

Energy for Tomorrows World:

A Summary of Conventional and Renewable Options

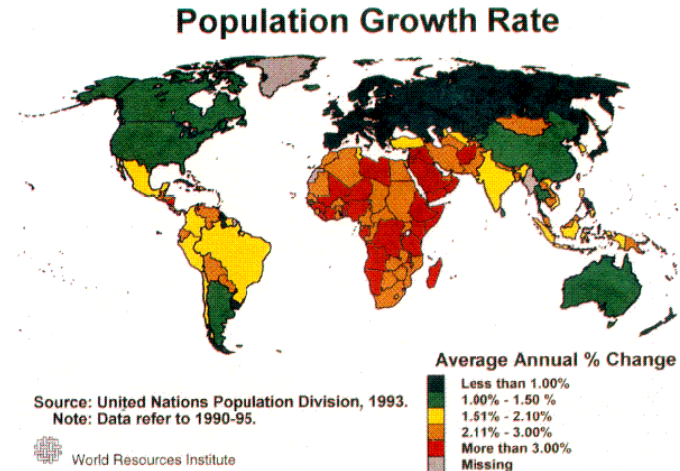
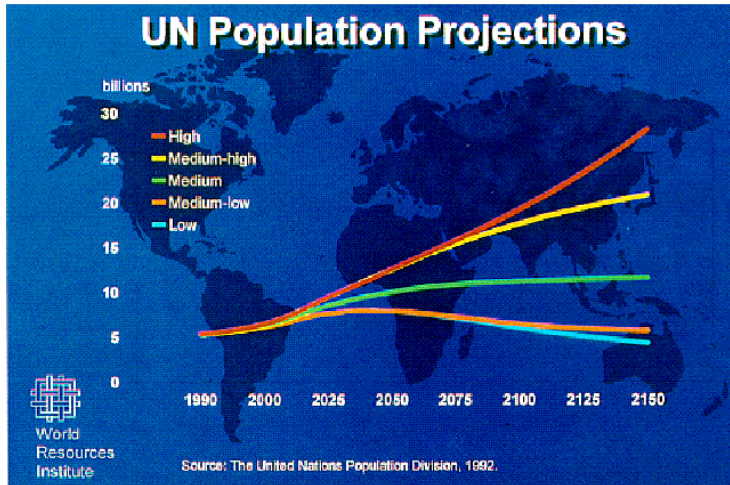
Adam McLean

June 4, 2001

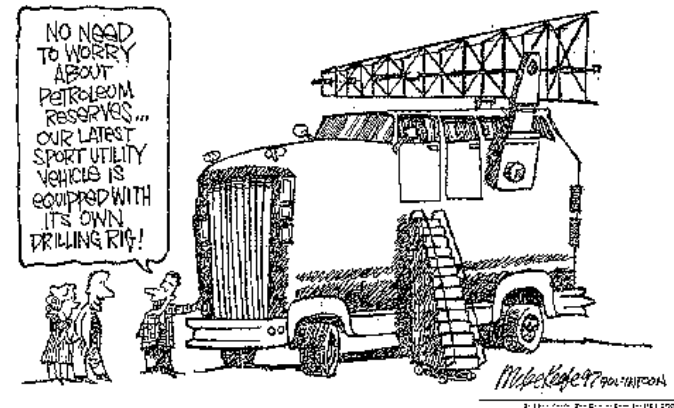
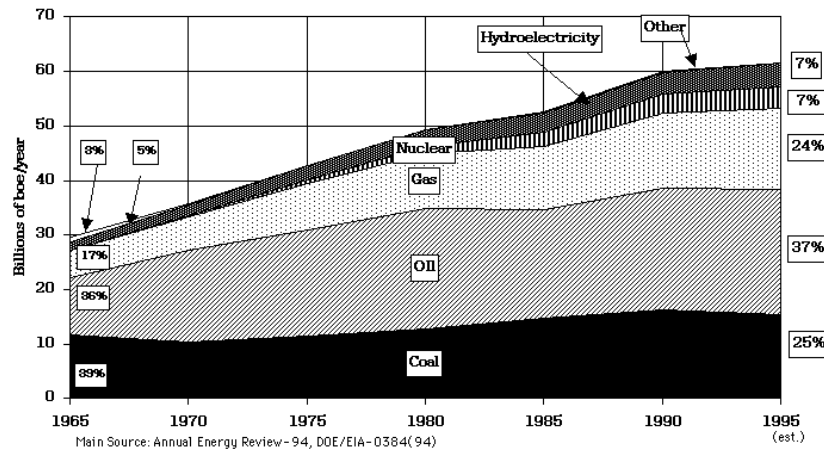
Outline of Presentation

- **Energy use: Is it really so bad?**
- **What Else is Wrong?**
- **Nonrenewable Energy Sources**
- **What is a Renewable Energy Source?**
- **Renewable Energy Sources**
- **Under Development**
- **What are the Barriers?**
- **An Uncertain Future**
- **Conclusions**

Energy Use: Is it Really so Bad?

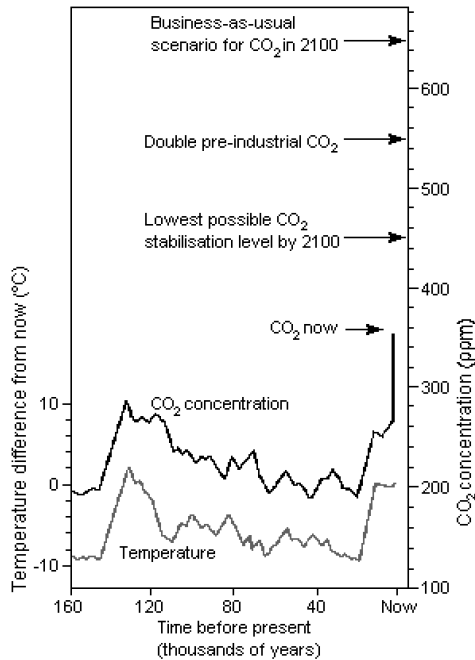
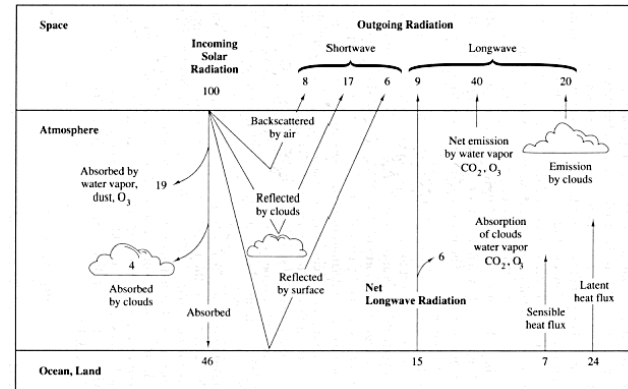


Fossil Fuels Still Account For Over 85% of the Primary Energy Consumed in the World

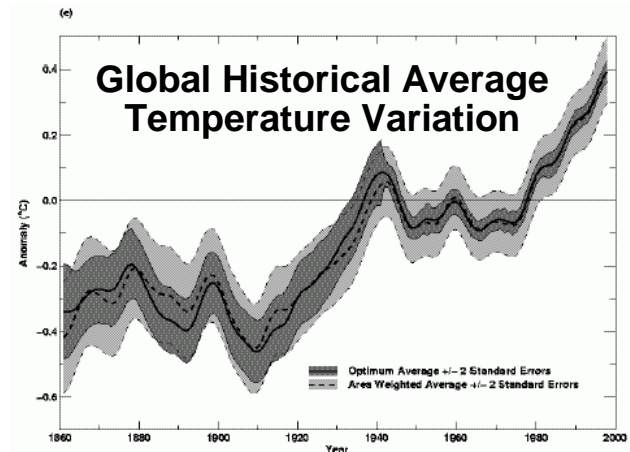
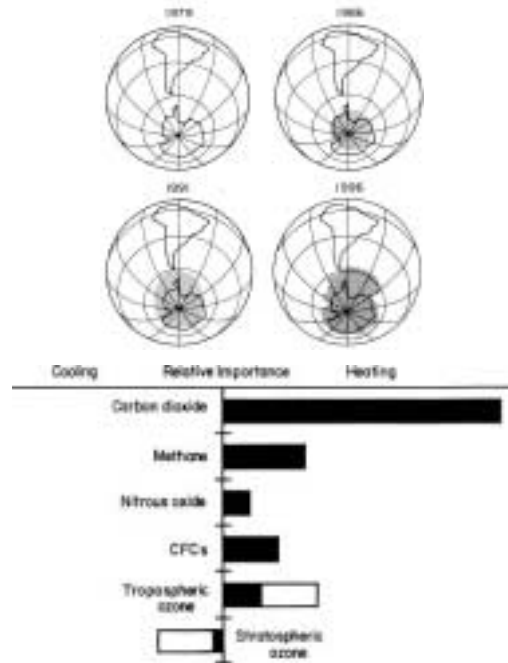


What Else is Wrong?

- Today, the global average surface temperature is about 15°C. This is 33°C warmer than the average surface temperature of the moon, which is about the same distance from the Sun as the Earth. The moon, of course, does not have an atmosphere, and therefore no greenhouse gases to trap extra heat.



Growth of the Antarctic Ozone Hole

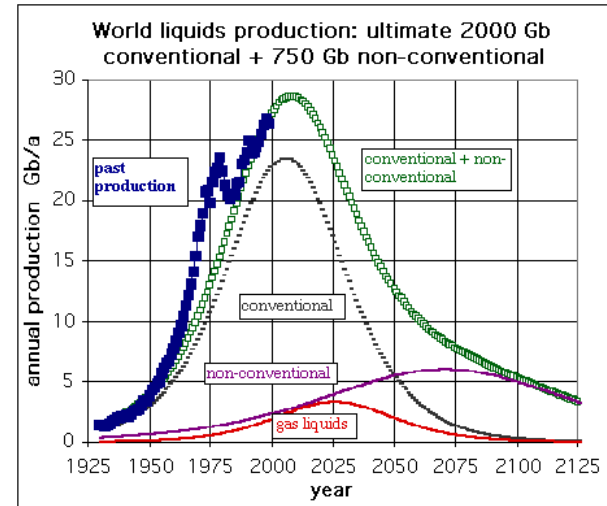


Concentration increases since 1750:

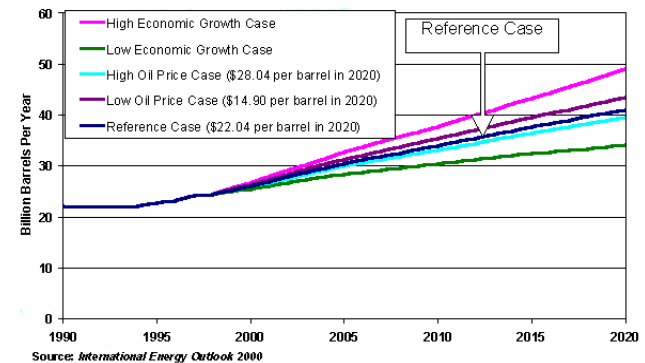
- Carbon Dioxide: 280 ppm 360 ppm (29%)
- Nitrous Oxides: 280 ppb 360 ppb (11%)
- Methane: 0.70 ppm - 1.70 ppm (143%)

Nonrenewable Energy Sources: Oil

- **Benefits:**
 - Wide range of applications for proven technology
 - Tax advantage for investors
 - Easy to transport and convert to electricity
- **Disadvantages:**
 - Direct environmental damage caused by oil spills
 - Contribution to global air pollution
 - Peak production is expected very soon ~2015!
 - Reserves will run out in year ~2100
 - During the 1970 Oil Crisis, America imported 24% of it's oil dependency
 - America currently imports 51% of it's oil demand
 - Reference case projection for 2010 is 60%, \$100 billion per year outflow

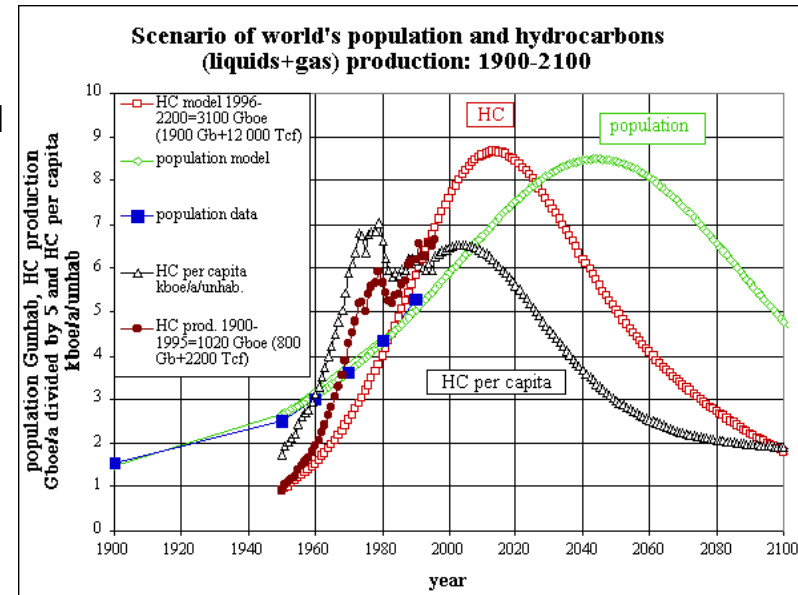


EIA World Oil Production Projections, 1990-2020



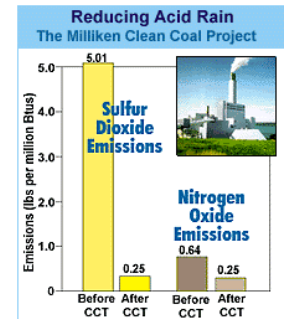
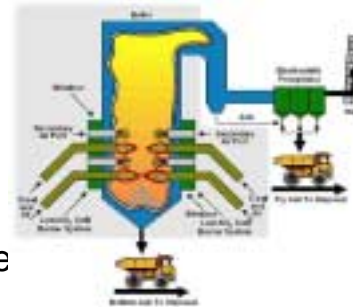
Nonrenewable Energy Sources: Natural Gas

- **Advantages:**
 - 1/2 CO₂ of coal, 3/4 CO₂ of oil production
 - Easy to transport
 - Versatile fuel which can be used for space and water heating, process heat for industry, cooking, transportation and electricity generation
 - Plants can be quickly turned on and off to supply 'peak' power demand
 - Co-generation plants up to 50% efficient
- **Disadvantages:**
 - Cost is highly dependant on price of fuel
 - Generally more expensive than coal
 - Peak production is expected in ~2010
 - Reserves will run out in year ~2150



Nonrenewable Energy Sources: Coal

- “When it rains in China's coal country, soot rubs off blackened tree trunks like ink.”
- Advantages:
 - far more plentiful than gas and oil
 - safe, proven technology
 - cheap power for a great number of people
- Disadvantages:
 - huge contribution to global pollution and greenhouse



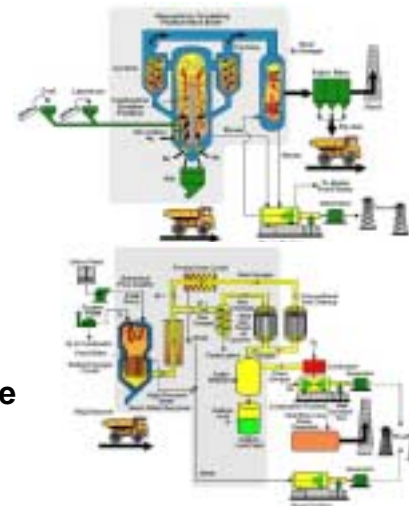
• Low Emission Coal Technology

– Fluidized Bed Combustion

- » Burn coal in pulverized form, suspended on mixture of jets
- » Removes pollutants inside the boiler (no scrubber required)
- » Reduces SO₂ by 90-95%
- » Reduces Nox by 90+%

– Gasification Combined Cycle

- » coal turned into gas and cleaned before burning
- » gas burned in turbine to create electricity
- » Exhaust from turbine hot enough to boil water -> combined cycle
- » 95-99% impurities can be removed



Nonrenewable Energy Sources: Nuclear Fission

- **Advantages:**
 - Very high capacity, continuous source for baseload power
 - Proven technology
 - Most regulated and inspected industry anywhere
 - Technology also used for numerous medical, agriculture, etc. applications
- **Disadvantages:**
 - Nuclear Waste... from fuel and decommissioning
 - High initial capital cost
 - Lack of public knowledge and acceptance

**Energy Conversion:
Typical Heat Values of Various Fuels**

Brown coal	9.7 MJ/kg
Firewood	16 MJ/kg
Black coal	24-30 MJ/kg
Natural Gas	39 MJ/m ³
Crude Oil	45-46 MJ/kg
Uranium (light water reactor)	500,000 MJ/kg

(MJ = Megajoules)



Prospects for Renewable Energy Sources

Technical Potential of Renewable Resources

(After W. Hafele, *ENERGY IN A FINITE WORLD—A Global Systems Analysis*, Ballinger (1981))

Type	Annual Energy Potential (billion boe/y)	Comment
Biomass	30	Requires cultivation of virtually all of the productive land in the world
Hydropower	15	A high quality product, equal to 3 times as much fuel. Includes minor potential from glaciers
Wind	15	High quality energy but utilization must deal with difficulties of energy storage
Waves & Ocean Currents	0.03	Minor quantities available, but they do not add up to anything significant
OTEC	5	Potential is greater if ocean heat can be diverted on a gigantic scale. Still speculative.
Geothermal	10	Much more stored heat is available for "mining" but technology is not available
Tidal	0.2	Very localized potential
Total	75	

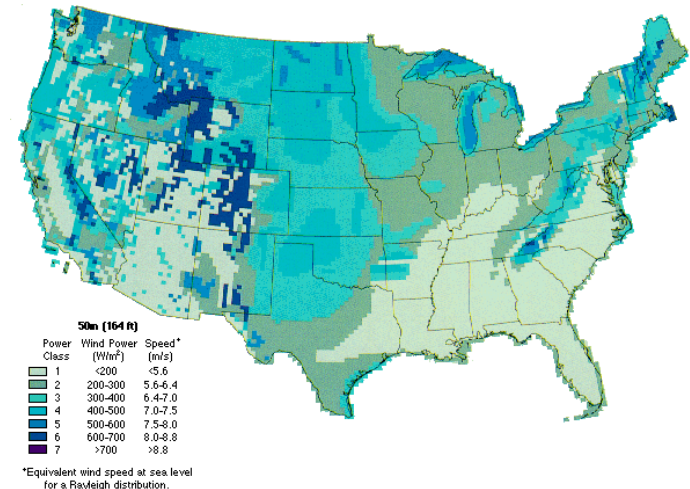
Renewable Energy Sources: Wind

- **Advantages:**

- Continuous but variable source
- Proven technology in Europe (Denmark sells 1/2 of total world installed wind capacity of 4500MW/year)
- Total installed wind capacity >21,000MW
- Wind turbines now are 50kW - 3MW in size
- Built to last >20 years
- Can be land or water based
- Highly distributed production
- Actually blades kill very few birds...

- **Disadvantages:**

- Large land area required
- Operate at only 15-25% capacity
- Storage is absolutely required
- Maintenance is difficult and \$\$\$
- Loud (>100 dB) near base



Wind Energy Resource Atlas of the United States
Map 2-6 Annual average wind resource estimates in the continuous United States.

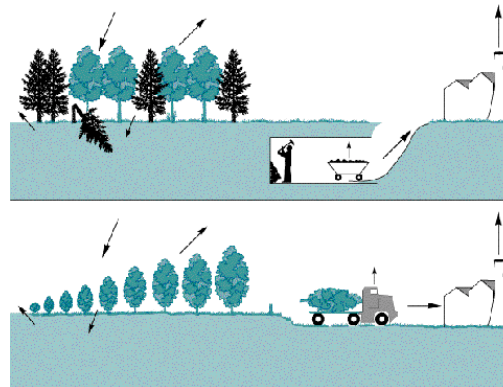
Renewable Energy Sources: Biomass

- **Advantages:**

- Low regeneration time (wood - 7years, biofuels - 1-3 months)
- Small capital cost
- Small scale (50-100MW) is practical for developing countries (15% of world use, 35% of developing energy)
- Continuous operation for baseload power
- Creation of jobs in agriculture
- Biomass Integrated Gasifier/Fuel Cell (BIG/FC) system releases virtually no pollution, 80+% efficiency

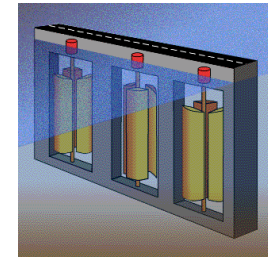
- **Disadvantages:**

- Particulate and Carbon Monoxide pollution for current generation
- Land-use intensive

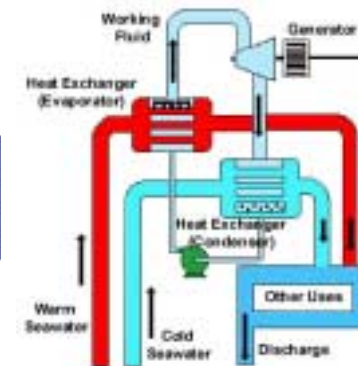
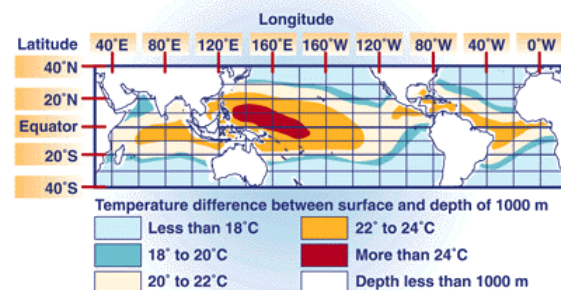
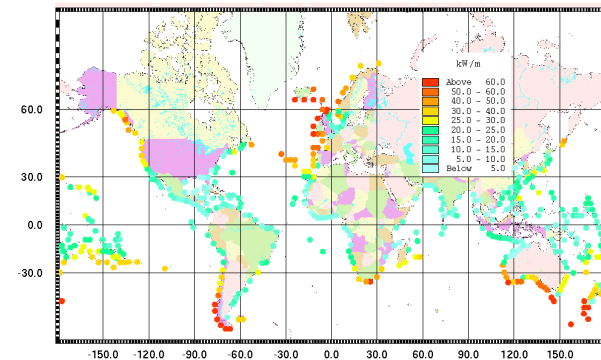


Renewable Energy Sources: Hydro

- **Hydroelectric**
 - Medium to large installations
 - Dependant on rainfall
- **Tidal**
 - Twice a day
 - Very limited locations
- **Wave**
 - Continuous but variable source
 - Limited areas of applicability
 - Might interrupt normal seashore operations
- **Ocean Thermal Energy Conversion**
 - 2% theoretical efficiency
 - 10⁷MW power available
 - Closed or open cycle plants
 - Continuous source



Global Coastal Wave Power Estimates



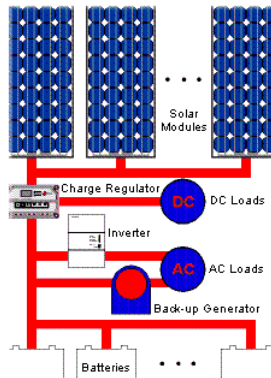
Renewable Energy Sources: Solar

– Advantages

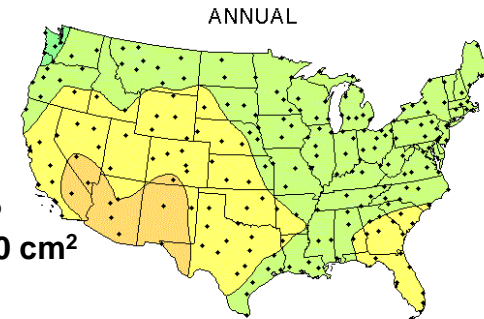
- » Vast amount of untapped energy potential
- » The amount of solar energy reaching Earth each day could supply our power for 1 year
- » Uses include heating and photovoltaics
- » Individual cells have approached 25% in conversion efficiency

– Disadvantages

- » Large initial capital investment
- » Capacity highly dependant on location
- » Due to contact losses and non-productive surface areas, large solar array efficiency has only reached 11%
- » 1kW at 11% efficiency requires a collecting area of 3,700 cm²
- » Exotic chemicals required for high efficiency (eg. Pn-GaAs, GaSb, nip-Ga-In)
- » Few employment opportunities



Average Daily Solar Radiation Per Month



Flat Plate Tilted South at Latitude

This map shows the general trends in the amount of solar radiation received in the United States and its territories. It is a spatial interpolation of solar radiation values derived from the 1961-1990 National Solar Radiation Data Base (NSRDB). The dots on the map represent the 239 sites of the NSRDB. Maps of average values are produced by averaging all 30 years of data for each site. Maps of maximum and minimum values are composites of specific months and years for which each site achieved its maximum or minimum amounts of solar radiation. Though useful for identifying general trends, this map should be used with caution for site-specific resource evaluations because variations in solar radiation not reflected in the maps can exist, introducing uncertainty into resource estimates. Maps are not drawn to scale.

NREL
National Renewable Energy Laboratory
Resource Assessment Program

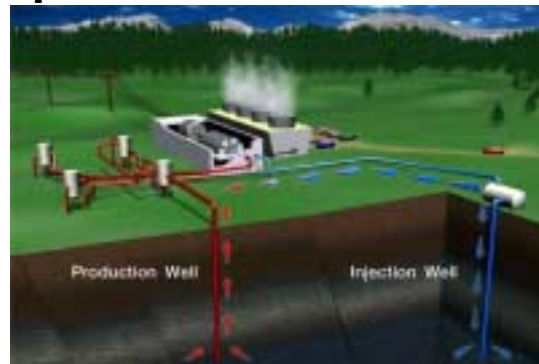
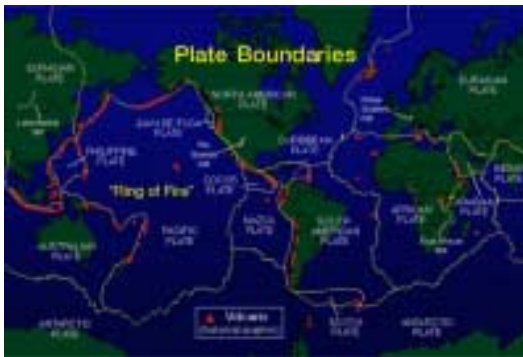
kWh/m²/day



FIG. A1.13-2

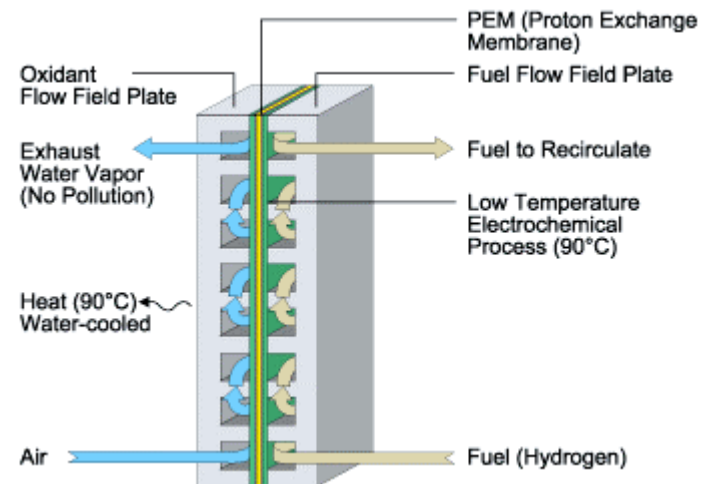
Renewable Energy Sources: Geothermal

- **Currently 8,200 MW installed capacity in 21 countries (mostly developing)**
- **Advantages:**
 - Provides clean, safe energy using little land
 - Renewable and sustainable
 - Generates continuous, reliable baseload power
 - Modular development and remote power applications
- **Disadvantages:**
 - Only available in specific locations around the globe



Energy Storage

- **Energy carriers, not producers**
- **Batteries:**
 - Acres of batteries charged during low demand periods
 - Designed for load leveling
 - 1 acre could store 400MWh of energy, deliver 40MW for 10 hours
 - Batteries require environmentally damaging chemicals
- **Pumped hydro**
 - Advantage of 64% efficiency
 - Disadvantage of limited locations for use
- **Flywheels**
 - Fused Silica flywheel has 25 times energy storage per kg than lead-acid batteries
- **Hydrogen**
 - Very high energy density storage per kg
 - H must be separated from H₂O
 - Very energy intensive process
- **Compressed air**
 - Must cool air as it's compresses
 - Highly pressurized containment vessels are a safety concern



Barriers to Use of Renewable Source

- **Legislative Barrier:** The need is not seen or understood. Continuous short term view. Will an alternative provide enough jobs, be affordable?
- **NIMBY (Not In My Back Yard) Barrier:** Many things are now unacceptable to the public.
- **Ignorance Barrier:** The public doesn't understand the need to invest in alternative energy sources now.
- **Industry Barrier:** Economics of alternative energy are not well understood, can industry make a profit? Taxing fossil fuel sources would subsidize renewables but this may never happen. Limited experience.
- **Capital Cost Barrier:** High capital cost of equipment. Without government subsidies, some facilities just can't get built. Tax breaks and low interest loans will be needed.
- **Uncertainty Barrier:** Will new technology come along and make obsolete what has been done?
- **Environmental Barrier:** False perceptions of risk to replace conventional energy sources. Lack of a single standard governing the definition of 'green'. Difficulty identifying and quantifying benefits of green practices.
- **Energy Storage Barrier:** All forms of alternative energy require efficient and reliable energy storage to compensate for low duty cycle

Summary

<i>Evaluation</i>	<i>Solar Thermal</i>	<i>PV</i>	<i>Hydro</i>	<i>Wind</i>	<i>OTEC</i>	<i>Tidal</i>	<i>GEO</i>	<i>Biomass</i>
Capital Costs	Large	Large	Enormous	Moderate	Enormous+	Enormous	Small	Small
Operating Costs	Moderate	Moderate	Neglegible	Small	Unknown	Neglegible	Small	Moderate
Efficiency	15%	5--10%	80%	42%	7% +	25%	100%	25%
Renewable	Yes	Yes	Yes	Erratic	Yes	Yes	NO	Maybe
Storage	Not Needed	Unclear	Built-IN	Essential	Not Needed	Unclear	Not Needed	Not Needed
Pollution	None Really	Waste Heat	None	Visual	None	None	Steam Plumes	Particulates; CO
Levelized Costs	25 cents KWH	16 cents KWH	4 cents KWH	4.5 cents KWH	Unknown	Unknown	Low	Unknown
Environmental Impact	Moderate	Large	Enormous	Small	Unknown	Outrageous	Small	Moderate
Large Scale	Too Expensive	Possible - Expensive	Proven already	Very Possible	The Solution	Discrete Locations	Discrete Locations	Net Energy Gain?
Small Scale	NO	Difficult	Low Head --> Legal	Definitely	NO	NO	NO	Absolutely
Unit Capacity	1000 MW	Depends on Acreage	2000-6000 MW	Highly Variable	As large as you need	250 MW	1000 MW	50-100 MW
Employment	Few	Few	Few	Few	Lots to build it	Some	Few	Many

Toward the Future...

- **Adam's Predictions...**
 - Oil and Gas will very quickly become very expensive
 - More coal use but very slow acceptance of new burning technologies
 - More nuclear!
 - More renewables in the form of wind (watch for wind turbines) and biomass generation
 - Solar will remain a highly specialized production method

To Conclude...

- **When your electricity bill asks ‘Would you agree to paying a x cent premium to support clean energy production?’ what will you say?**
- **Thank you for your attendance :)**