburg was a marvel as on March 4, 1936, the largest man made object ever to fly
- In first year, the *Hindenburg* flew 191,583 miles carrying 2,798 passengers and 160 tons of freight and mail

Hydrogen As a Fuel

Inexpensive Generation and storage Issues

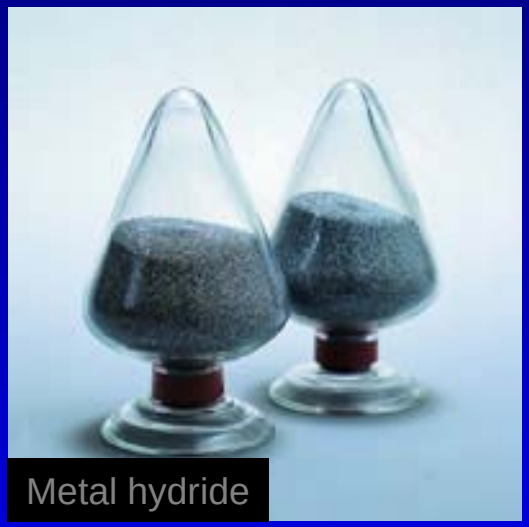
NASA has been a heavy user of hydrogen in space programs for several decades. This shows a storage tank for liquid hydrogen and hydrogen tank trucks

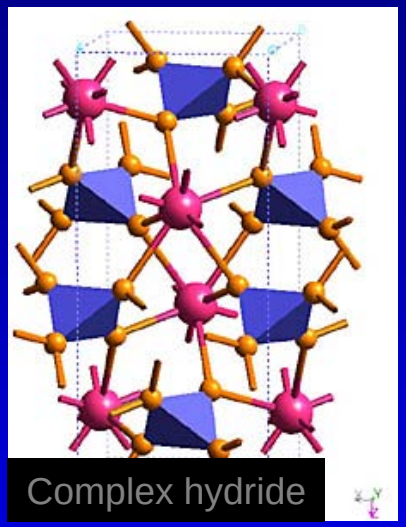


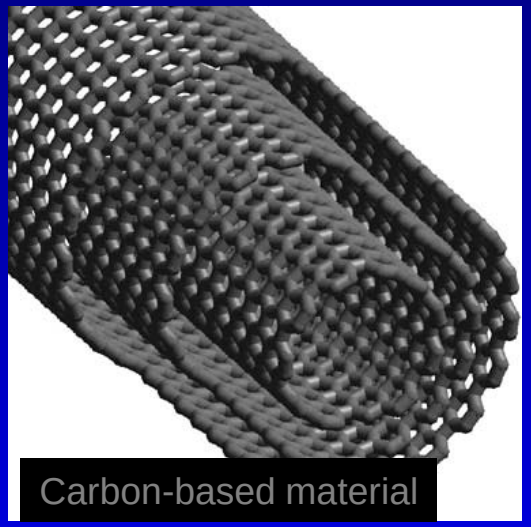
C=Carbon H=Hydrogen

Trends in energy use: Hydrogen-to-Carbon ratio increases as we become less dependent on carbon-based fuels.
(Courtesy: "Wired" 10/97)

Solid materials for hydrogen storage: Synthesis & Theoretical understanding


Metal hydride


Complex hydride


Carbon-based material

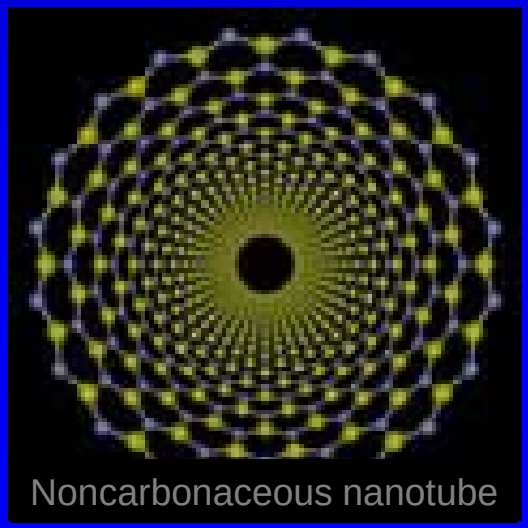
$NaBH_4$

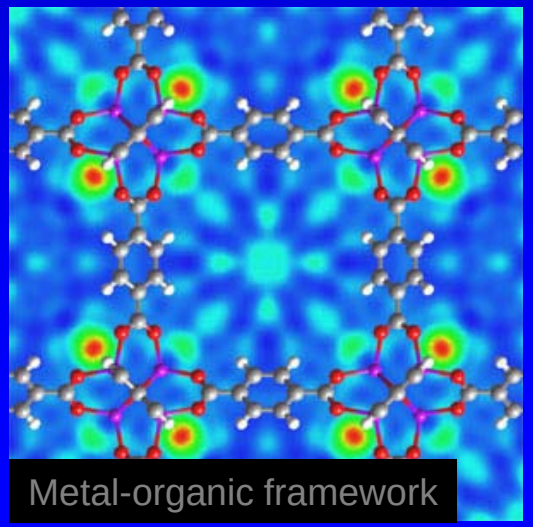
Weight of hydrogen stored = 4/(23+11+4) = 10.5 %

$LiAlH_4$

4/(7+27+4) = 10.5%

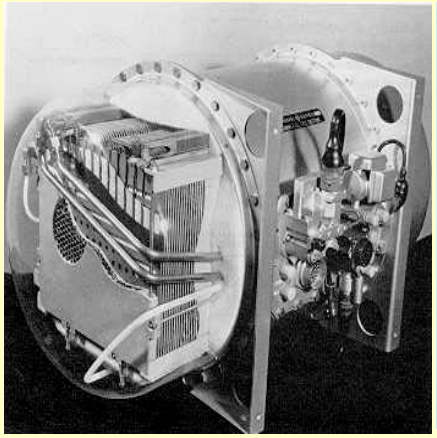
6.5% DOE Benchmark


Noncarbonaceous nanotube


Metal-organic framework

Fuel cells

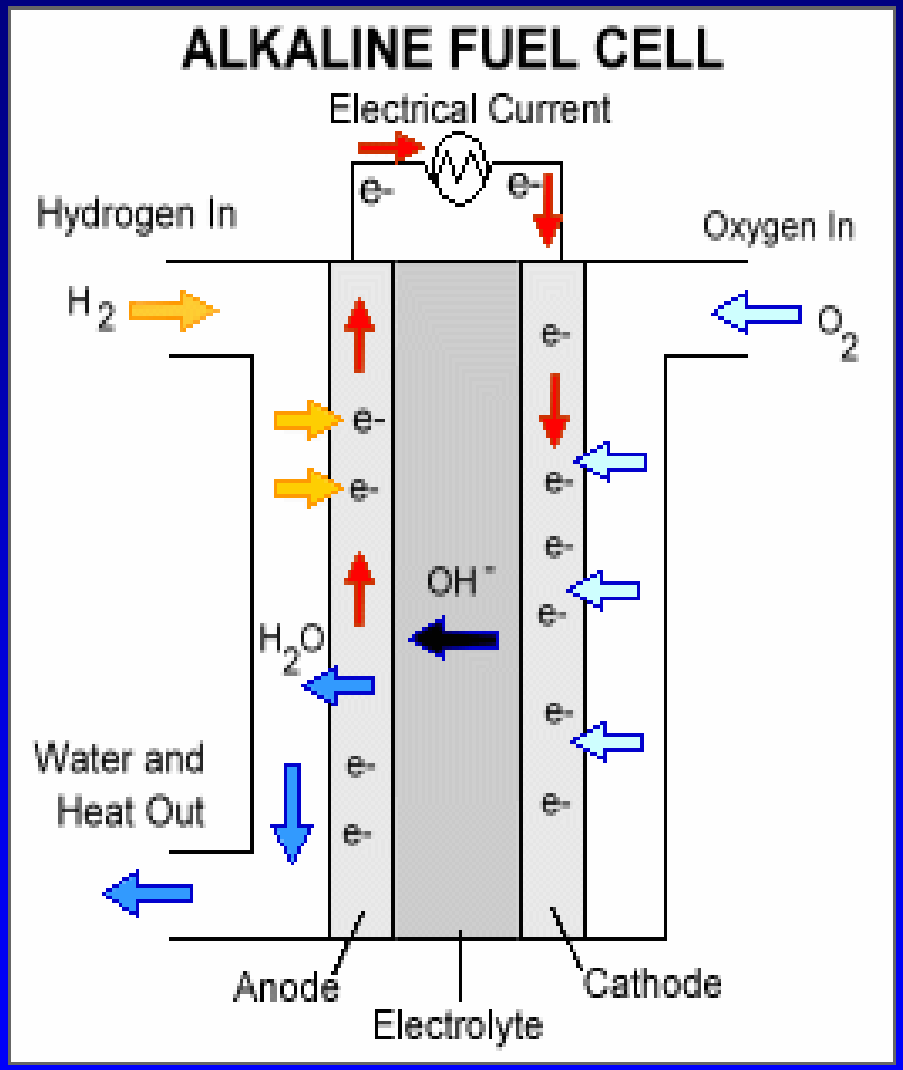
- Electrochemical devices which convert chemical energy directly to electrical energy
- Higher efficiency
- Higher lifetime
- No moving parts
- Extremely quite in operation
- Less emission



Li-ion $\rightarrow$180 Wh/kg Vs Fuel cell $\rightarrow$ 1000 Wh/kg

Sensors	0.1 W
Cell Phones	1.0 W
PDA	10.0 W
Camera	50 W
Laptop	100 W
Power Tool	200 W

Fuel cell:AFC



Anode

$$2H_2 + 4OH^- \rightarrow 4H_2O + 4e^-$$

Cathode

$$O_2 + 2H_2O + 4e^- \rightarrow 4OH^-$$

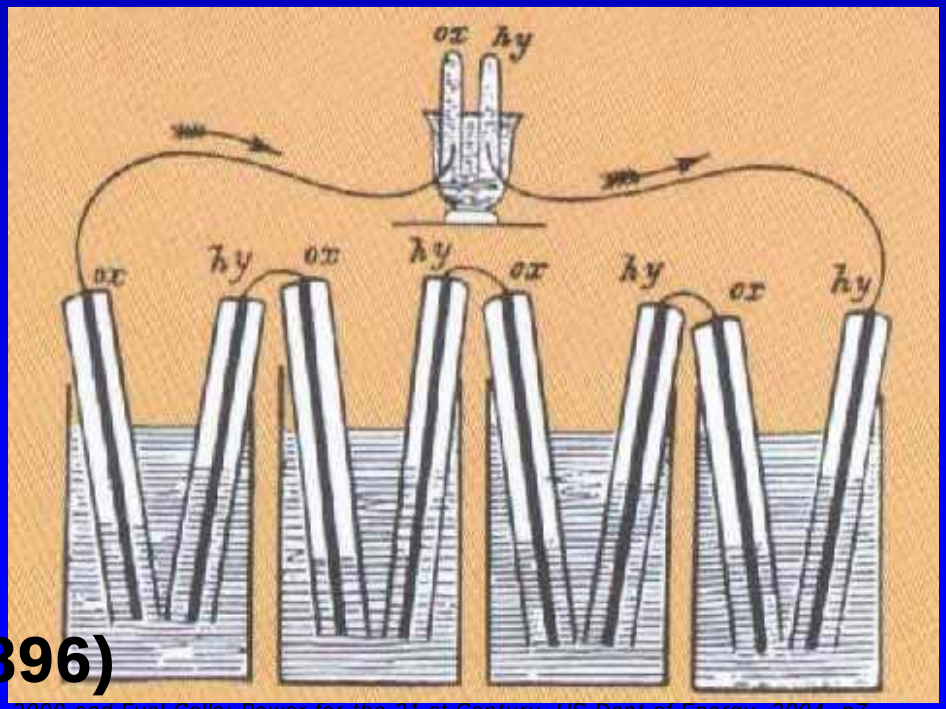
Electrolyte: KOH, NaOH

Fuel cell: history

- The history of fuel cell (FC) begins with Sir William Grove who completed experiments on the electrolysis of water in 1839.
- From 1889 until the early twentieth century, many people tried to produce a FC that could convert coal or carbon to electricity directly. These attempts failed because not enough was known about materials or electricity.
- In 1932, Francis Bacon developed the first successful FC. He used hydrogen, oxygen, an alkaline electrolyte, and nickel electrodes. In 1952, Bacon and a co-worker produced a 5-kW fuel cell system.
- The large boost in FC technology came from NASA. In the late 1950's, NASA needed a compact way to generate electricity for space missions. Nuclear was too dangerous, batteries too heavy, and solar power too cumbersome. The answer was FCs. NASA went on to fund 200 research contracts for FC technology.
- Both the alkaline and polymer electrolyte fuel cells have demonstrated their capabilities in the Apollo, Gemini and Space Shuttle manned space vehicle programs.
- The major efforts are presently focused on developing stationary power units and power systems for transportation applications, i.e. electric vehicles.
- 1962 Research into solid oxide technology begins to accelerate in the US and Netherlands; Allis-Chalmers Manufacturing Company demonstrates a 20-horsepower fuel-cell-powered tractor

Fuel cell: history

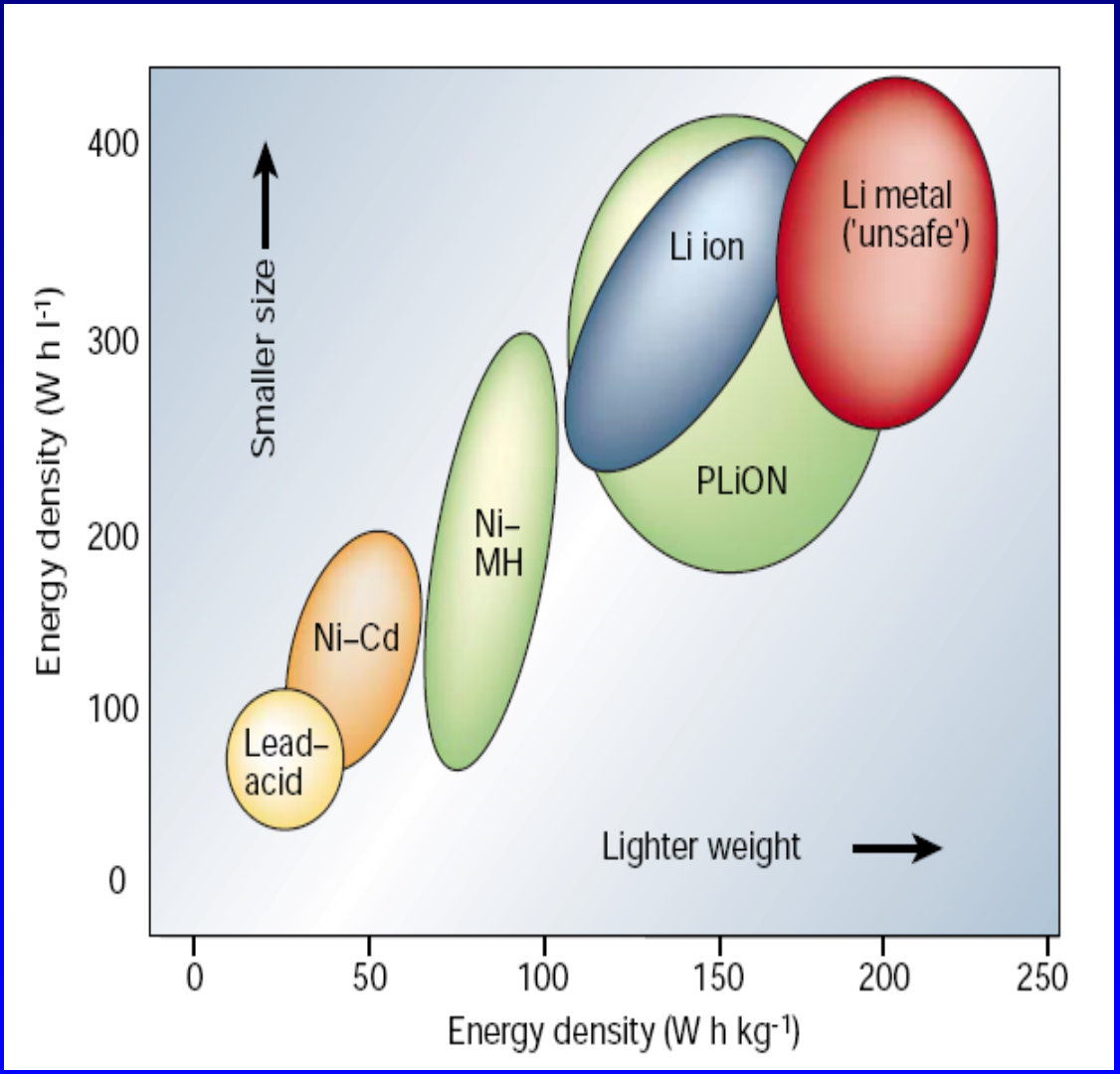
1838	Christian Friedrich Schoenbein carries out first systematic scientific investigation on the fuel cell effect
1845	Sir William Grove invents first fuel cell (H_2SO_4) + platinum electrodes, H_2 and O_2)
1896	William Jacques develops first fuel cell for household use
1900	Walther Nernst first uses zirconia as a solid electrolyte
1921	Emil Baur constructs the first molten carbonate fuel cell



Sir William Grove (1811–1896)

Source: The Birth of the Fuel Cell 1835 – 1845, Ulf Bossell, Switzerland, 2000 and Fuel Cells; Power for the 21 st Century, US Dept of Energy, 2004, p7.

Comparison of the different battery technologies in terms of volumetric and gravimetric energy density. The share of worldwide sales for NiCd, Ni–MeHand Li-ion portable batteries is 23, 14 and 63%, respectively.).



Direct Methanol Fuel Cells for Portable Devices

Toshiba- DMFC, 100 mW, 2cc Fuel Tank, 99.5% methanol

NEC- avg 14W output 300 cc fuel, 10% methanol, last ~5 hrs

Better, smaller, less-costly, environmentally safe, and much more efficient, technologies of the methanol-based MicroFuel Cell are expected to eventually obsolete small batteries, capable of a digital cellular telephone on standby for 6 months as opposed to 2 weeks and provide 1 week of talk time instead of the current 5 hours given by lithium ion battery

Hybrid Nano-materials for energy generation and storage

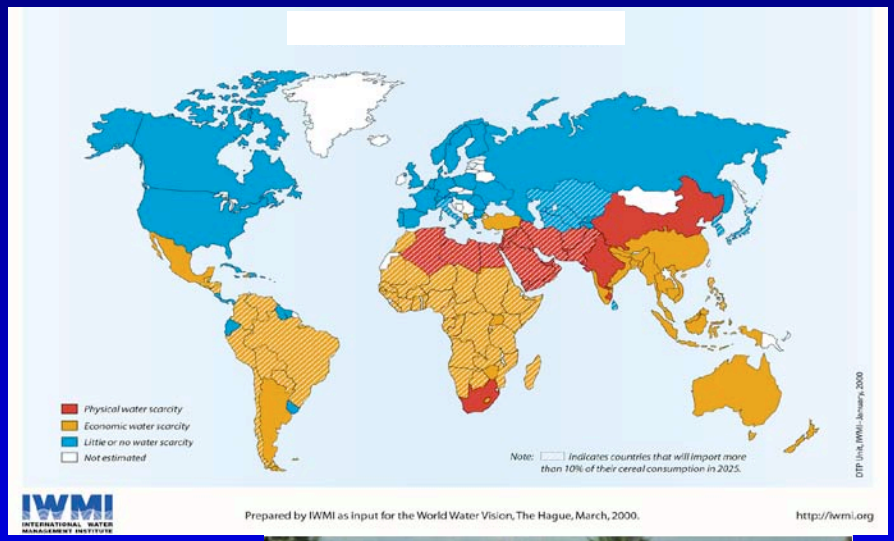
- HYDROGEN ECONOMY
- FUEL CELLS
- Lithium BATTERIES
- SUPERCAPACITORS
- SOLAR ENERGY STORAGE
- SYNTHETIC TREES: 1000

times more CO_2 absorbing capability

Canadian actress Laura Harris reacts during an interview by reporters about the new FCX Clarity at a Honda Motor Co. plant in Takanezawa, Tochigi prefecture (state) Monday, June 16, 2008. The Japanese automaker has begun commercial production of its new zero-emission, hydrogen fuel cell car, called the FCX Clarity.

TOP 10 GLOBAL PROBLEMS

1. Energy
2. Water
3. Food
4. Environment
5. Poverty
6. Terrorism and war
7. Disease
8. Education
9. Democracy
10. Population



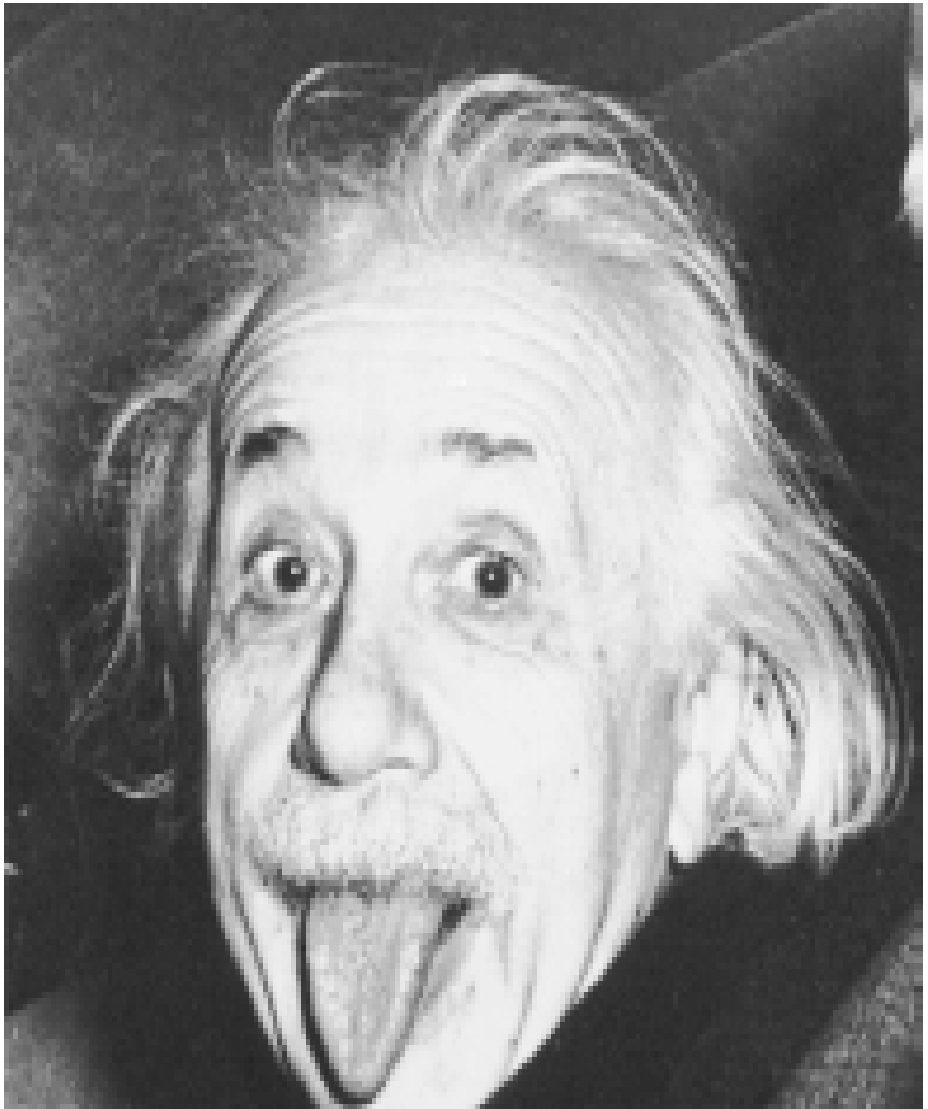
Scientific Breakthroughs in new Materials and Processes - NANOTECHNOLOGY

FORECASTS FOR THE FUTURE

- COST EFFECTIVE RESIDENTIAL SOLAR PV
- HOME ENERGY STORAGE BY FUEL CELLS & BATTERIES
- ZERO ENERGY BUILDINGS
- RENEWABLE ENERGY BASED CARS
- FLOATING WINDTURBANES-2015
- ENERGY STICKS-2020
- ENERGY FROM FUSION – 2050
- SOLAR REACTORS TO MAKE SYNTHETROL
- MATTER-ANTIMATTER?
- MINI-SUNS

saves 50 watt per person per day (cost $8500)

THANK YOU ALL!



… Scientists have fun!