

## Environmental Degradation Energy Utilization

Klaus S. Lackner  
Columbia University  
New York, NY

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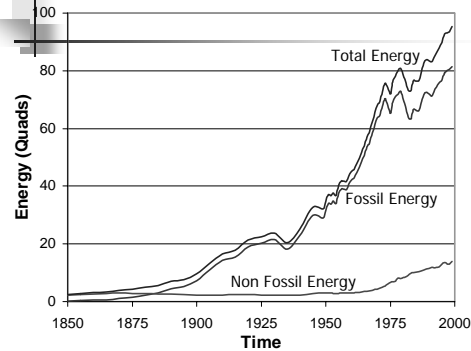
## Energy Sources

- Biomass – Firewood
- Draft animals
- Wind/water – mills
- Solar – heat and photovoltaic
- Fossil carbon – coal, oil, gas, tar & shale
- Nuclear Energy
- Fusion

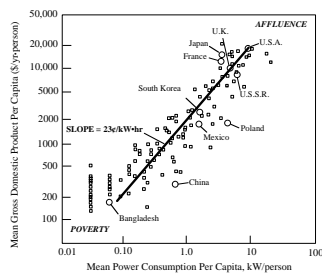
## Energy Uses

- Heat
  - cooking, metallurgy, chemical products – fertilizers to plastics
- Mechanical energy
  - Transportation, manufacturing, agriculture
  - Cooling
  - Desalination
  - Cleanup

## US Annual Energy Consumption



## Energy consumption and wealth



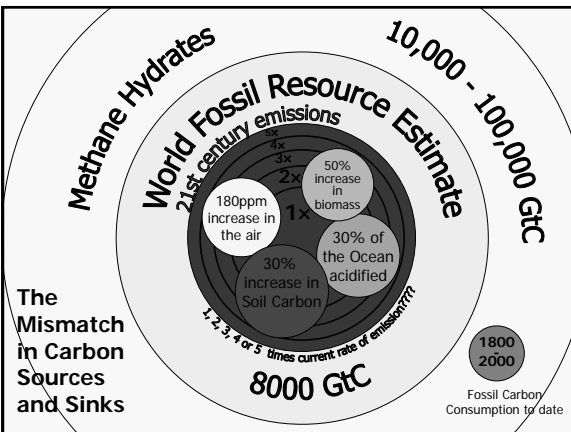
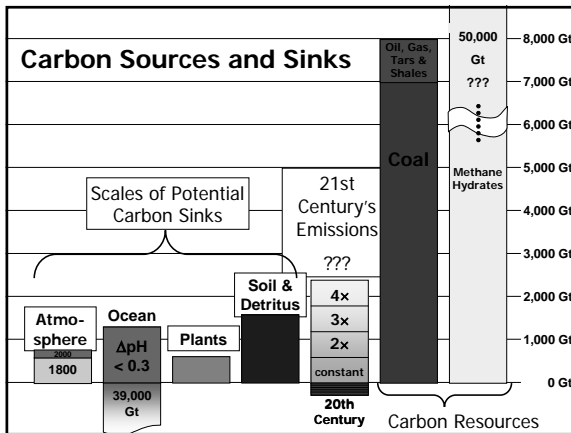
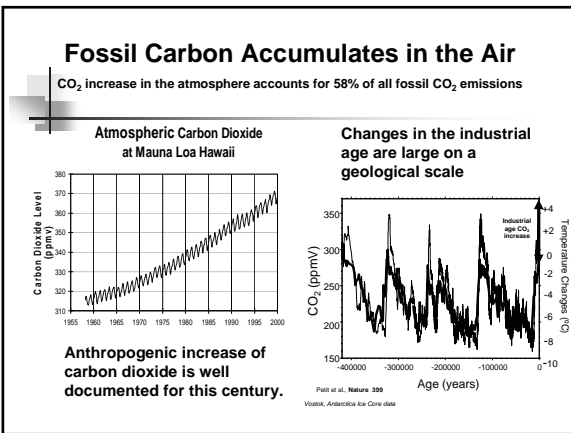
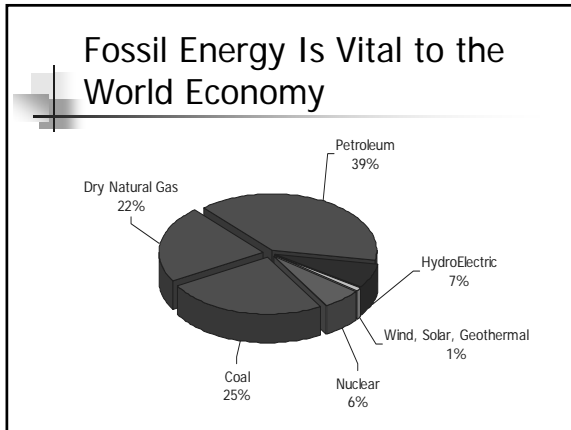
*10 billion people trying to consume energy as US citizens do today would raise world energy demand 10 fold*

## Pollution Issues

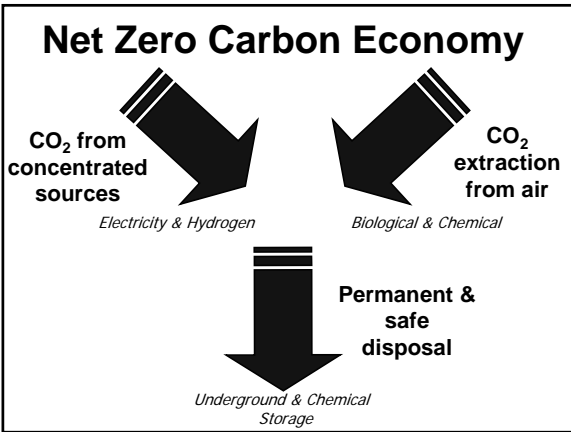
Pollutant	Sources	Comments
Soot, smoke ash, aromatic compounds	Power plants, (coal), steam engines, diesel engines	Air quality, deposit of soot, blackens objects, sufficient to drive natural selection to black moths, health hazard, deposits in lungs, e.g., London smog, climate impact through creating opacity, largely but not completely controlled today. Still a big impact in parts of Asia.
Sulfur compounds, SO <sub>x</sub>	Power plants (coal, heavy oil), diesel engines, gasoline engines (Sulfur content has been reduced)	Acid rain, lakes are acidified (particularly those without buffering capacity e.g. in Canada and Scandinavia), corrosive, causes erosion of limestones, and sandstones particularly in buildings, and outdoor sculptures, e.g. gothic cathedrals, dissolves synthetics like nylons, further reductions are likely, but technology to deal with the problem is in place and applied (however notice grandfathering).
Nitrogen compounds, NO <sub>x</sub>	Cars, power plants, any combustion process, NO <sub>x</sub> results from the oxidation of atmospheric nitrogen with atmospheric oxygen in high temperature flames	Air quality issues, NO <sub>x</sub> is a precursor to photochemical smog, i.e. the production of tropospheric ozone, e.g. smog in Los Angeles but elsewhere as well, diffuse impact on the ecological balance through eutrophication of lakes etc. NO <sub>x</sub> ultimately leaves the atmosphere, resulting nitrogen fixation greatly changes nitrogen availability to nearly all ecosystems. Current regulations limit NO <sub>x</sub> emissions.

### Pollution Issues II

Pollutant	Sources	Comments
Heavy metals, mercury, lead, cadmium, etc.	Coal fired power plants, mercury is present in the ash and is reduced to mercury vapor	Environmental poison, health hazards to humans, difficult to capture because concentrations are very low. Future regulations will impose far more stringent standards.
Fine particulates, sulfates, aromatics, etc.	Coal fired power plants, but also to a lesser extent, cars, (diesel), and conventional turbines	Apparent health hazard, statistical data point to strong correlations between fine particulate emissions from coal fired power plants and mortality rates. Particles smaller than 10 micron are unregulated, are a category of particular concern as they tend to make it into the lung where they get captured. Regulations are still being discussed. Visual pollution from power plant haze (e.g. Grand Canyon).
Carbon dioxide	Any fossil fuel based power source, coal plants, gas plants, cars, machinery etc.	Climate change and environmental change, global impact, direct human impact is considered minimal. Carbon dioxide is the normal end result of power generation from fossil fuels, it is therefore difficult to avoid it.



# 10 - 30 TeraWatt of Carbon Neutral Primary Energy



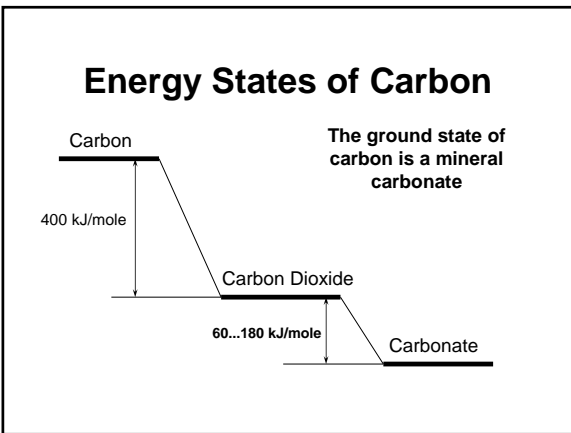
### Hydrogen economy cannot run on electricity

There are no hydrogen wells

*Tar, coal, shale and biomass could support a hydrogen economy.*  
*Wind, photovoltaics and nuclear energy cannot.*

Price Ranges for Raw Fossil Energy Resources

Resource	Price Range (Price per GJ)
Coal	~\$1.00 - \$2.00
Gas	~\$5.00 - \$10.00
Oil	~\$5.00 - \$10.00
Electricity	~\$10.00 - \$25.00



### Net Carbonation Reaction for Serpentine

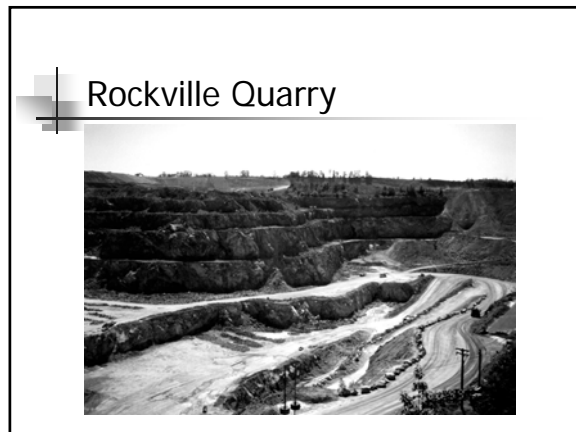
$$\text{Mg}_3\text{Si}_2\text{O}_5(\text{OH})_4 + 3\text{CO}_2(\text{g}) \rightarrow 3\text{MgCO}_3 + 2\text{SiO}_2 + 2\text{H}_2\text{O}(\text{l})$$

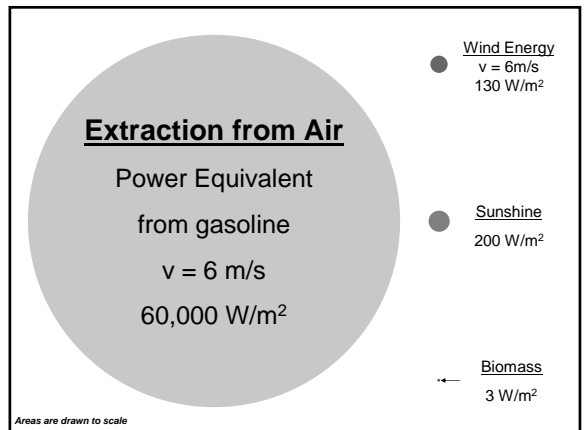
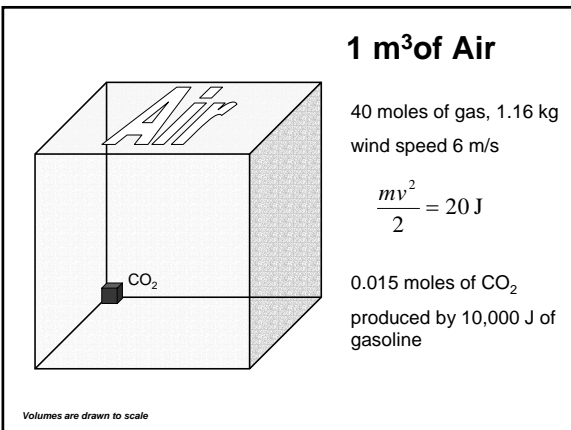
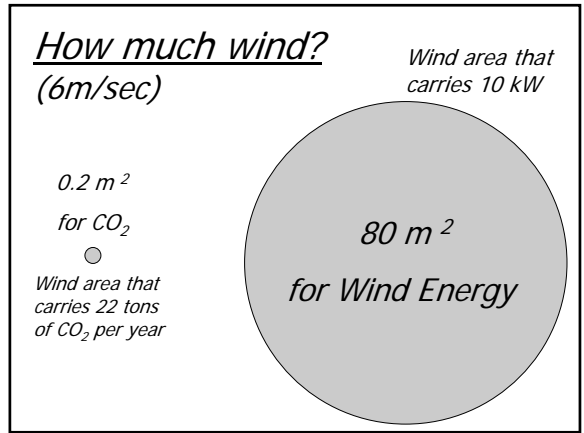
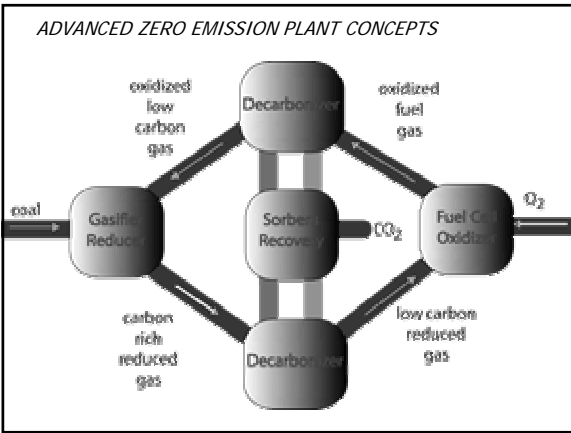
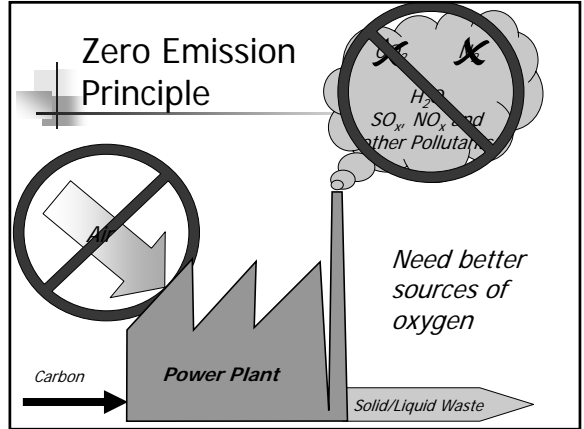
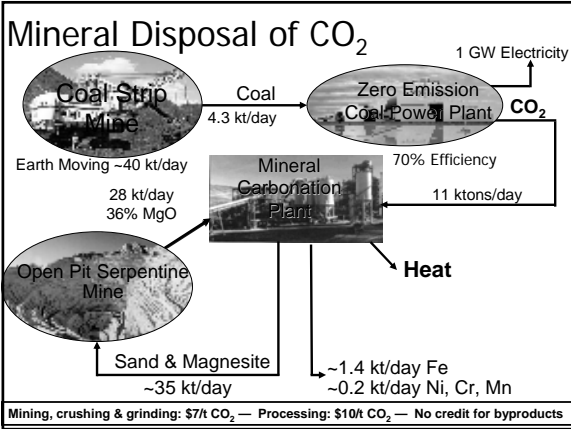
heat/mol CO<sub>2</sub> = -63.6 kJ

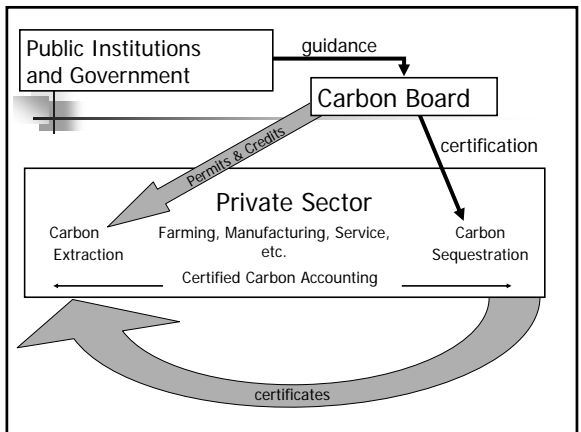
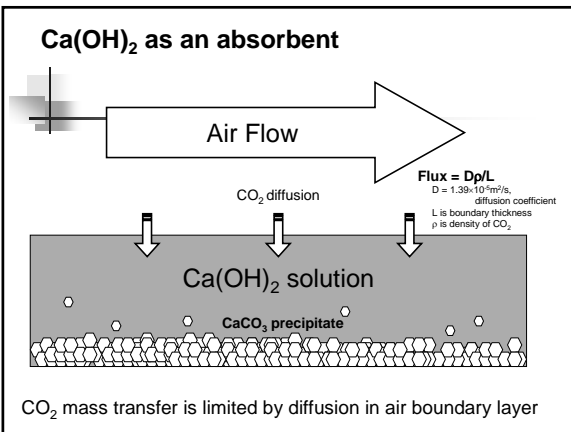
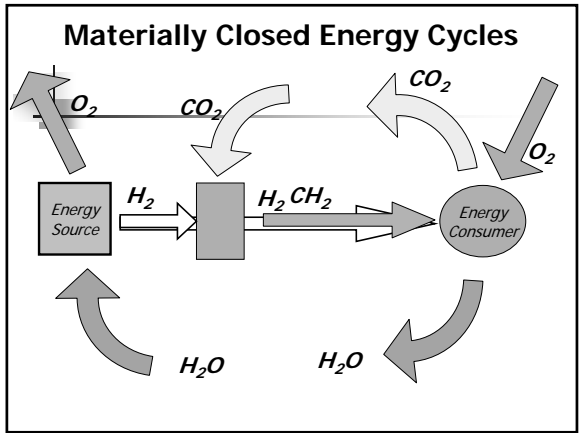
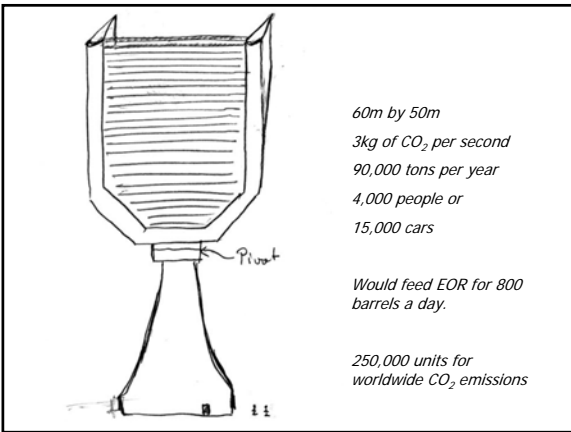
Accelerated from 100,000 years to 30 minutes

### Peridotite and Serpentinite Ore Bodies

Magnesium resources that far exceed world fossil fuel supplies







### Sustainable Development

- 1 – 2 billion without any electricity

