Engineering security of supply: how to develop flexible, adaptable, robust renewable energy systems

A.M. KANNAN, Professor
ARIZONA STATE UNIVERSITY
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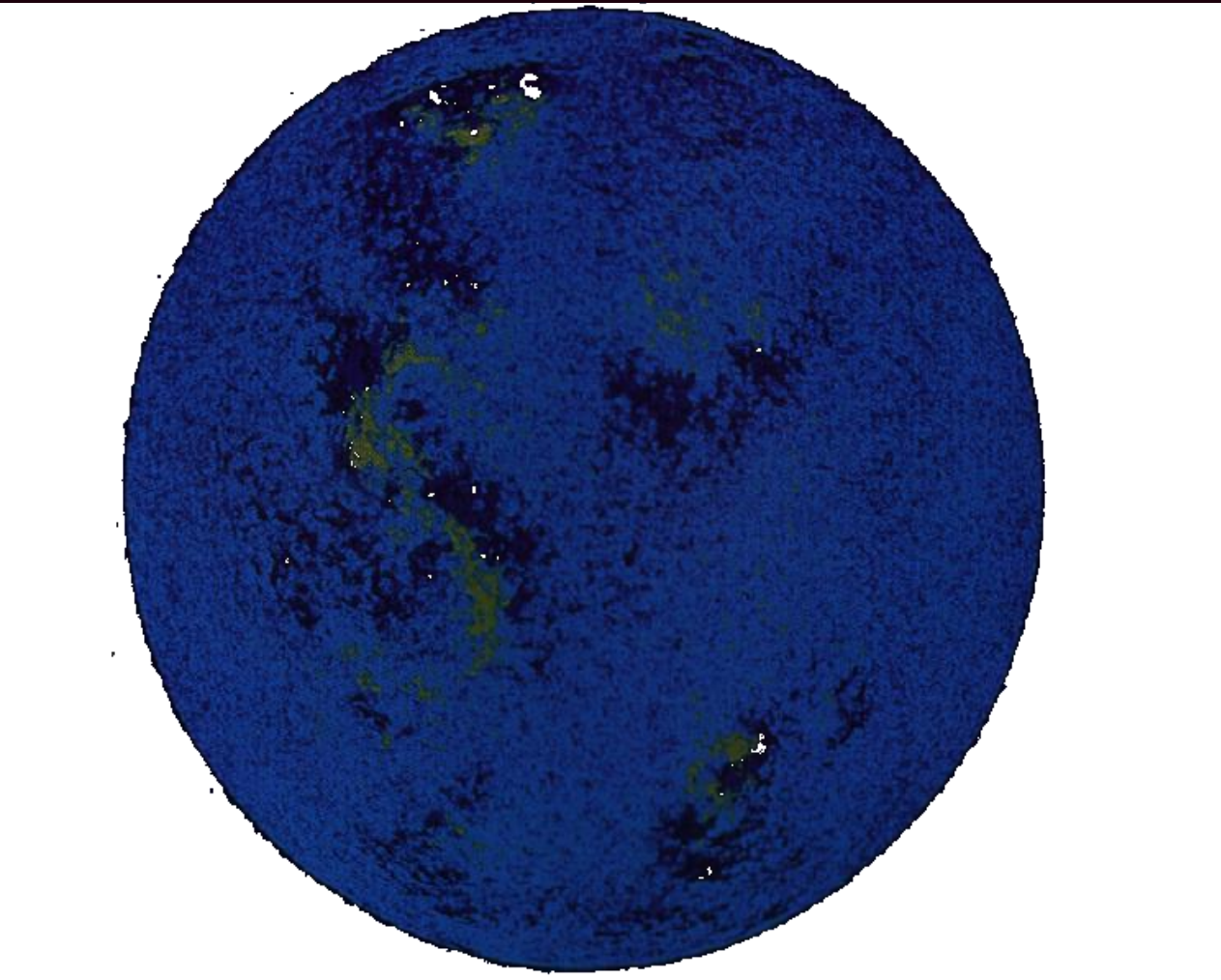
Humanity's Top Problems

- ENERGY
- **WATER**
- **FOOD**
- **ENVIRONMENT**

2007 **~ 7 Billion People**
2050 **~ 10 Billion People**

This is what it should look like

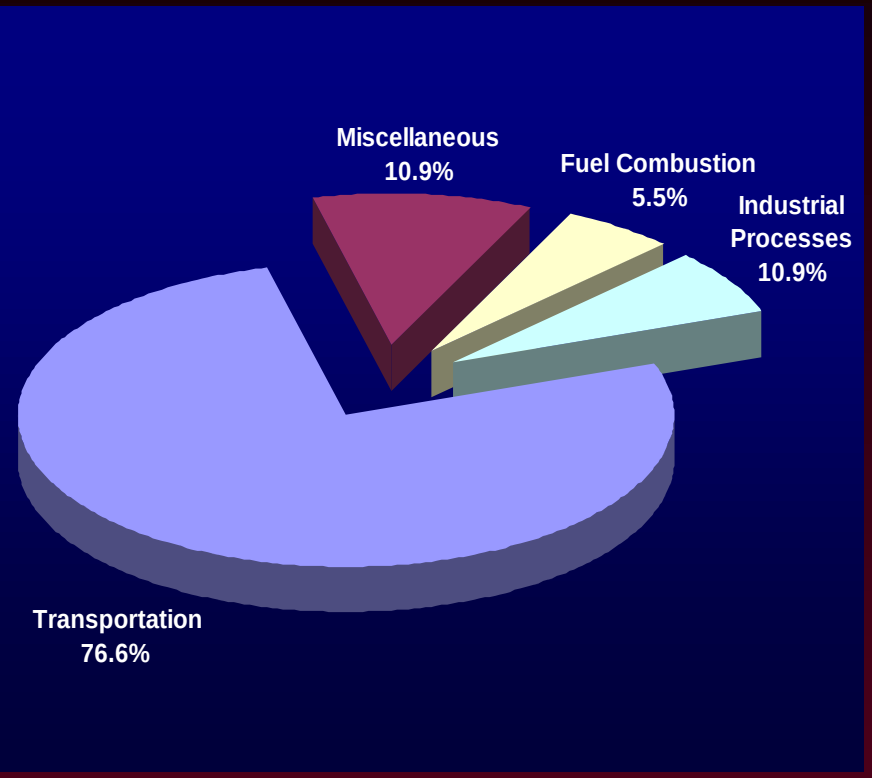
Where we are headed without using alternative energy sources...



Clean Energy Drive

"The Stone Age did not end because we ran out of stones, and the Oil Age will not end because we run out of oil" - **Don Huberts Shell Hydrogen**

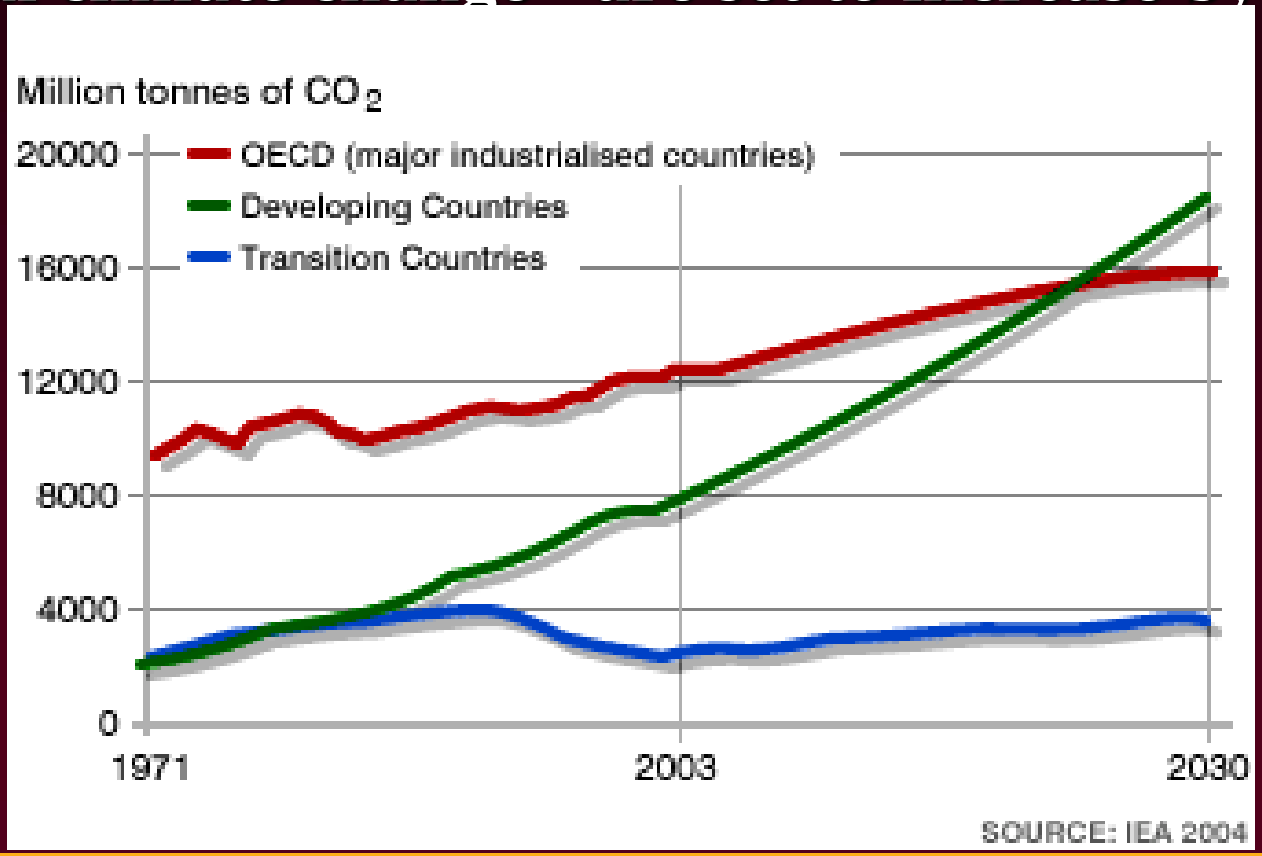
Greenhouse emission



Transportation sector leads to > 75 %

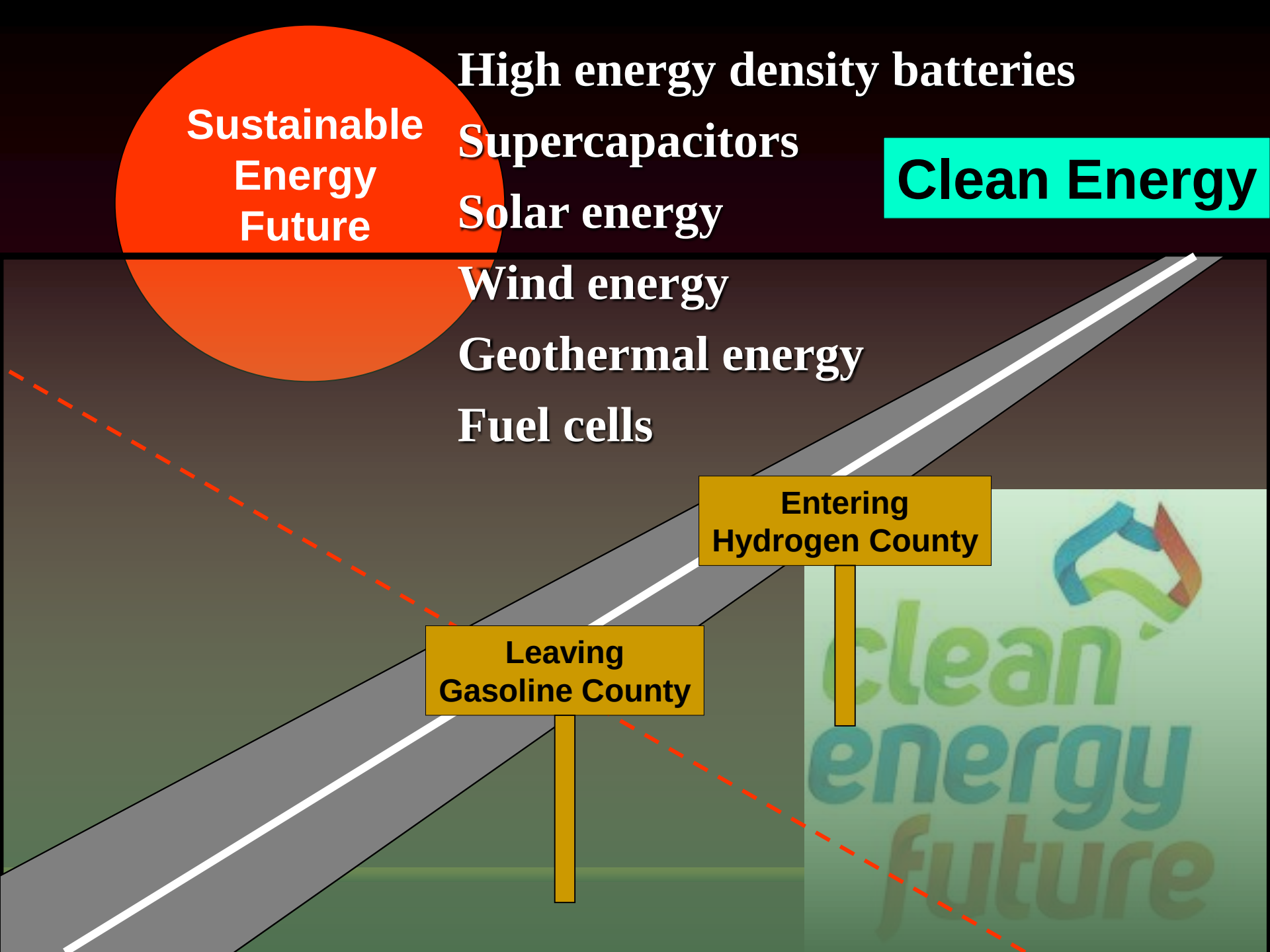
Carbon Emissions

- Carbon emissions - thought to be a major cause of global climate change - are set to increase by 60%.



Automotive emission

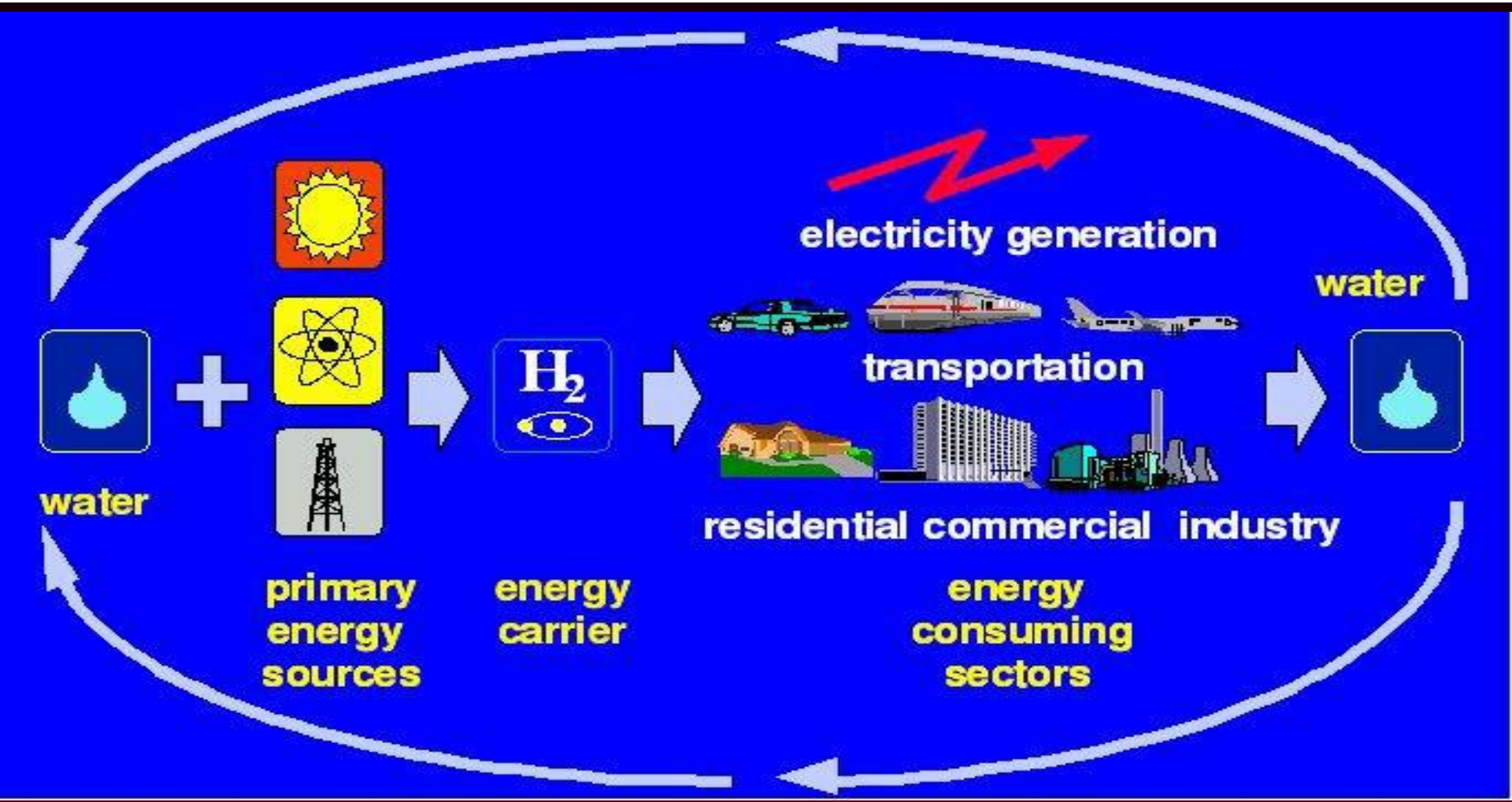
Greenhouse and Tropospheric Gases	Air Toxics	Solids/Liquids
Carbon Dioxide (CO_2), a greenhouse gas, produced by complete combustion.	**Hydrocarbons (HC)**, derived from unburned fuel during incomplete combustion, additionally **Volatile Organic Compounds (VOCs)**, arising from fuel evaporative emissions, these may include benzene, toluene, xylene, 1,3-butadiene, acetaldehyde, and formaldehyde. Subsequent reaction in sunlight creates smog and other forms of air pollution.	**Particulate Matter (PM)**, soot and smoke (microscopically suspended particles primarily arising from carbon, condensed water vapor, and soluble HCs) produced by internal combustion (notably diesel) engines.
Carbon Monoxide (CO), a toxic by-product of incomplete combustion.		
Nitrogen Oxides (NO_x), also a greenhouse gas, which is formed by the interaction between oxygen and nitrogen in high temperatures and pressures found in engine combustion chambers.		
Sulfur Dioxide (SO_2), which contributes to the formation of acid rain, dependent upon sulfur content of fuel (typically low for cars and trucks).		


Sustainable Energy Future
High energy density batteries
Supercapacitors
Solar energy
Wind energy
Geothermal energy
Fuel cells
Clean Energy
Entering Hydrogen County
Leaving Gasoline County
clean energy future

H_2 ECONOMY

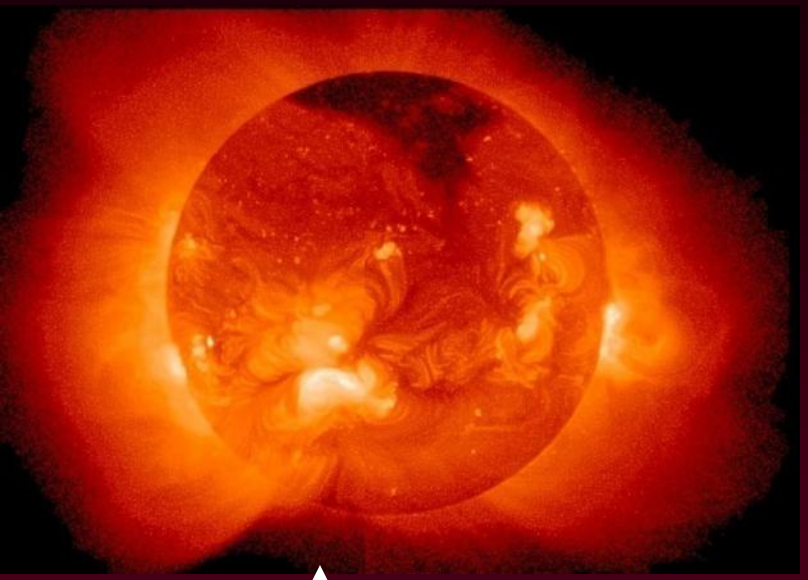
- The international community recognizes hydrogen as a key component in a clean, sustainable energy system, or hydrogen economy.
- The future hydrogen economy features hydrogen as an energy carrier in the stationary power, transportation, industrial, residential and commercial sectors.
- Hydrogen as an energy carrier will be produced via water electrolysis using electricity from solar, wind or other renewable resources and stored, transported by truck or pipeline, and used in a fuel cell, turbine, or engine to generate an electric current with water as the only by-product.

Energy of the Future World

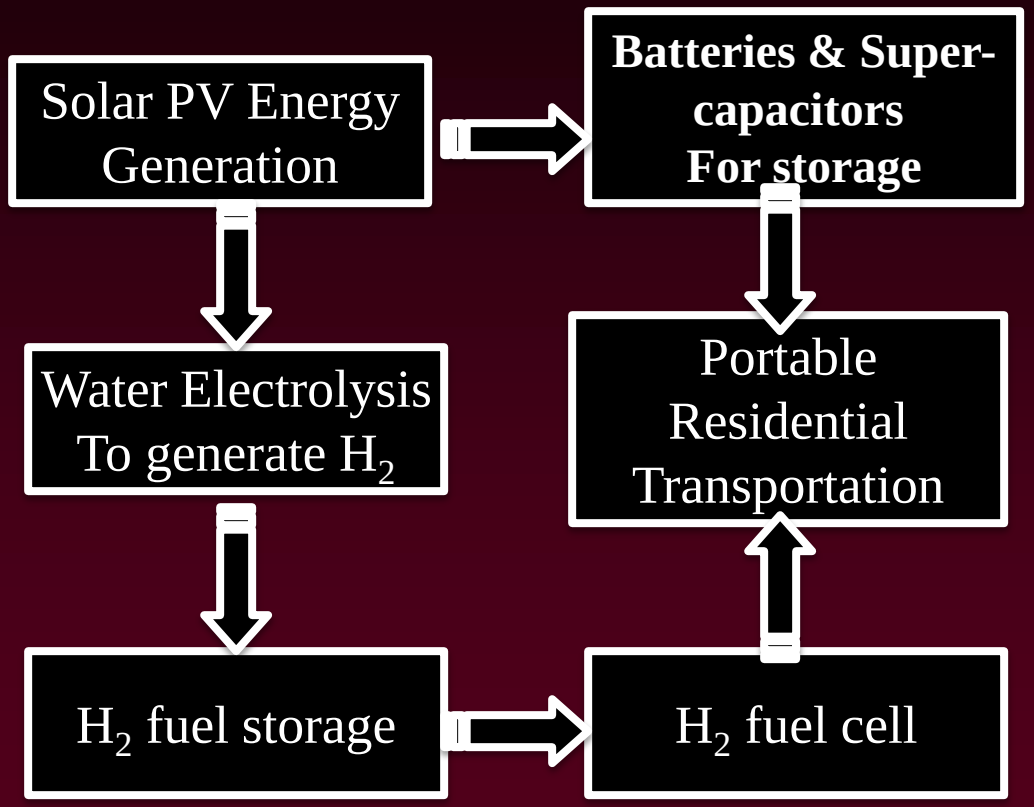


Transform from HC economy to Hydrogen Economy

Clean Energy Cycle

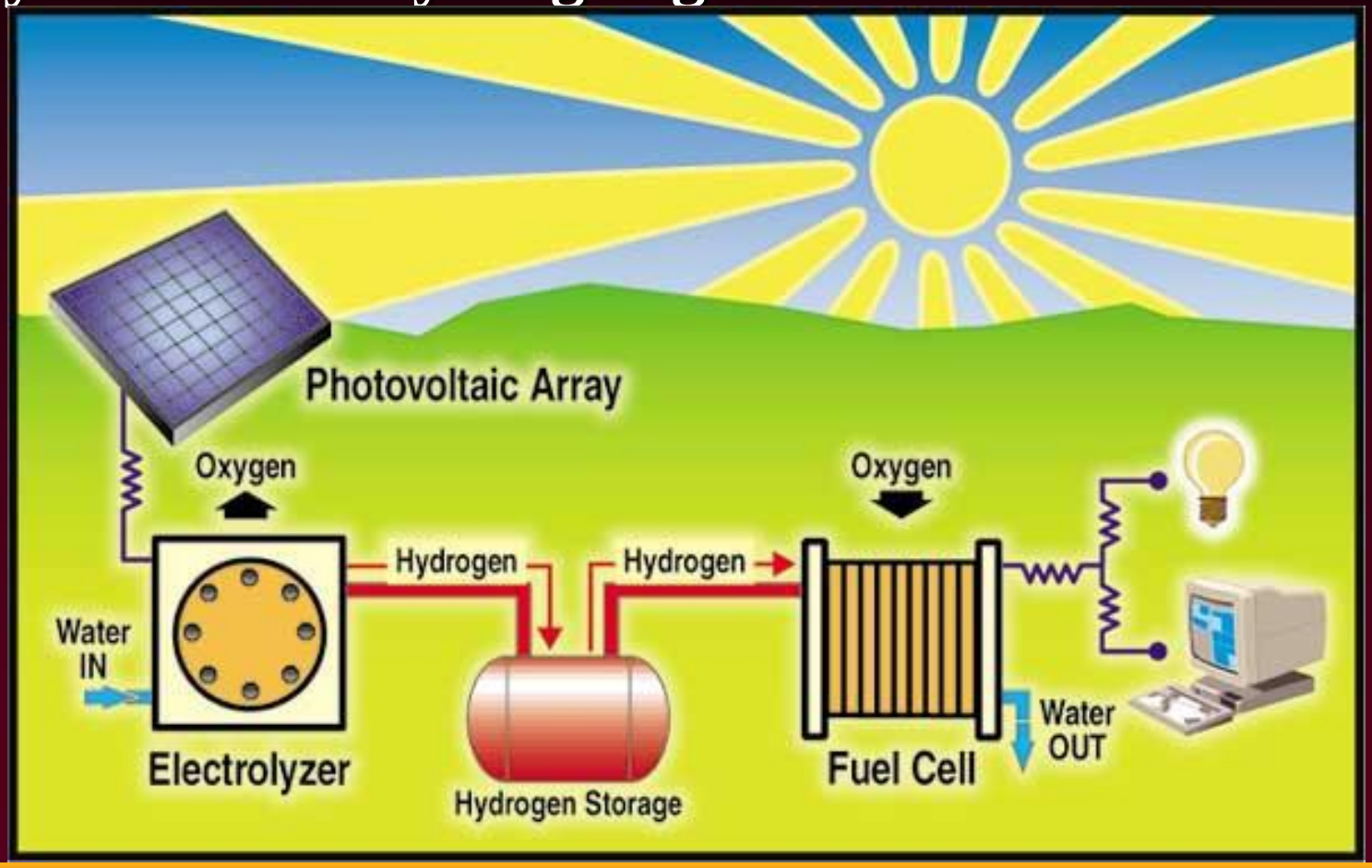


Use Nanostructured materials For multi-spectral PV cells to harness more energy from sun



Solar H_2 Cycle

- **Fully renewable hydrogen generation**



Ref: IEE, Mexico

Renewable Energy

- A Renewable Energy Source cannot run out and causes so little damage to the environment and its use need not be restricted
- Renewable Energy is replenished continuously
- No energy system based on mineral resources is renewable because, one day, the mineral deposits will be used up
- **This is True for Fossil Fuels and Uranium**

Renewable Energy Sources

- Solar, Wind, Biomass and tides are based directly or indirectly on Solar Energy
- Hydroelectric Power is not necessarily a renewable energy source because large scale projects can cause ecological damages and irreversible consequences
- Geothermal heat is renewable but must be used cautiously to guard against irreversible ecological effects

Unlimited Renewable Energy

- There is no shortage of renewable energy as it can be taken from Sun, Wind, Water, Plants and Garbage to produce electricity and fuel
- For ex., the sunlight that falls on the US in one day contains more than twice the energy the country normally consumes in a year
- California has enough wind gusts to produce 11 % of the world's wind electricity

No Greenhouse Gas

- Clean Energy sources can be harnessed to produce electricity and process heat with less effect on the environment than fossil fuel would cause
- Emissions from gasoline fueled cars and factories and other facilities that burn oil affect the atmosphere through greenhouse effect
- About 81 % of all US greenhouse gases are CO_2 emissions from energy related sources

Why do we need renewable energies?

- The United States currently relies heavily on coal, oil, and natural gas for its energy.
- Fossil fuels are *nonrenewable*, that is, they draw on finite resources that will eventually dwindle, becoming too expensive or too environmentally damaging to retrieve.
- In contrast, *renewable energy* resources - such as wind and solar energy - are constantly replenished and will never run out.

Benefits of Renewable Energy

- In contrast to the fossil energy, renewable energy is an attractive source for several reasons:
  - long lasting life
  - Increased jobs
  - Increased comfort
  - Industry and energy self-sufficiency through decreased dependence on other nations

Solar

- Most renewable energy comes either directly or indirectly from the sun.
- Sunlight, or solar energy, can be used directly for heating and lighting homes and other buildings, for generating electricity, and for hot water heating, solar cooling, and a variety of commercial and industrial uses.

100 % Solar power stadium in Taiwan

Wind

- The sun's heat also drives the winds, whose energy is captured with wind turbines.
- Then, the winds and the sun's heat cause water to evaporate.
- When this water vapor turns into rain or snow and flows downhill into rivers or streams, its energy can be captured using hydropower.

Biomass

- Along with the rain and snow, sunlight causes plants to grow.
- The organic matter that makes up those plants is known as biomass.
- Biomass can be used to produce electricity, transportation fuels, or chemicals.
- The use of biomass for any of these purposes is called biomass energy.

Hydrogen

- Hydrogen also can be found in many organic compounds, as well as water.
- It's the most abundant element on the Earth.
- But it doesn't occur naturally as a gas.
- It's always combined with other elements, such as with oxygen to make water.
- Once separated from another element, hydrogen can be burned as a fuel or converted into electricity.

Geothermal

- Not all renewable energy resources come from the sun.
- Geothermal energy taps the Earth's internal heat for a variety of uses, including electric power production, and the heating and cooling of buildings.
- And the energy of the ocean's tides comes from the gravitational pull of the moon and the sun upon the Earth

Ocean

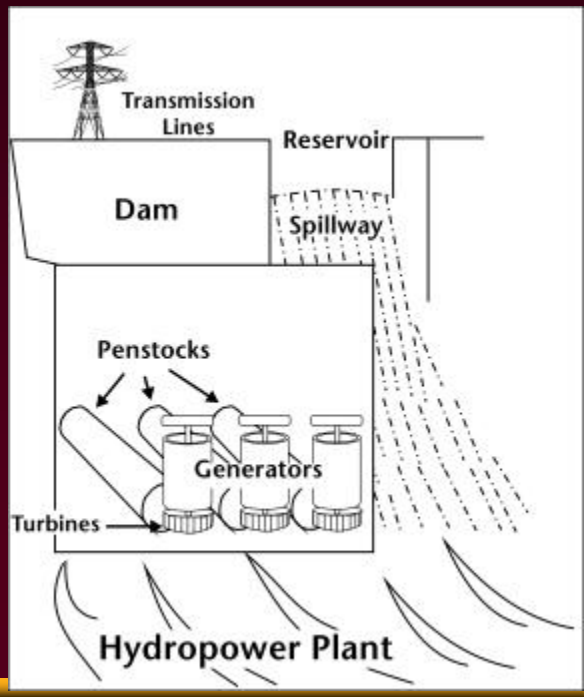
- The ocean can produce thermal energy from the sun's heat and mechanical energy from the tides and waves.
- Ocean energy covers a series of emerging technologies that use the power of ocean currents, waves, and tides to create energy.
- While very few of these technologies have been implemented on a commercial scale, they show much promise for future development.

Ocean

- **Tidal Current Technology**
  - All flowing water carries kinetic energy. Moving water carries much more energy than the moving air used in wind power because water is much denser than air.
- **Wave Energy Technology**
  - The concentrated power of breaking waves shapes shorelines and erodes beaches.
  - However, it is the kinetic energy associated with up-and-down oscillations within the water column that is transformed into electricity by most wave energy technologies.
- **Ocean Thermal Technology**
  - Ocean thermal energy conversion (OTEC) technology produces electricity by taking advantage of the temperature difference between the ocean's warm surface layer and cold deeper layer.

Hydropower

- Flowing water creates energy that can be captured and turned into electricity.
- This is called hydroelectric power or hydropower.
- Hydropower is the ideal fuel for electricity generation because, unlike the nonrenewable fuels used to generate electricity, it is almost free, there are no waste products, and hydropower does not pollute the water or the air.



Nuclear Power

- Nuclear power plants provide about 17 percent of the world's electricity.
- Some countries depend more on nuclear power for electricity than others.
- In France, for instance, about 75 percent of the electricity is generated from nuclear power, according to the International Atomic Energy Agency.
- There are more than 400 nuclear power plants around the world, with more than 100 in the United States

Nuclear Power

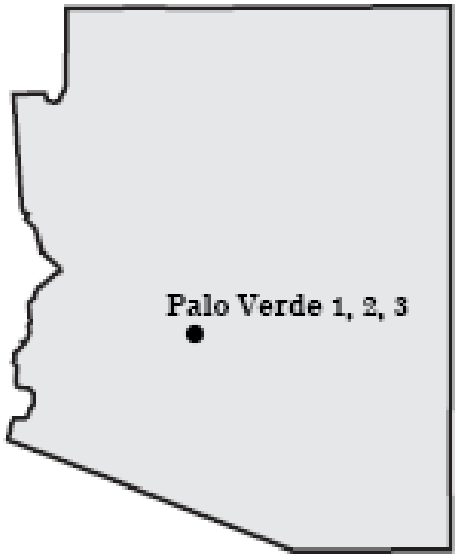
- America's 104 nuclear power plants generate nearly 20 percent of the nation's electricity, while emitting no carbon dioxide or controlled pollutants.

U.S. Nuclear Generating Statistics

Year	Total generation (MWh)	Nuclear Energy (MWh)	Capacity (%)	Capacity (MW)
2001	3,736,643,653	768,826,308	89.4	98,159
2002	3,858,452,252	780,064,087	90.3	98,657
2003	3,883,185,205	763,732,695	87.9	99,209
2004	3,970,555,289	788,528,387	90.1	99,628
2005	4,055,422,744	781,986,365	89.3	99,988
2006	4,064,702,228	787,218,636	89.6	100,334
2007	4,159,513,913	806,486,978	91.8	100,334

Nuclear Power Plants in AZ

Nuclear	23.7%
Coal	36.5%
Oil	0.0%
Gas	33.7%
Hydro	5.9%
Renewable and Other	0.0%



	City	Capacity (MW)	2007 Generation (MWh)	2005-2007 3-year Average Capacity Factor (%)
Palo Verde 1	Phoenix	1,311	8,841,133	60.7
Palo Verde 2	Phoenix	1,314	10,957,595	87.4
Palo Verde 3	Phoenix	1,247	6,983,663	77.8
Total		3,872	26,782,391	75.3

Sustainable Energy Technologies

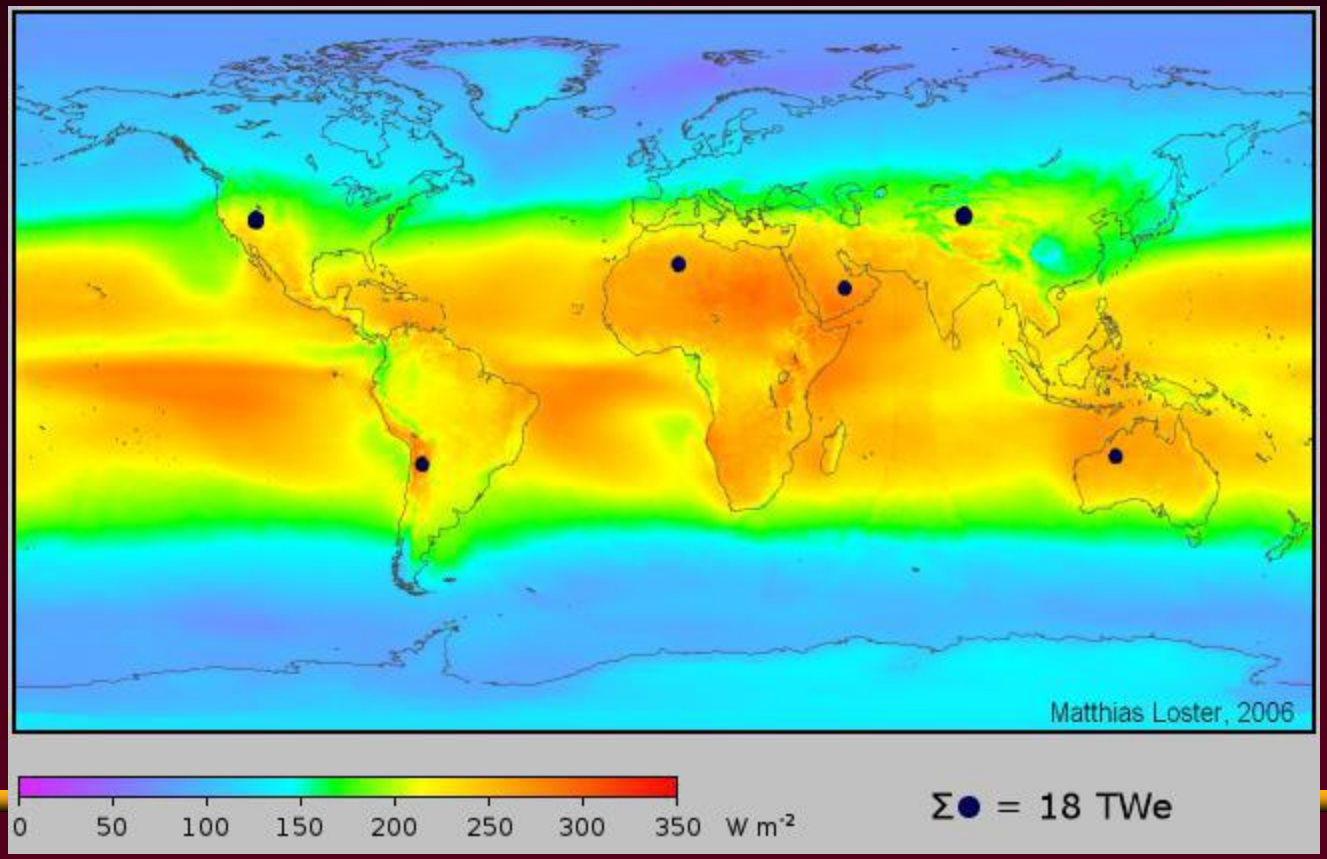
Solar Energy

Solar Photovoltaics

- Solar radiation reaches the Earth's upper atmosphere at a rate of 1366 watts per square meter (W/m^2).
- While traveling through the atmosphere 6% of the incoming solar radiation (insolation) is reflected and 16% is absorbed resulting in a peak irradiance at the equator of 1,020 W/m^2.
- Average atmospheric conditions (clouds, dust, pollutants) further reduce insolation by 20% through reflection and 3% through absorption.

Solar Irradiance

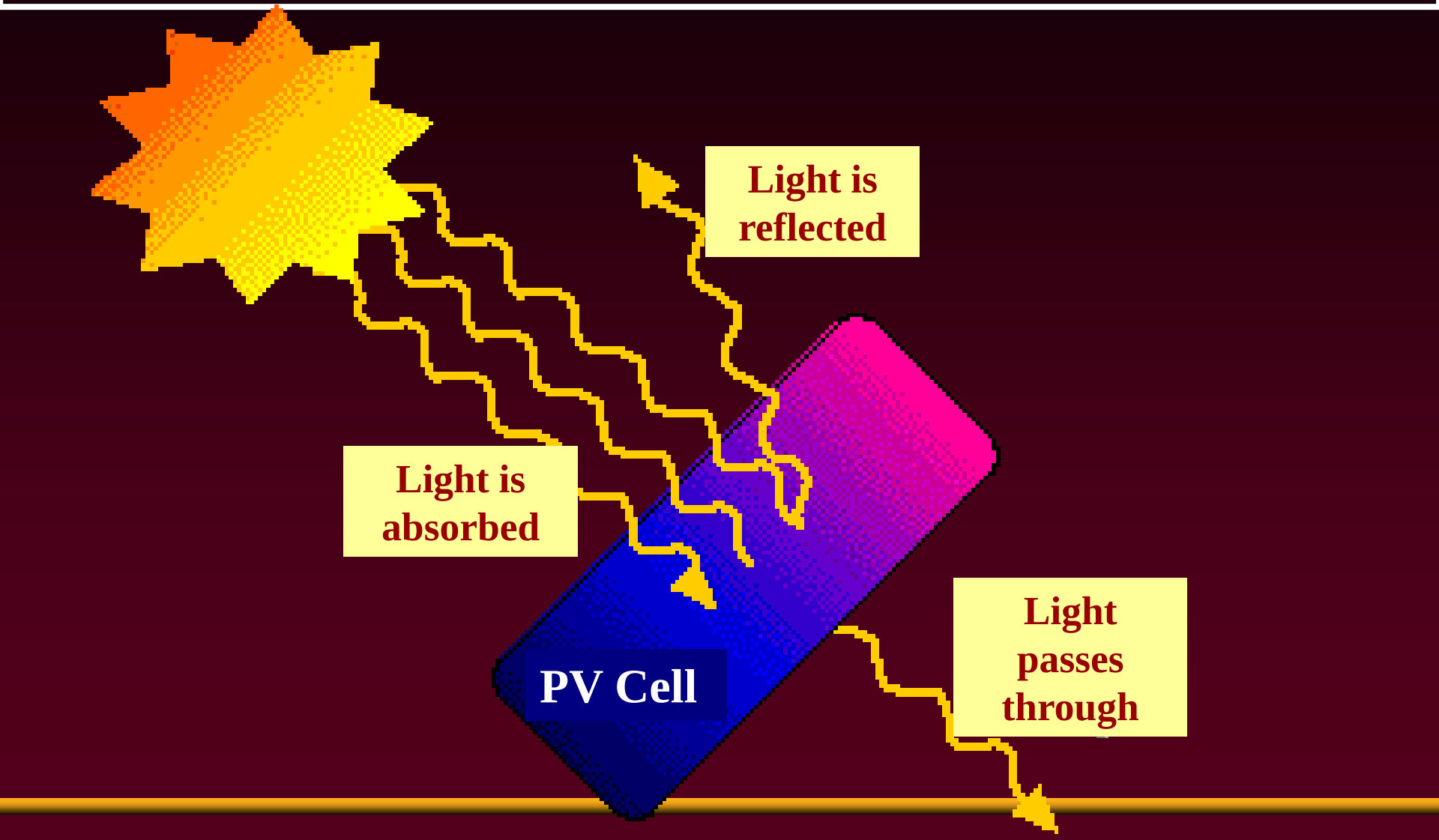
- Solar power systems installed in the areas defined by the dark disks could provide more than the world's current total primary energy demand (assuming a conversion efficiency of 8%). The 89 petawatts (10^{15}) of sunlight reaching the earth's surface is plentiful compared to the 15 terawatts (10^{12}) of average power consumed by humans



How does a photovoltaic panel work?

- A photovoltaic cell is a semiconductor. When light hits the photovoltaic (or PV) cell, the light can be reflected or absorbed or it can pass through the cell.
- If the light is absorbed into the cell, the light's energy is transferred to the electrons in the semiconductor. This causes the electrons to flow, creating an electrical current

How does a photovoltaic panel work?



Sustainable Energy Technologies

Wind Energy

Wind Energy

Wind Energy

- During the day, the air above the land heats up more quickly than the air over water.
- The warm air over the land expands and rises, and the heavier, cooler air rushes in to take its place, creating winds. At night, the winds are reversed because the air cools more rapidly over land than over water.
- Wind energy is mainly used to generate electricity.

Wind is called a renewable energy source because the wind will blow as long as the sun shines.

History of Wind Energy

- Since ancient times, people have harnessed the wind energy.
- Over 5,000 years ago, the ancient Egyptians used wind to sail ships on the Nile River.
- Later, people built windmills to grind wheat and other grains.
- The earliest known windmills were in Persia (Iran).
- These early windmills looked like large paddle wheels.
- Centuries later, the people of Holland improved the basic design of the windmill.
- They gave it propeller-type blades, still made with sails.
- Holland is famous for its windmills.

HOW WIND MACHINES WORK?

- Like old fashioned windmills, today's wind machines use blades to collect the wind's kinetic energy.
- Windmills work because they slow down the speed of the wind.
- The wind flows over the airfoil shaped blades causing lift, like the effect on airplane wings, causing them to turn.
- The blades are connected to a drive shaft that turns an electric generator to produce electricity.
- With the new wind machines, there is still the problem of what to do when the wind isn't blowing.
- At those times, other types of power plants must be used to make electricity.