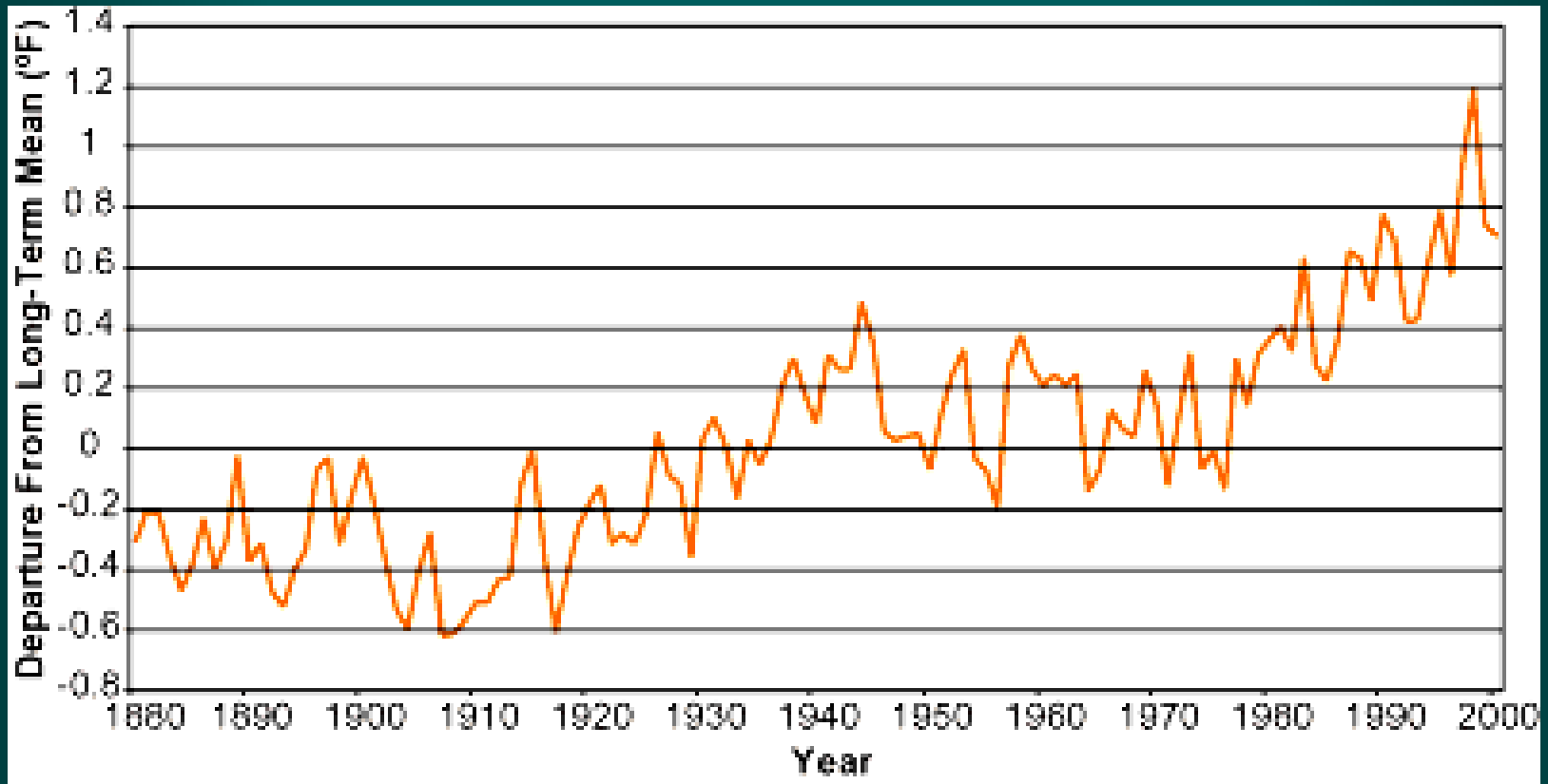


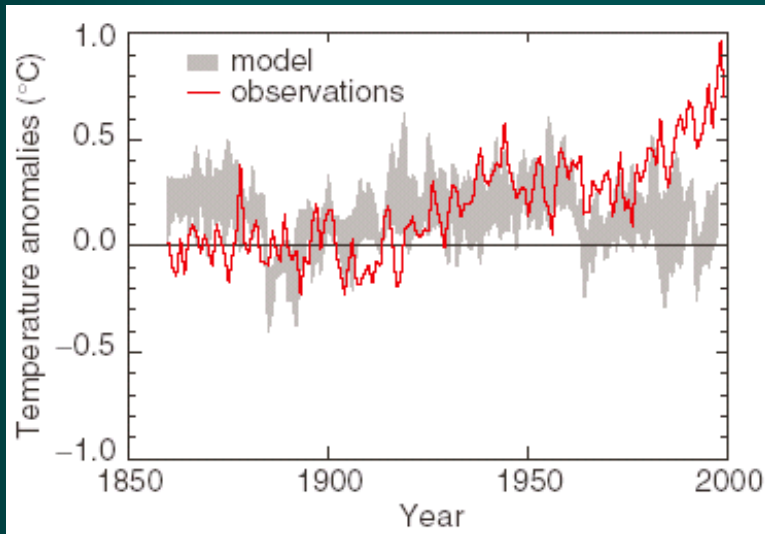
Renewable Energy Sources

In the last 100 years, the Earth warmed up by $\sim 1^\circ\text{C}$

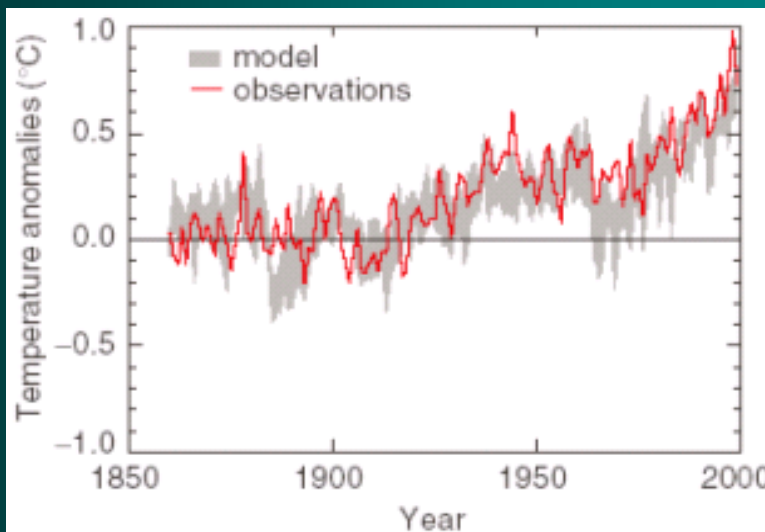


100 years is nothing by geological time scales!

Can we predict the past?

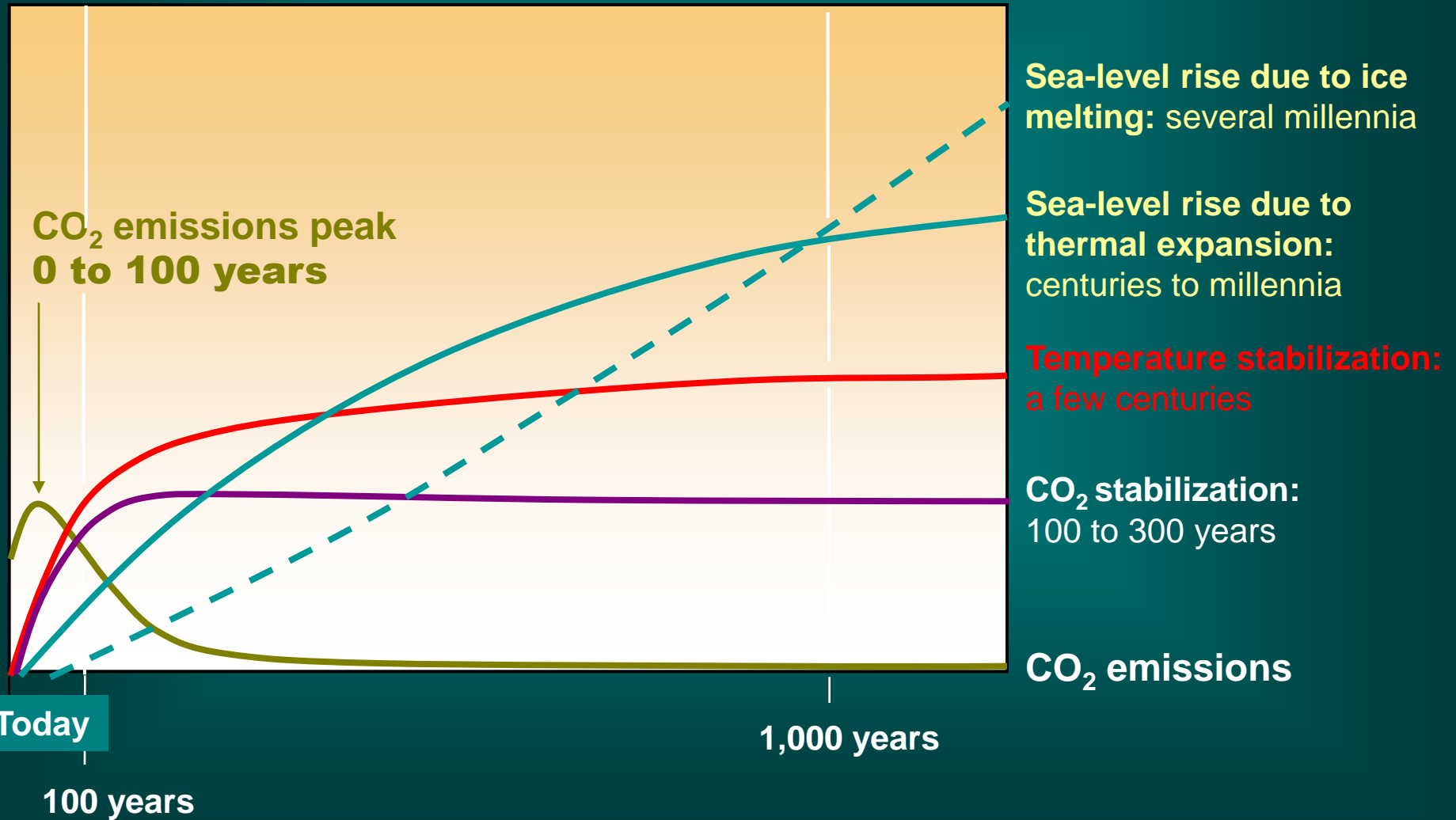


Climate change due to natural causes (solar variations, volcanoes, etc.)



Climate change due to natural causes and human generated greenhouse gases

CO₂ Concentration, Temperature, and Sea Level Continue to Rise Long after Emissions are Reduced

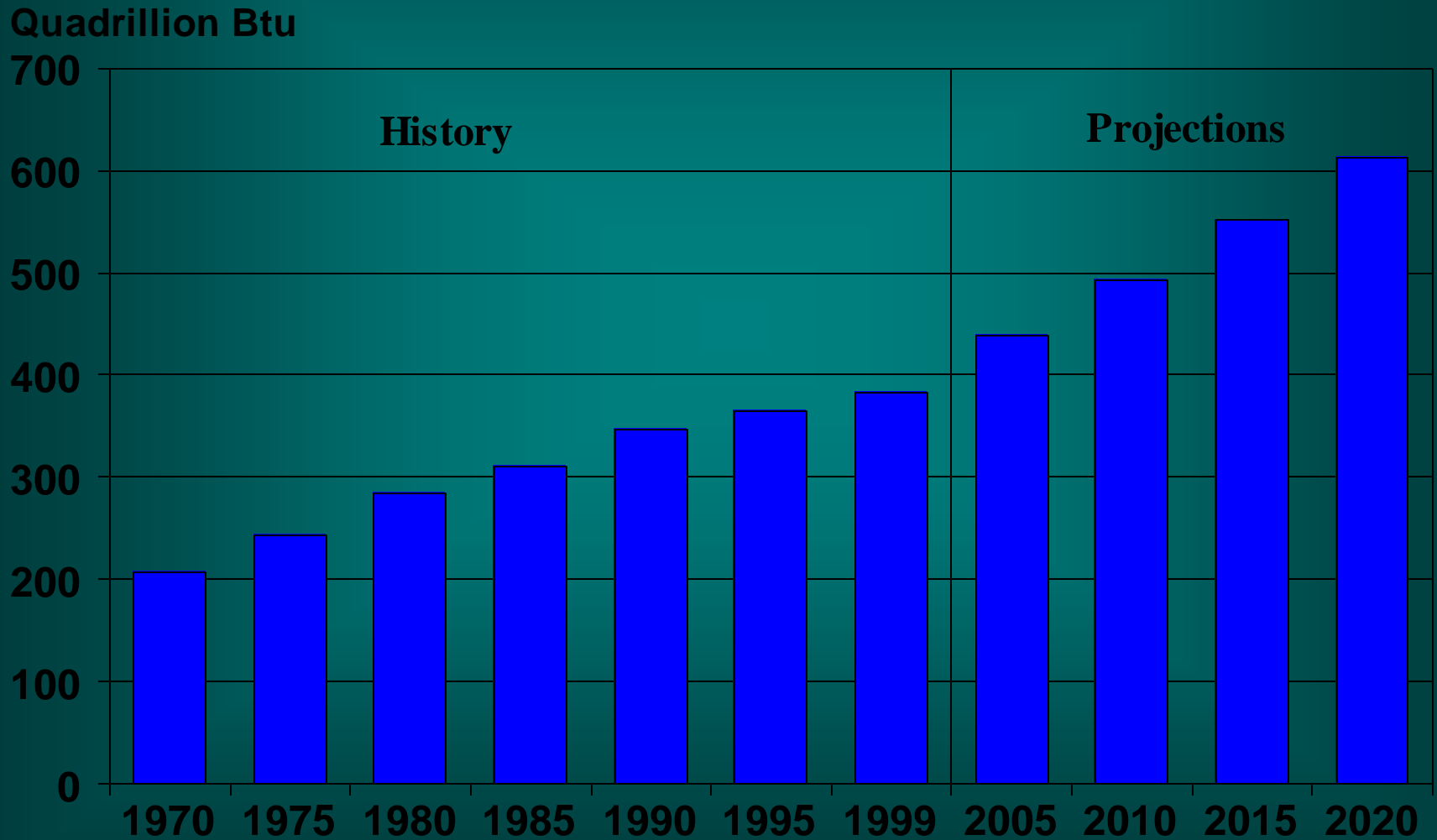


The possibility / likelihood of
global warming is disturbing ...

... but there may be a bigger problem!

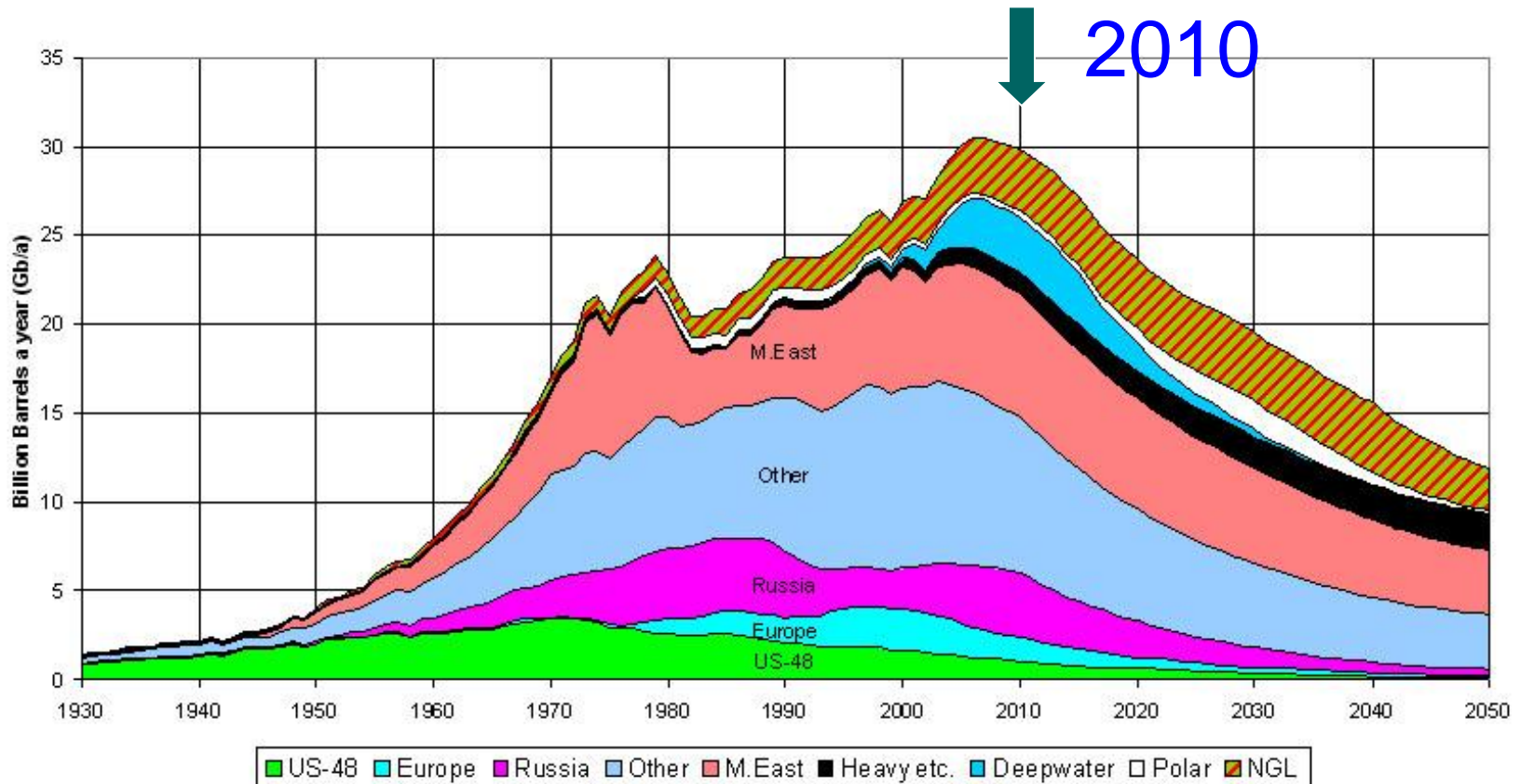
Consumption of Energy Increased by 85% Between 1970 and 1999

By 2020, Consumption will Triple



World production of oil and gas is predicted to peak within 10 - 40 years

OIL AND GAS LIQUIDS
2004 Scenario



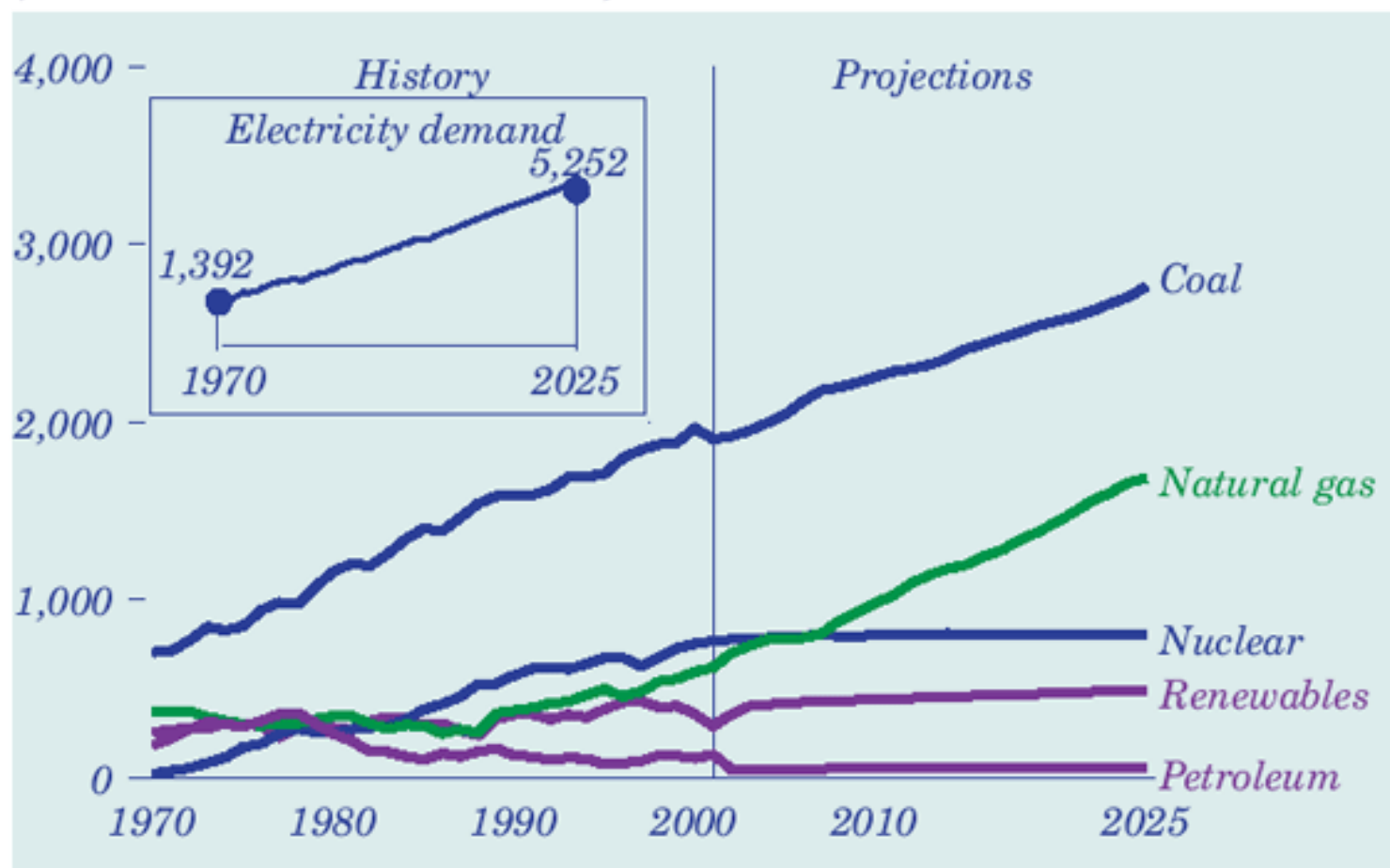


**Energy conservation and
efficiency can buy time
(a factor of ~2)**

but the fundamental problem remains



Figure 4. Electricity generation by fuel, 1970-2025 (billion kilowatthours)



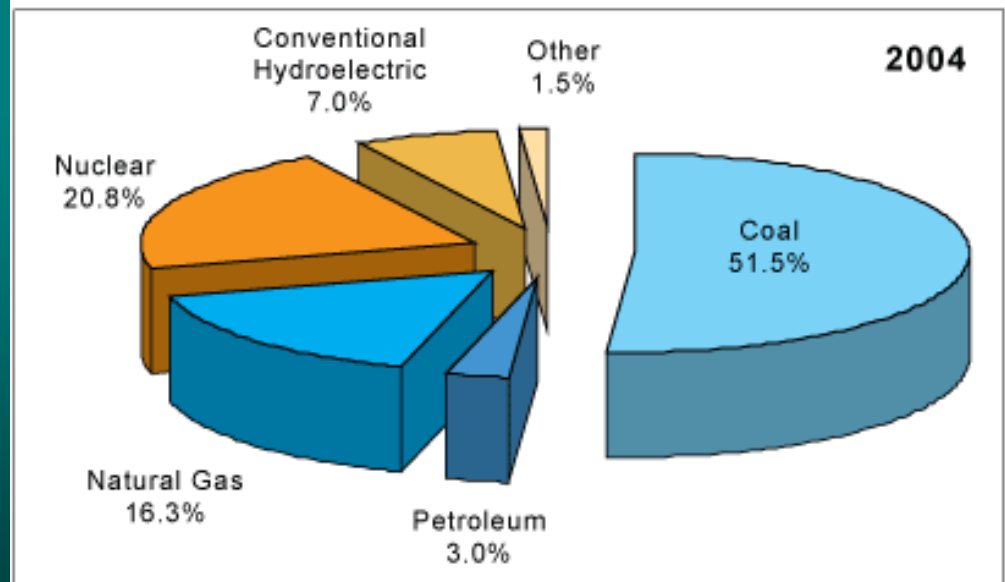
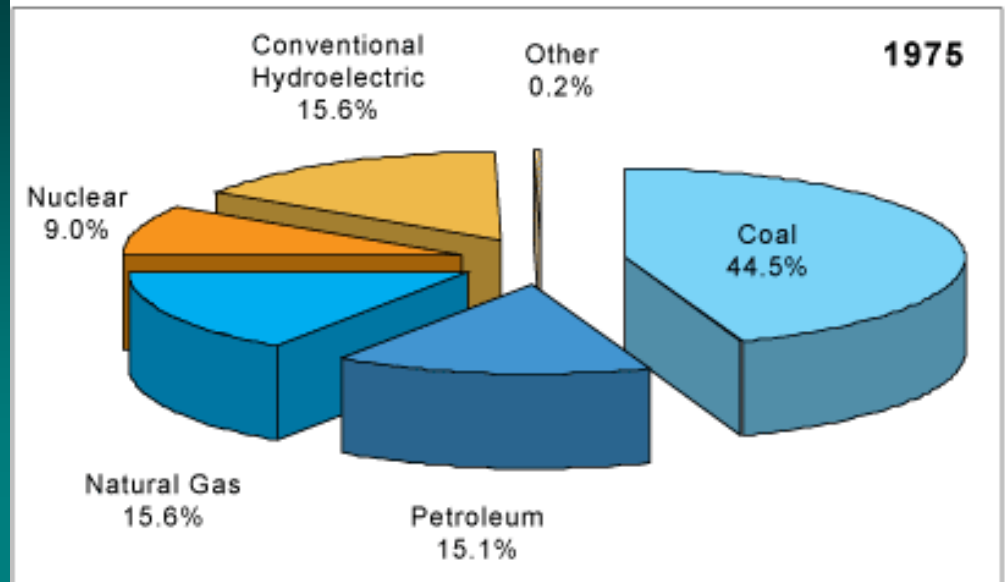
Electrical generation

Switch from petroleum to coal
and natural gas

Why has hydroelectric
declined?

When did nuclear go up?

U.S. Electric Power Generation by Fuel Type - Years 1975 and 2004



Estimates of depletable energy resources in the U.S.

Numbers = how long it would last if all energy came from one source

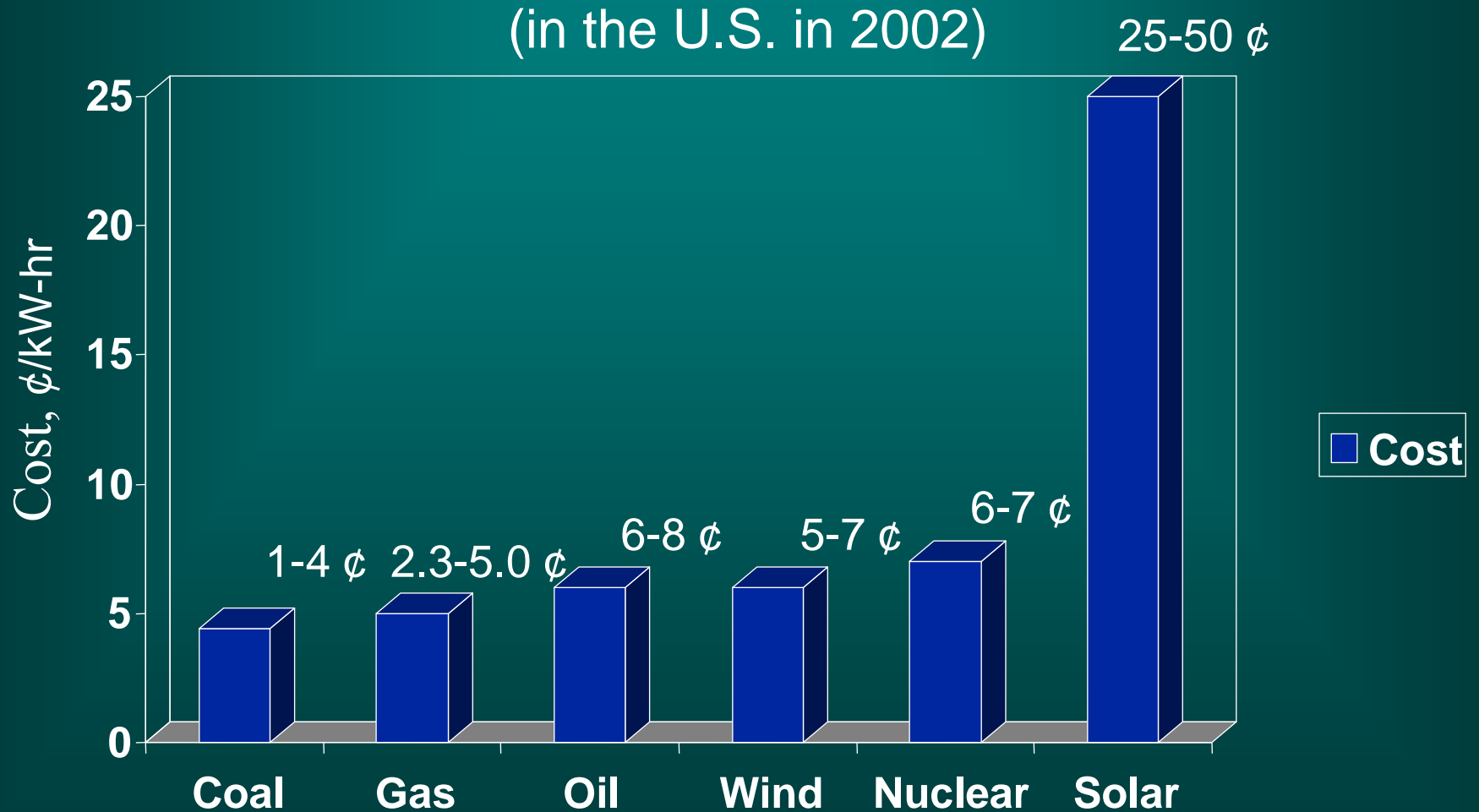
Resource	recoverable	recoverable and hoped for
Coal	125	1300
Petroleum	5	50?
Natural gas	5	50?
Oil shale	0	2500
Conventional reactors	3	15
Breeder reactors	115	750
Fusion		10^6 to 10^9
Geothermal surface	0.2	60
deep rock	0	600

Estimates of renewable energy

Numbers = proportion of current U.S. energy needs that could be supplied for an indefinite period.

Tidal energy	0.1
Organic Waste	0.1
Photosynthesis	0.23
Hydropower	0.14
Wind Power	5
Solar radiation	740

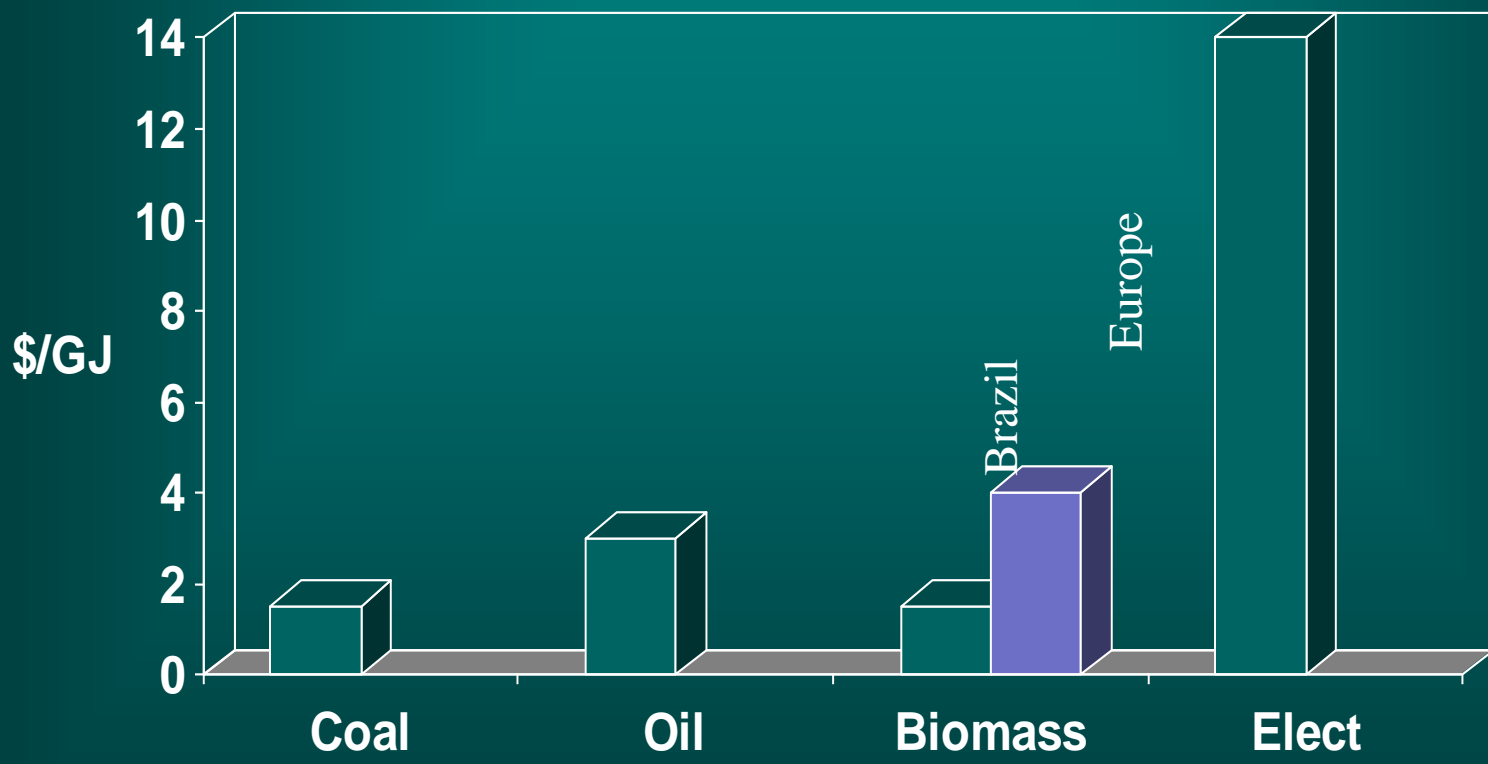
Today: Production Cost of Electricity



Courtesy Nate Lewis

Energy Costs

\$0.05/kW-hr

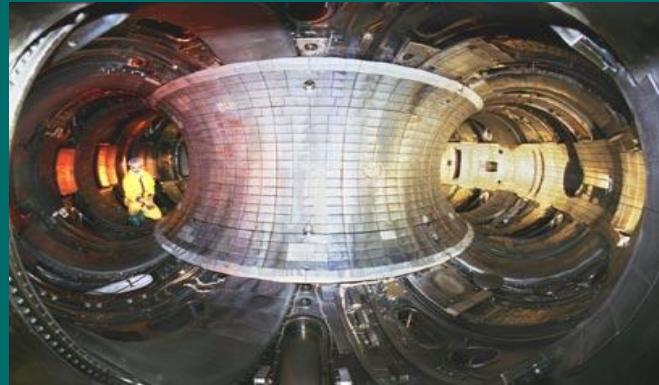


www.undp.org/seed/eap/activities/wea

Courtesy Nate Lewis

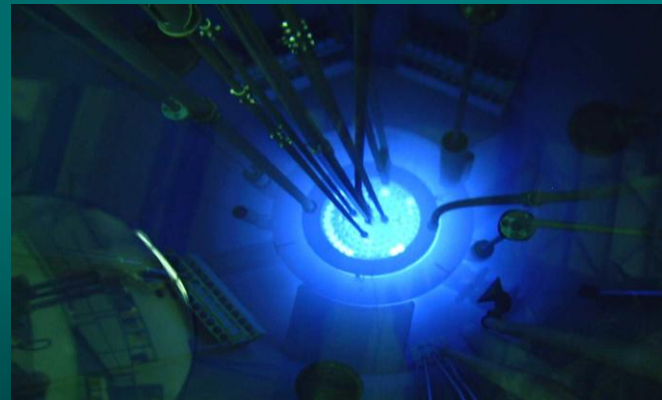
Potential Sources of Energy when Fossil Fuels Run Out

Nuclear Fusion



Magnetic Plasma Confinement, Inertial Fusion

Nuclear Fission



Waste & Nuclear Proliferation

10 TW = 10,000 new 1 GW reactors: i.e., a new reactor every other day for the next 50 years

Solar, Wind and Water



We do not know how to store electrical energy on a massive scale

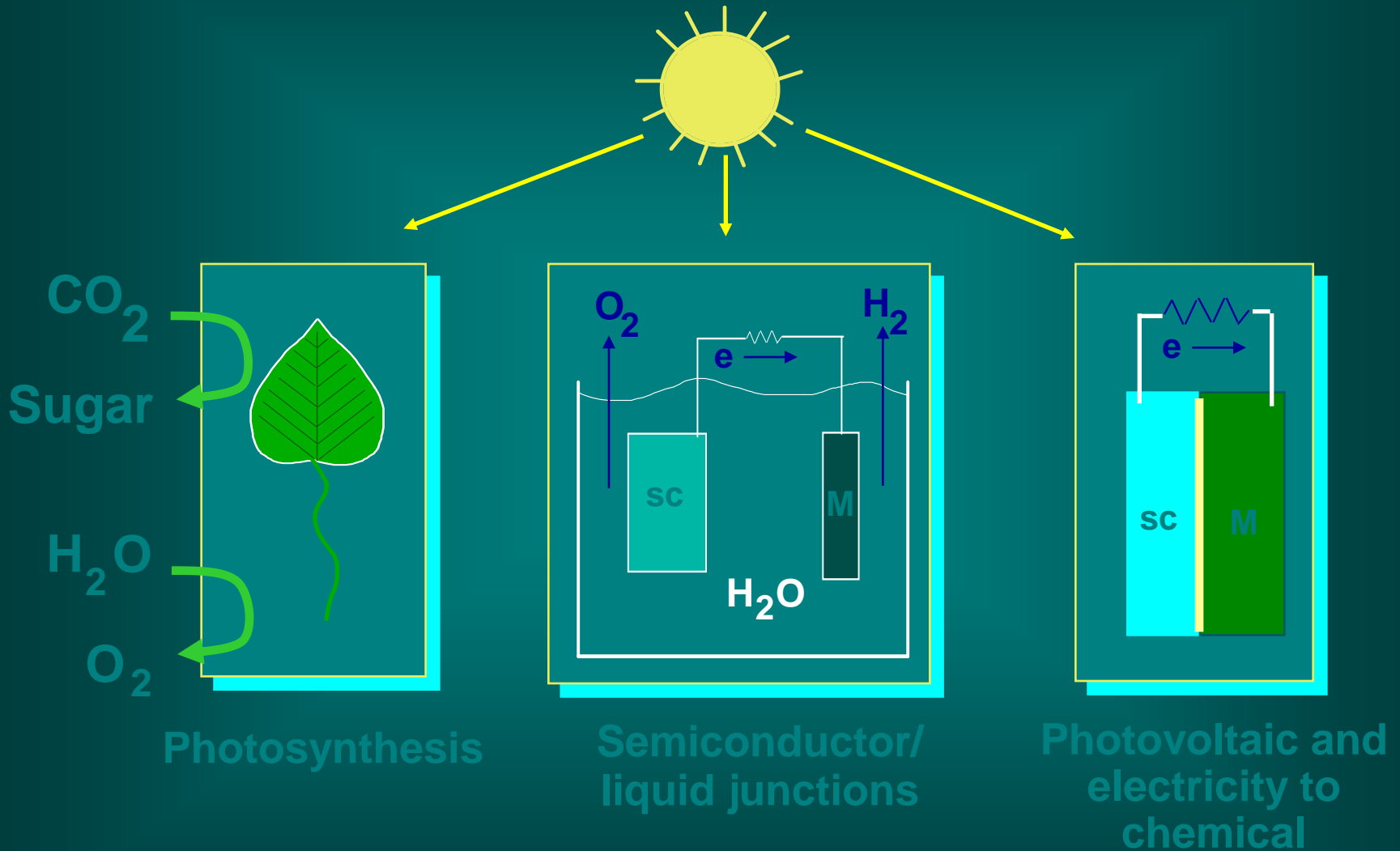


Geothermal

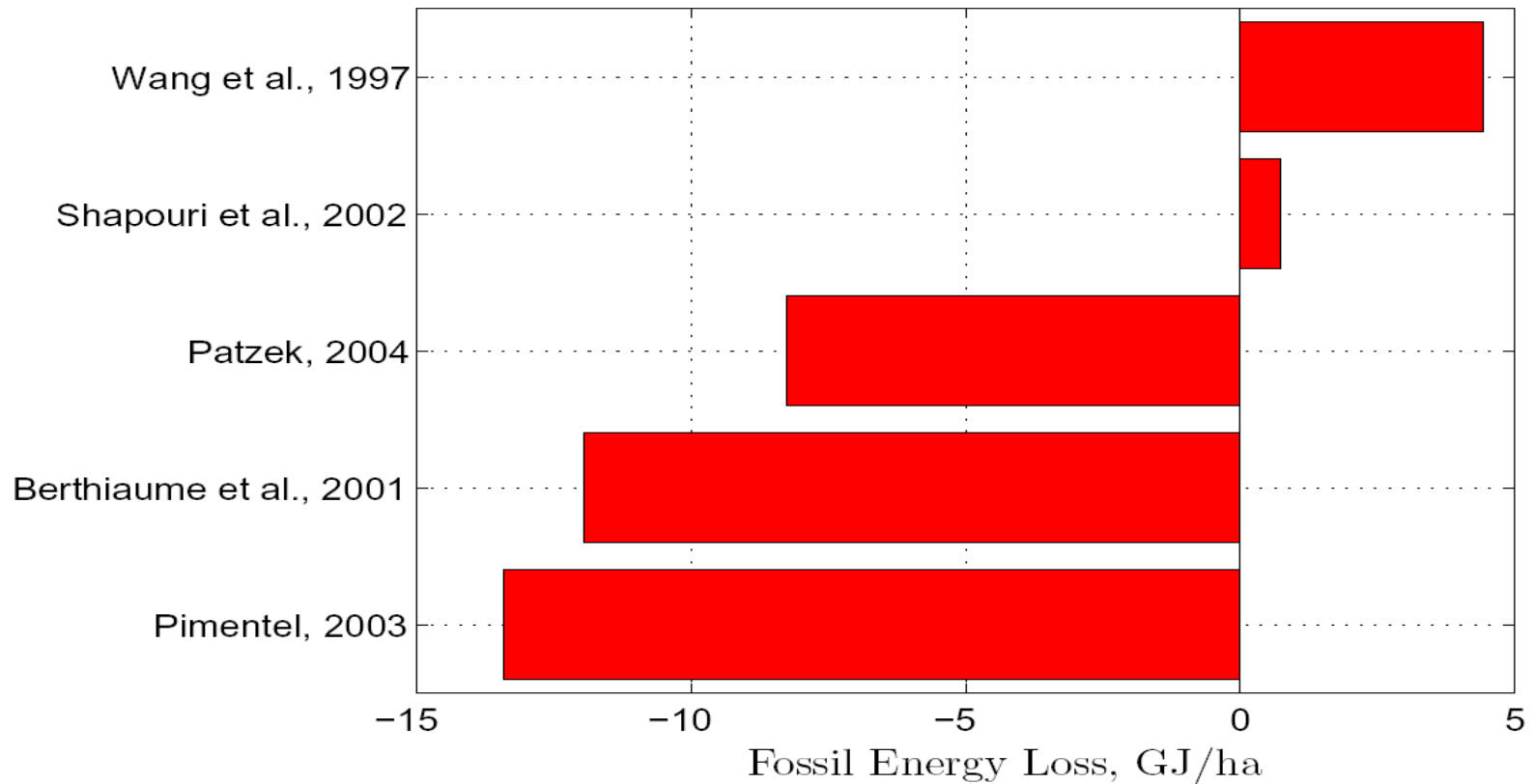
Heat near surface of the earth = geysers, volcanoes, hot springs



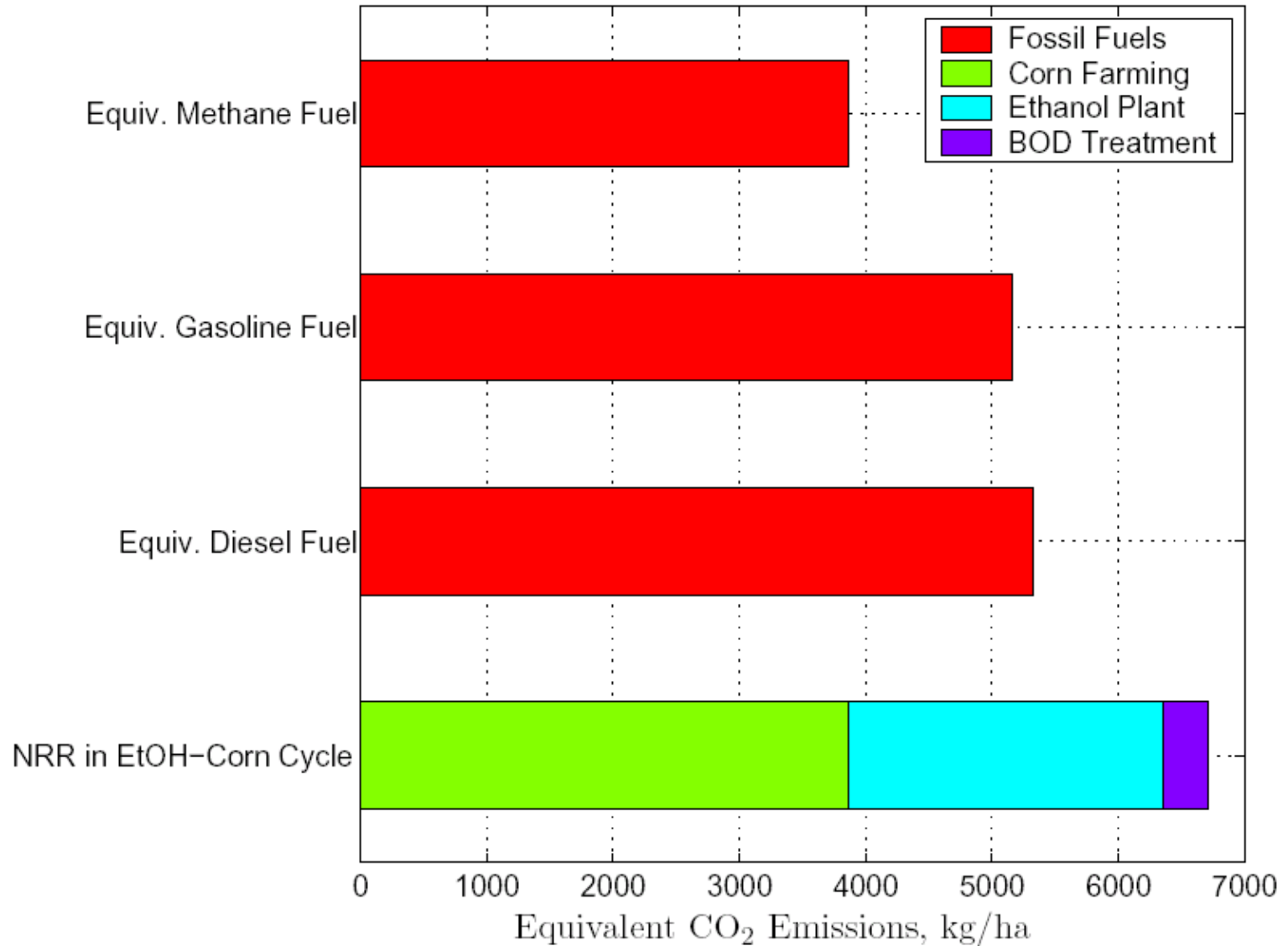
Solar to Chemical Energy



Energy gained in corn ethanol production



Total CO₂ emissions

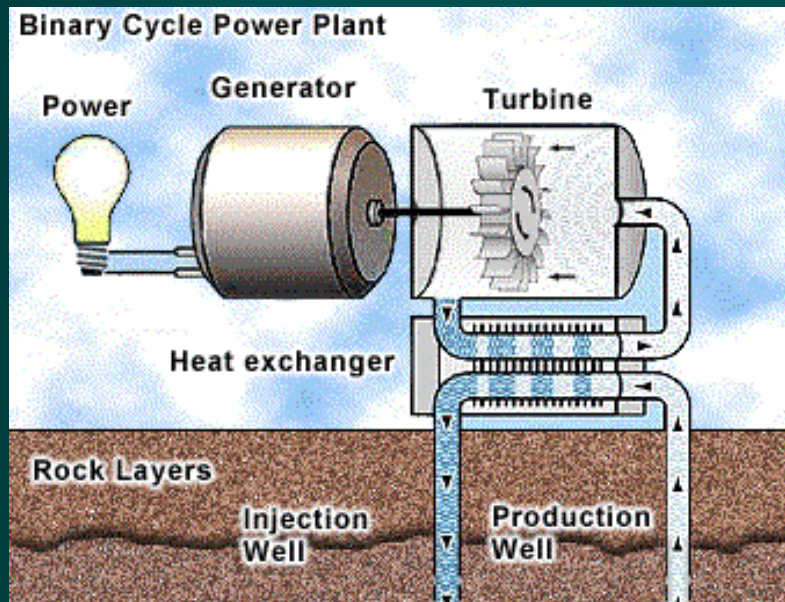


From Summary of Renewable Fuel Options (NCEP)

“Unlike corn ethanol, cellulosic ethanol has potential to achieve near-zero net carbon emissions.

Cultivation of cellulosic feedstocks requires very low energy inputs and, if sustainably managed, the carbon released during fuel combustion is reabsorbed by the growth of new feedstocks.”

Geothermal Energy in More Details



Use heat to make steam to turn turbine for electrical generation

Note: deep hot waters are corrosive to best to inject clean water in a closed system and bring it back to the surface as steam.

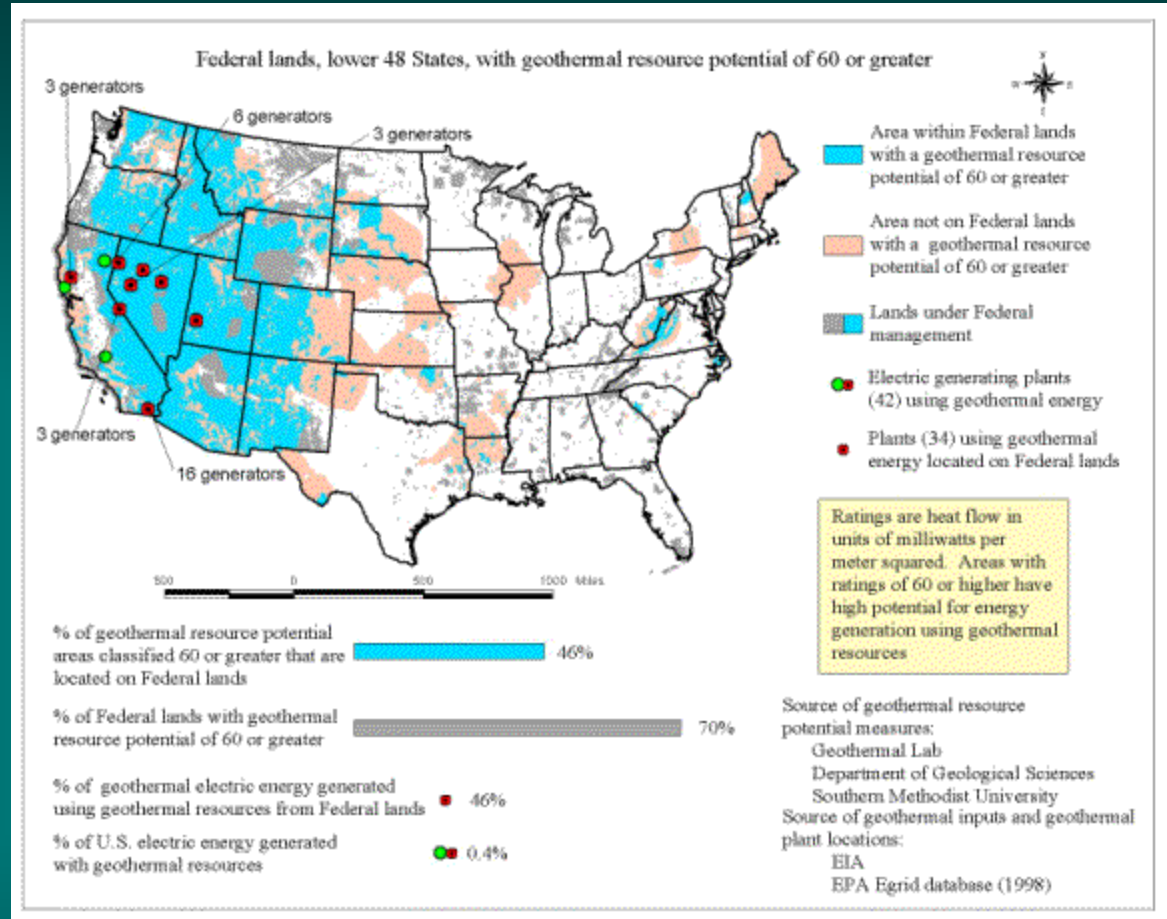


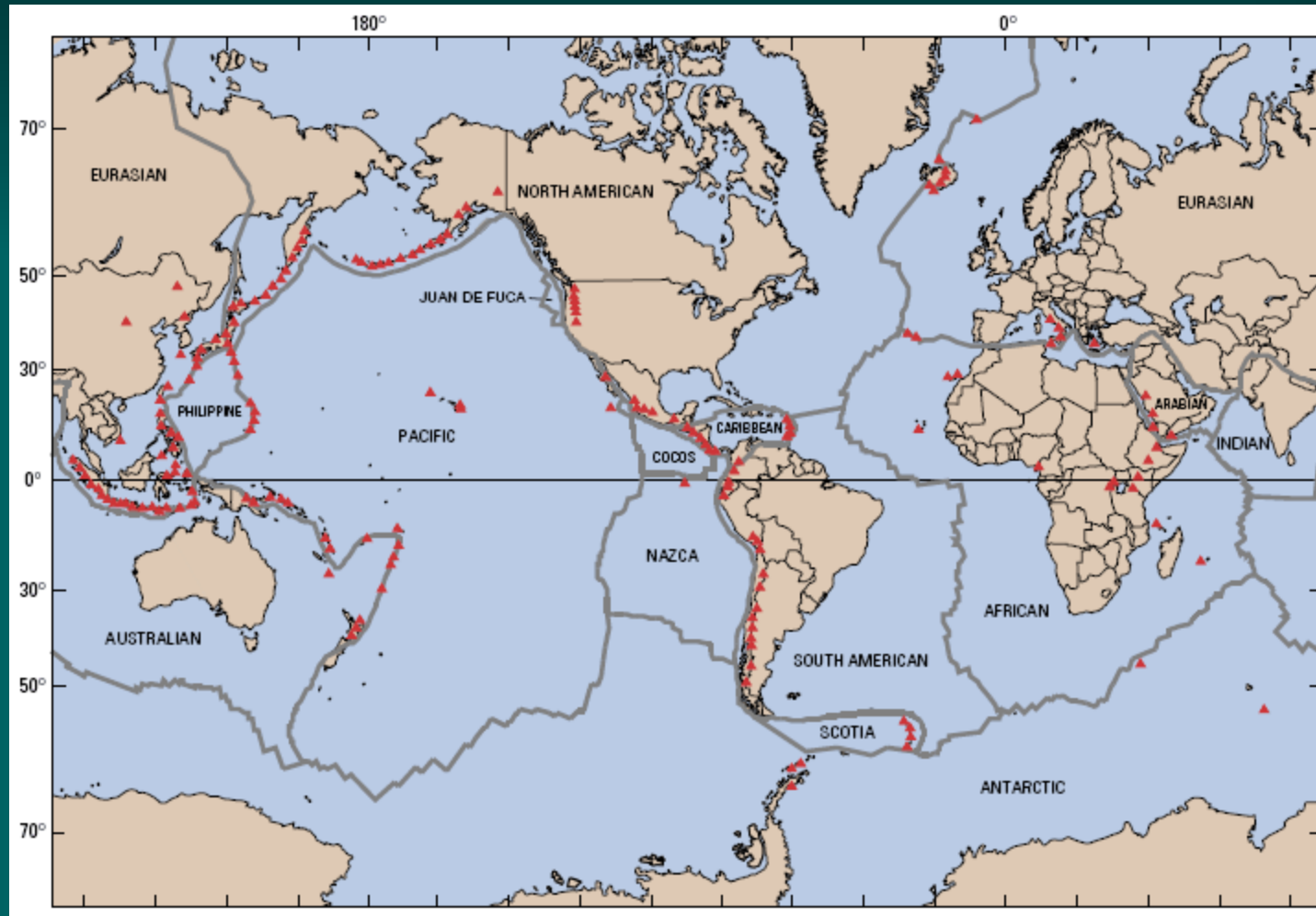
The Geysers, Calistoga, CA

Photo credit: National Renewable Energy Laboratory

In U.S., much done on public land = cheap

Very little potential in east and mid west





World wide distribution of volcanos, hot springs, etc.

Japan, Iceland, New Zealand big users of geothermal.

How do People in Iceland Heat Their Homes?

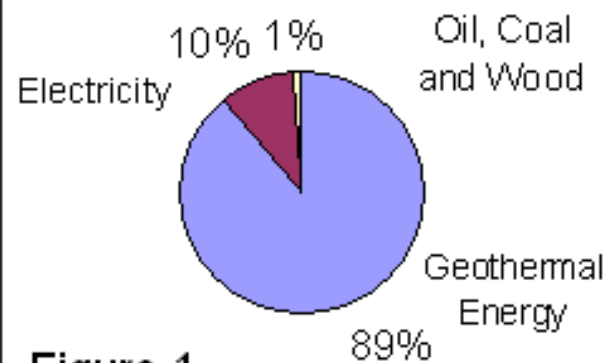
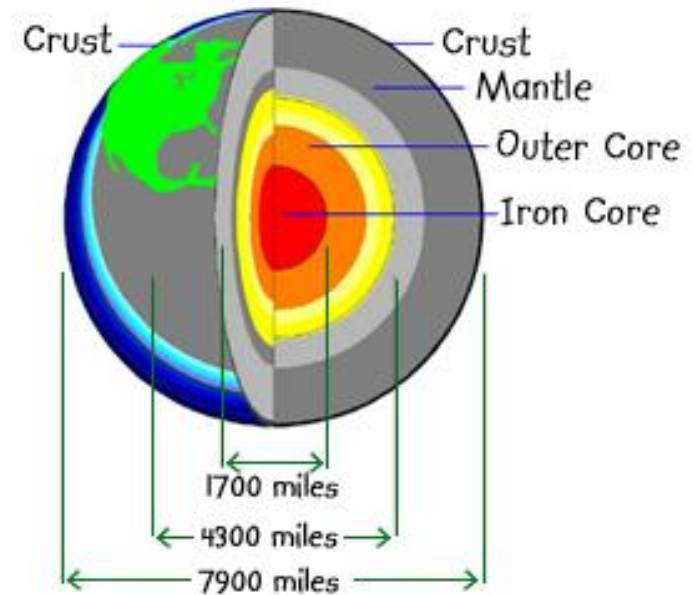
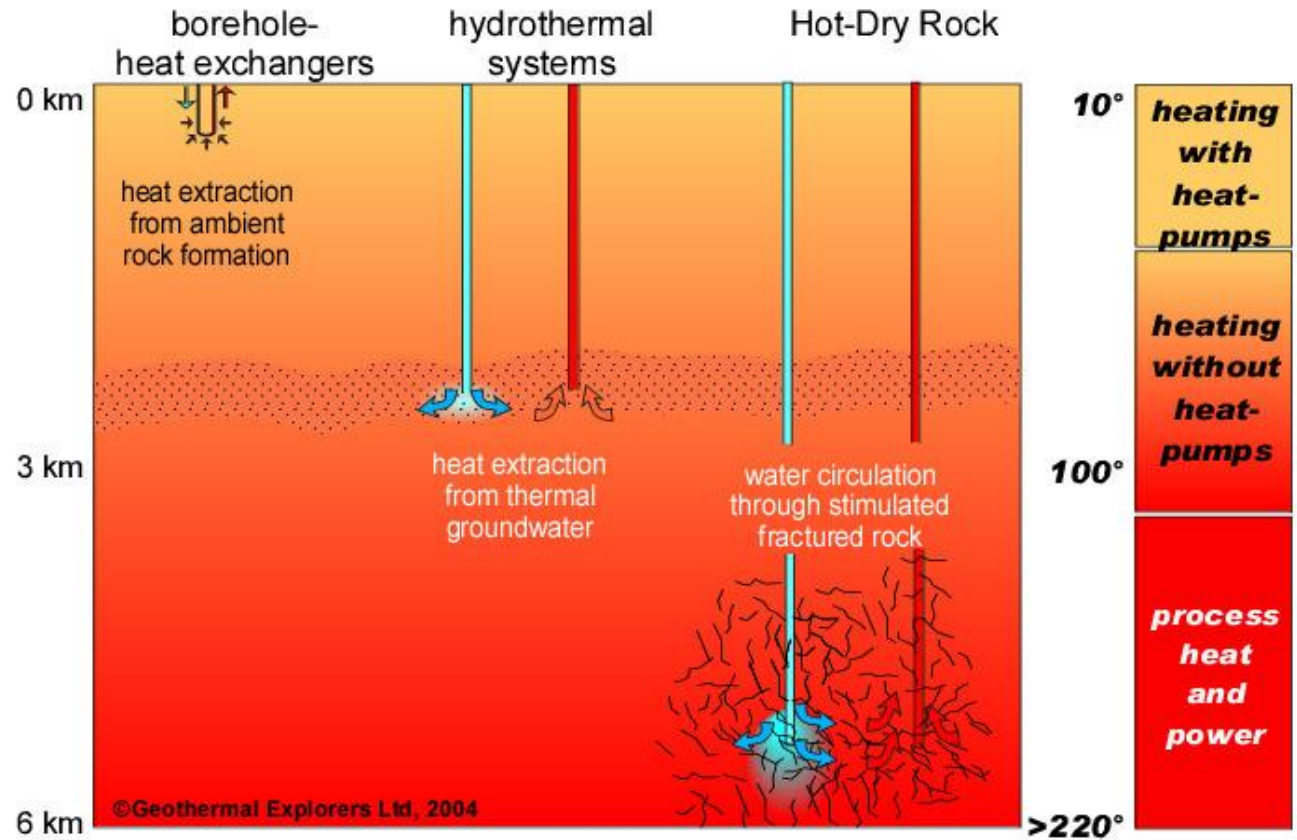


Figure 1

Cross Section of the Earth



Although hot areas near surface are limited, the earth is hot everywhere if you go down far enough.



Bright idea!? – drill deep enough to find heat. Since rock is a poor conductor of heat, set off a big bomb to crack the rock and allow heat to move – then pump down water to make steam.

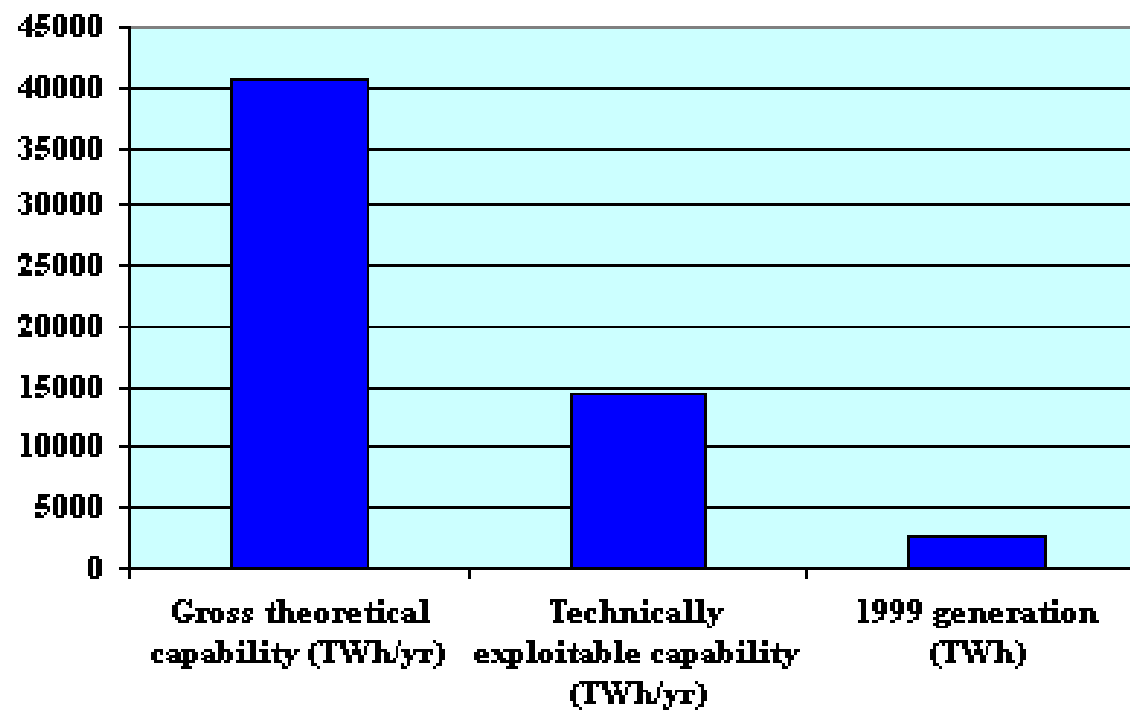
Hydropower in More Details



Hydropower = dams

Not much used in world,
why??

Figure 7.3: Hydropower - world gross theoretical/technically exploitable capability and 1999 generation (all schemes)



Almost all mega-dams are being built in countries with less than 50% dependence on hydropower as a source of electricity.

More than half of the world's 36,000 dams are located in China



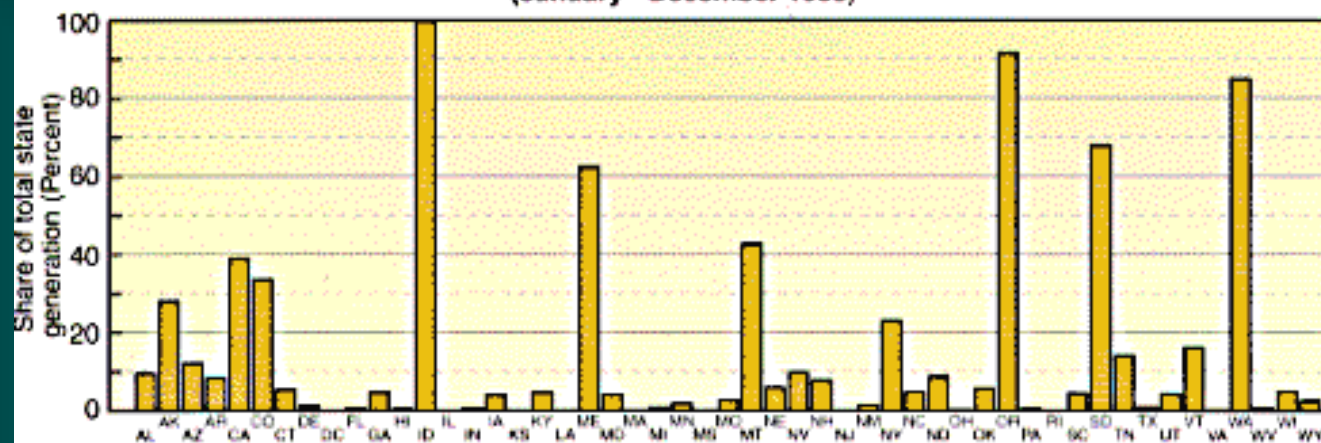
Dependence on hydropower, electricity generated by water systems and dams, 1992 percentages

- 100%
- 80 to 99%
- 50 to 80%
- 25 to 50%
- Less than 25%
- No hydropower
- No data

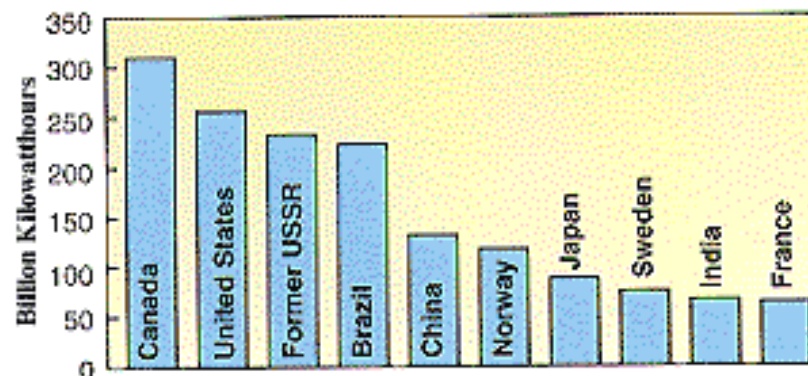
Norway,
Zambia,
Ghana big
users

21 million people in India have been displaced by dams in the last 40 years.

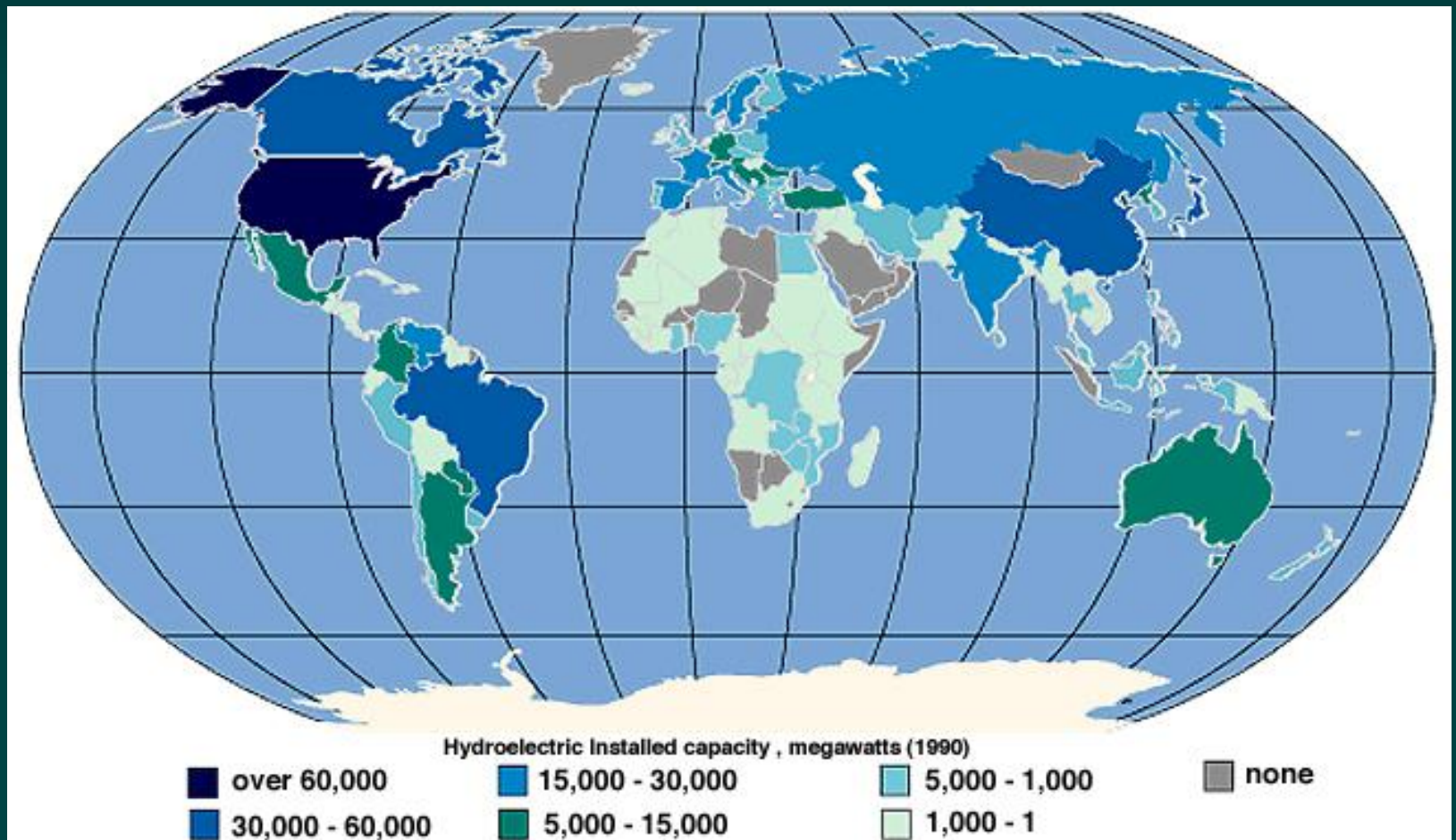
Electric Utility Hydroelectric Net Generation by State (January - December 1995)



Top Hydroelectric Generating Countries, 1992



EIA, Annual Energy Review 1994. July 1995, Table 11.20.
Hydropower provides 19% of the world-wide generation of electricity (1992)



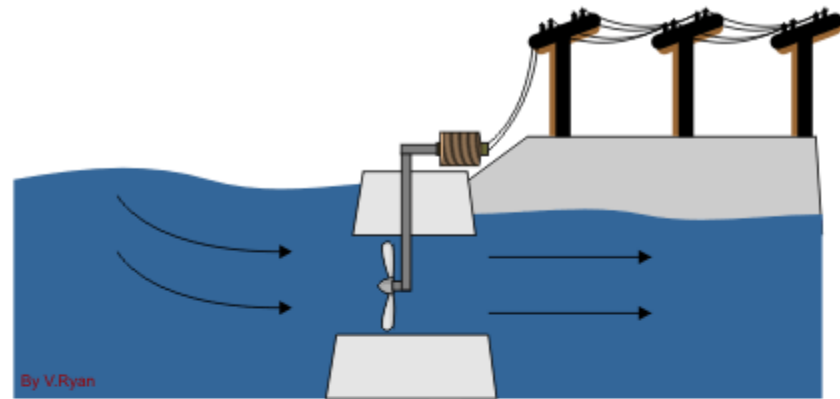
Most unused hydropower in U.S. = Alaska,
 In World = Canada, Russia

Problems with hydroelectric

- Location = unused rivers are in extreme north or low population areas
- Competition with recreational uses (U.S.) and environmental concerns
- Hard to build dams in populated river valleys
- Siltation of dams – limited life.

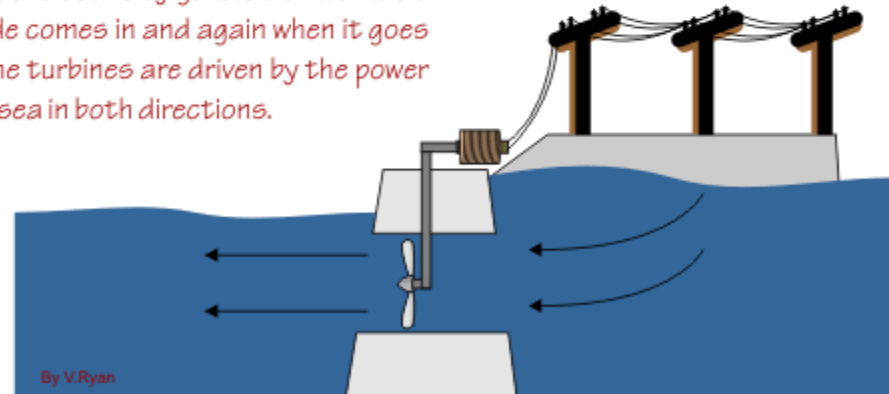
Tidal Power

1. In areas of large tides
2. Anywhere – build offshore dam

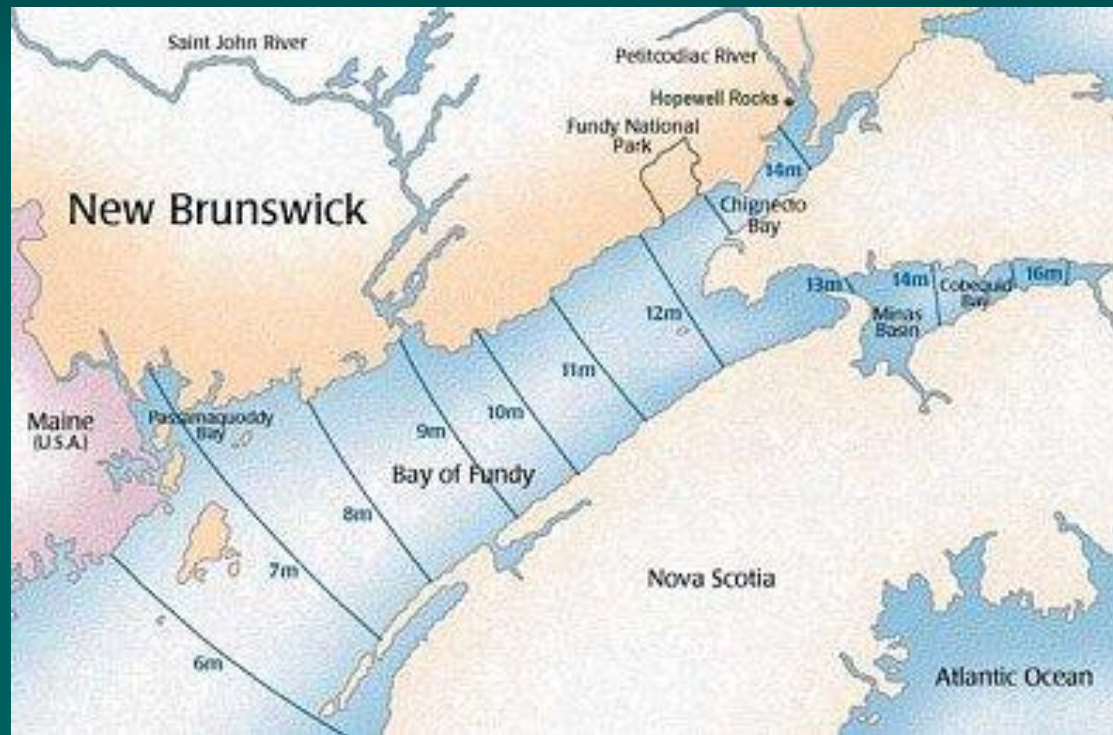


TIDE COMING IN

This tidal electricity generation works as the tide comes in and again when it goes out. The turbines are driven by the power of the sea in both directions.



TIDE GOING OUT



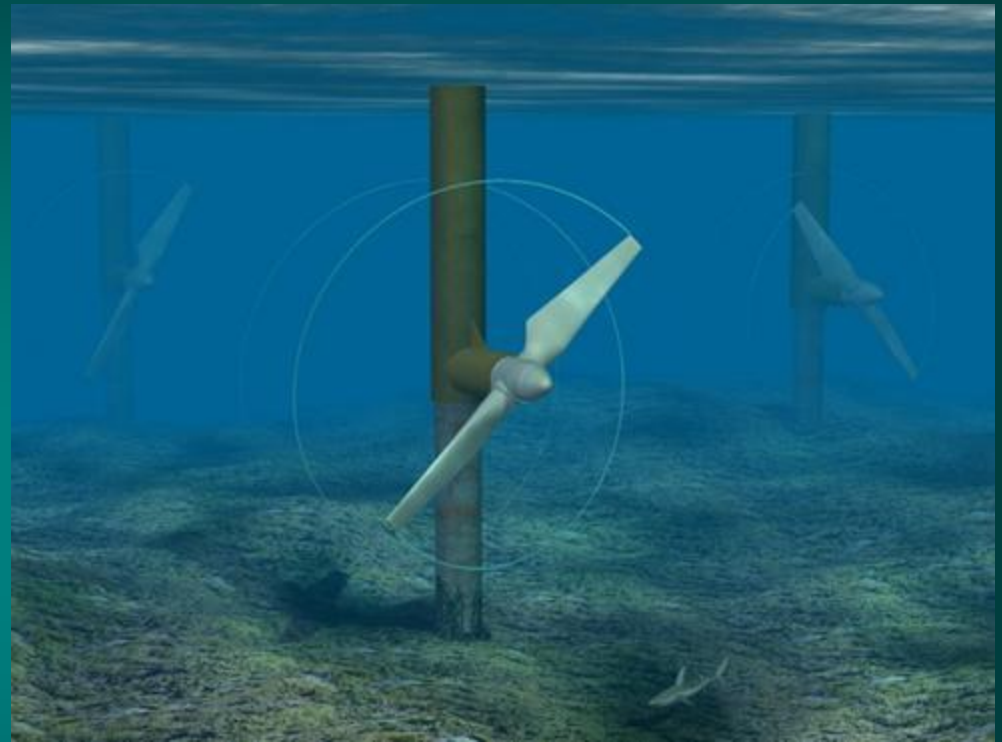
Highest tides in the world = Bay of Fundy
16 meters = 48+ feet!

Tidal power anywhere

1. No dam – but a turbine.

Problems:

1. Corrosion
2. Navigation
3. Appearance
4. Amount of energy available is low
5. Best tides are near poles – away from people.

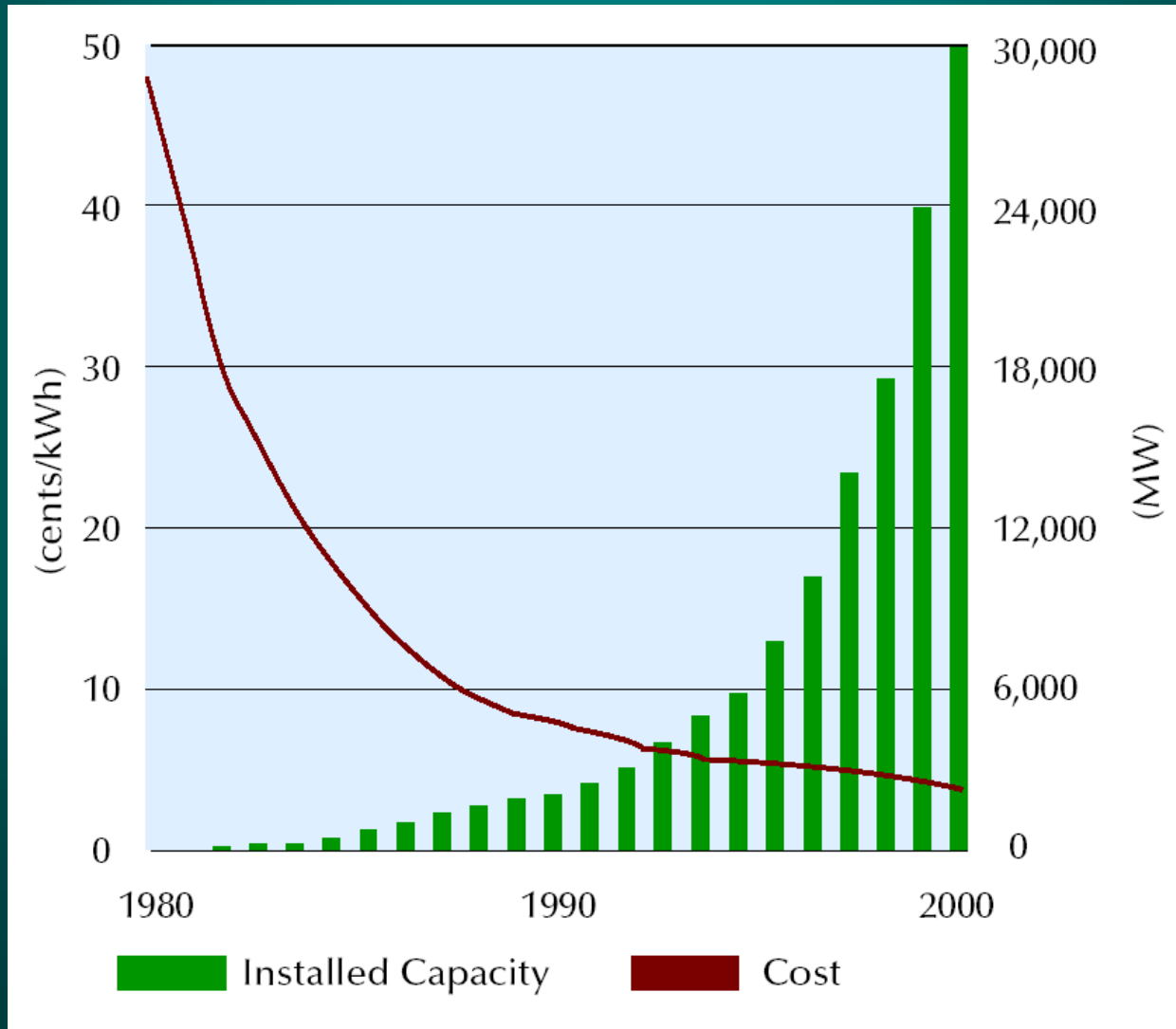


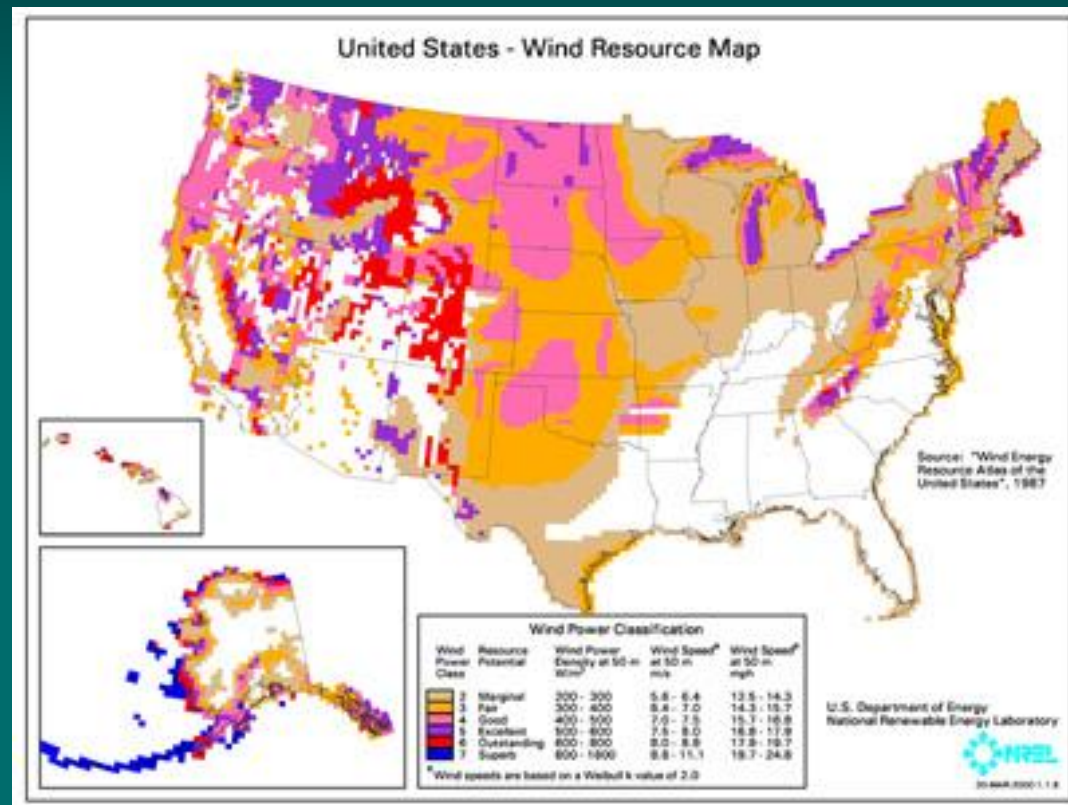
Wind Power in More Details

Banning Pass



Wind Power Generation

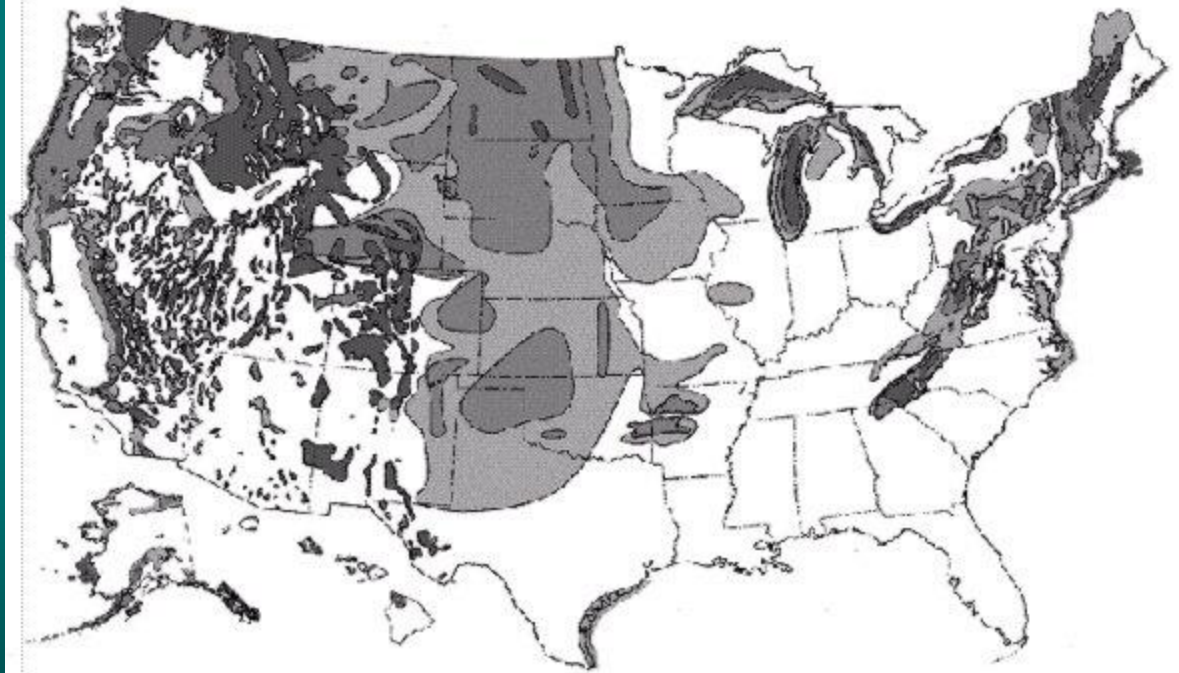




Best wind location = Aleutian Islands,
why no wind development there?

Wind Power Class	Wind Energy Resource Potential	Wind Power Density at 30 m [W/m ²]
3	Moderate	240-320
4	Good	320-400
5-7	Excellent	400+

Best U.S. localities
Midwest, mountains
And coastal areas.



Wind Resource Areas In California

Source: CEC, WPRS 2003





Netherlands =
coastal
development



England = off shore

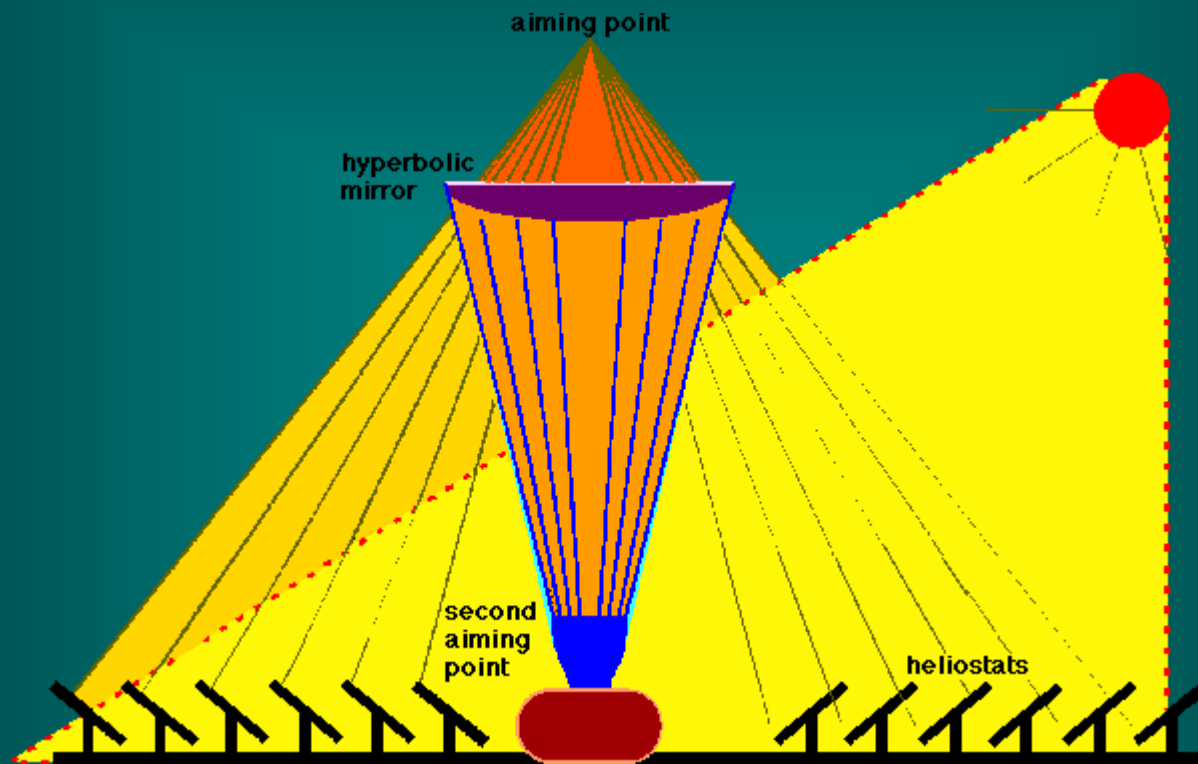
Wind energy problems

- Location – near population center
- Bird migration –
- Visual
- Must be coupled with other sources of electricity (intermittent supply)

Solar Energy in More Details

1. Solar Thermal

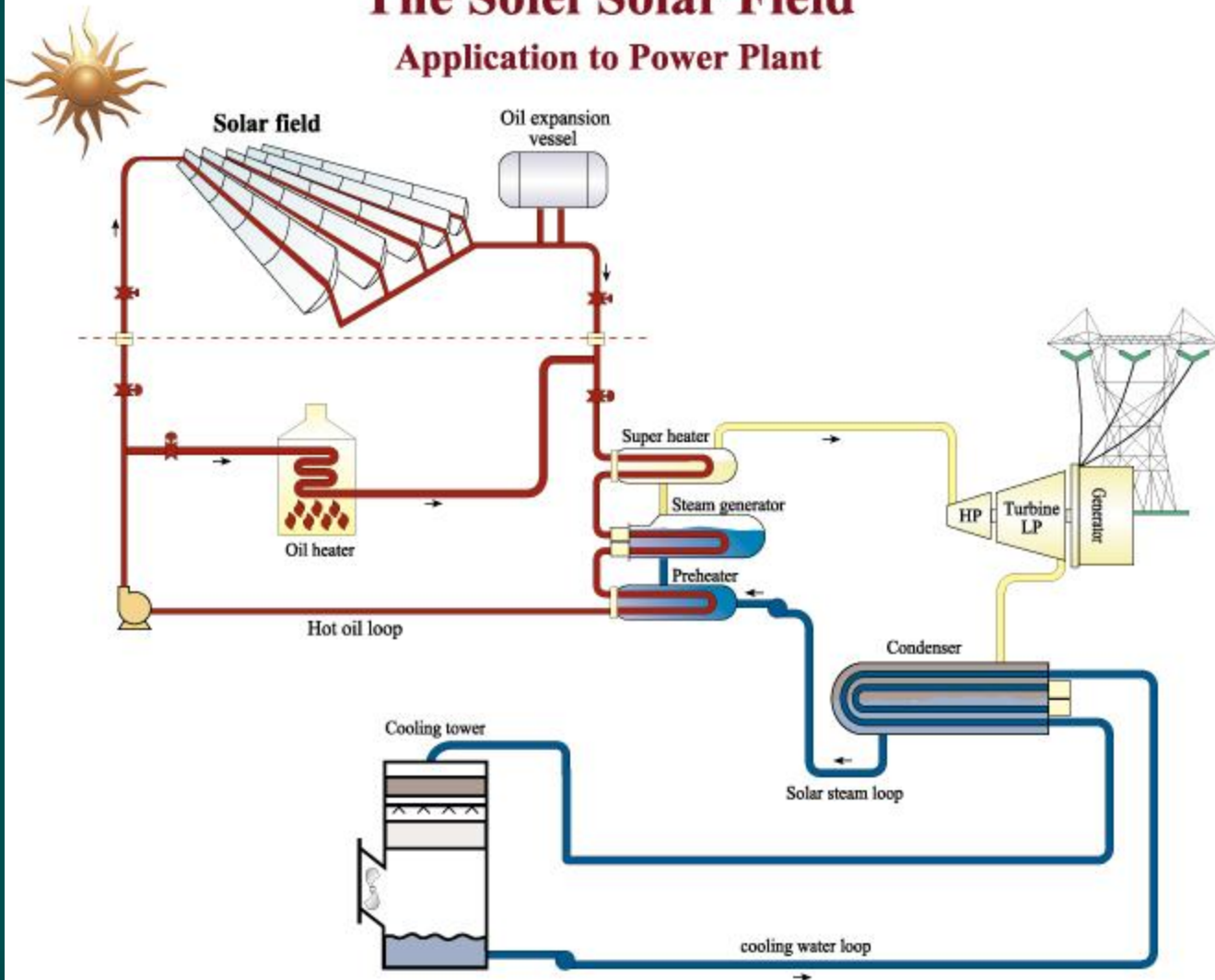




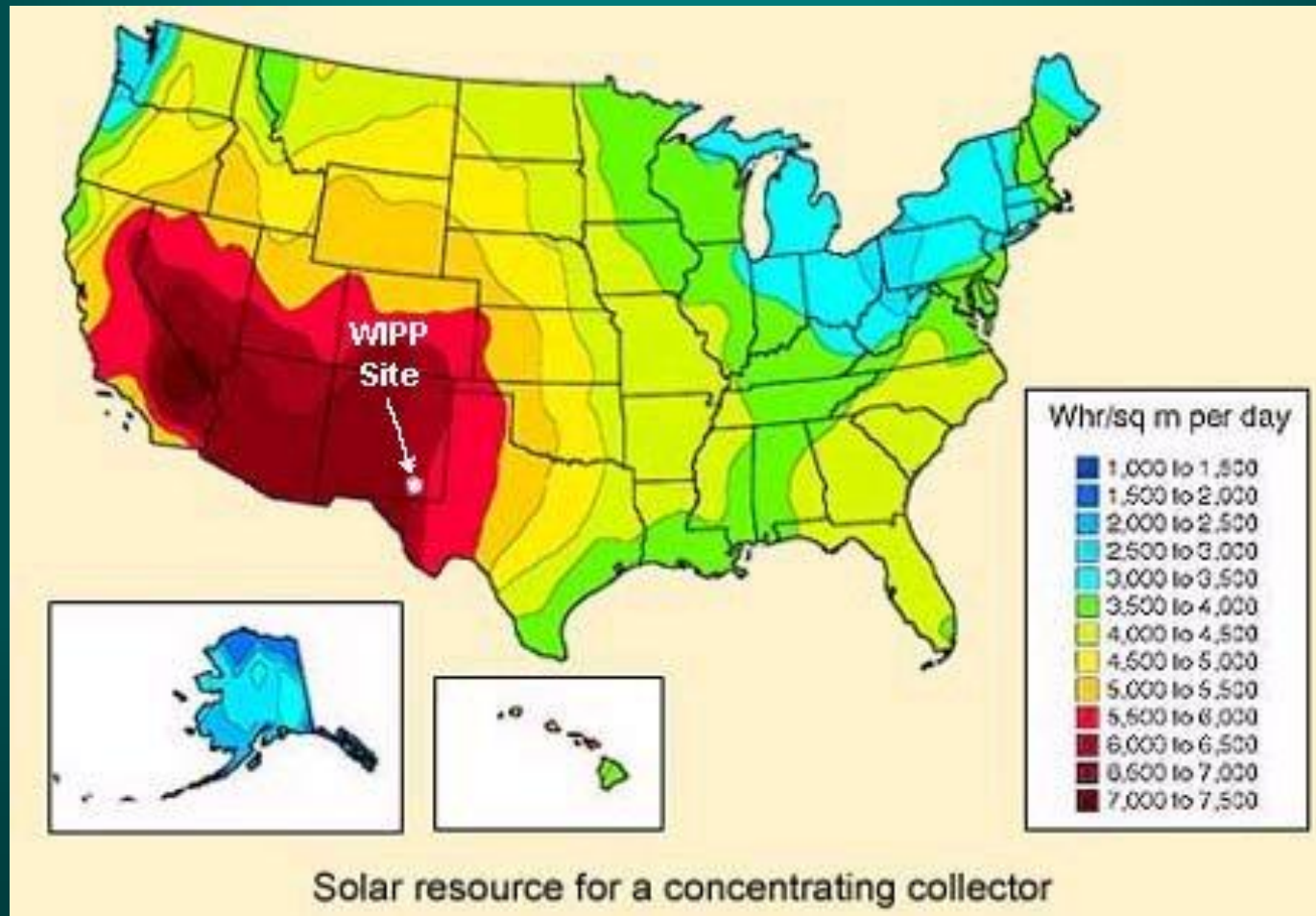
At focal point = heat liquid – steam
to turn turbine

The Solel Solar Field

Application to Power Plant



Solar Resource for a Concentrating Collector



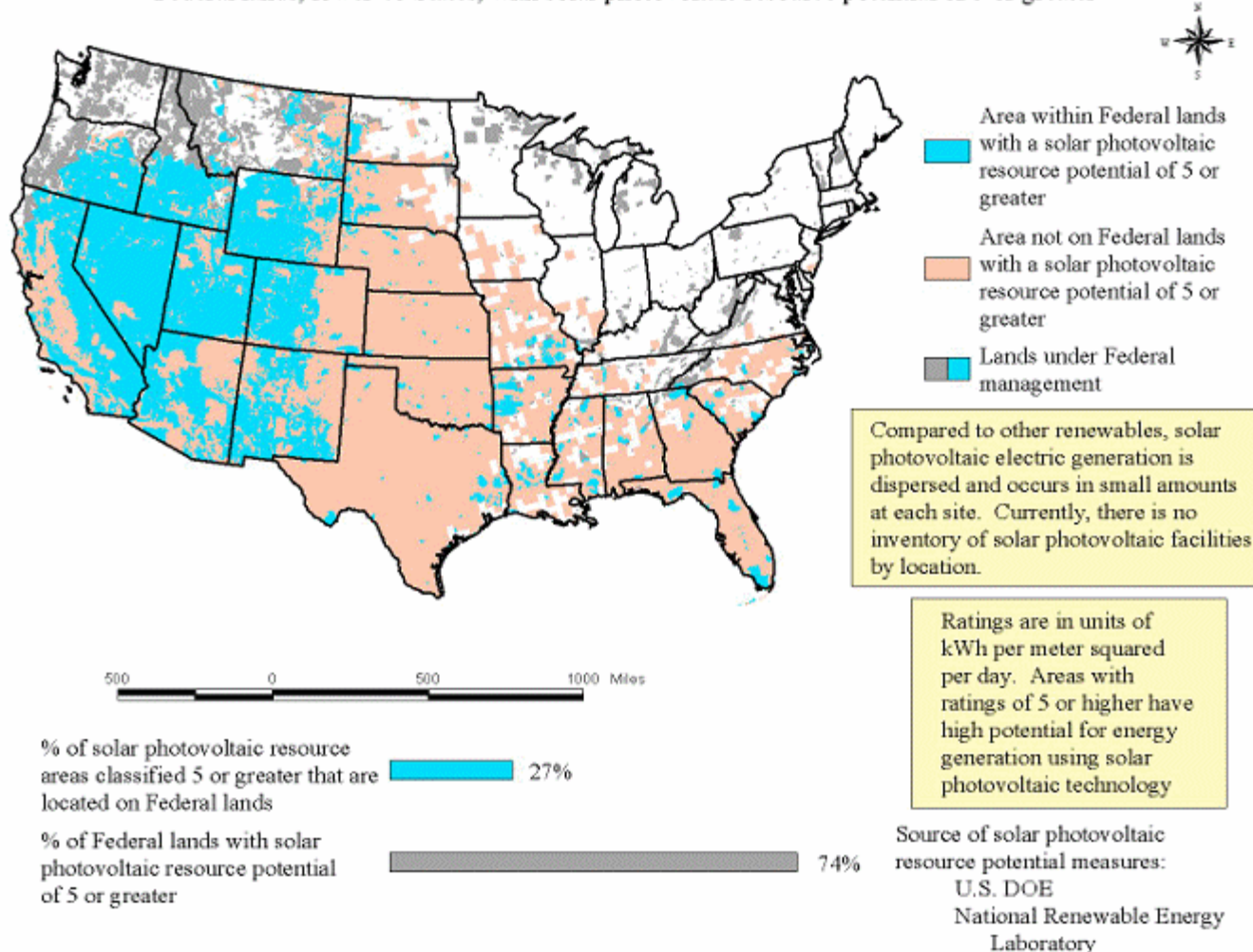
Big Plants

World's largest concentrating solar thermal power stations

Capacity (MW) 	Technology type 	Name 	Country 	Location 	Notes 
354	parabolic trough	Solar Energy Generating Systems	 USA	Mojave desert California	Collection of 9 units
75	parabolic trough ^[61]	Martin Next Generation Solar Energy Center ^[62]	 USA	near Indiantown, Florida	Expected Late 2010
64	parabolic trough	Nevada Solar One	 USA	Las Vegas, Nevada	
50	parabolic trough	Andasol 1	 Spain	Granada	Completed November 2008
20	solar power tower	PS20 solar power tower	 Spain	Seville	Completed April 2009
11	solar power tower	PS10 solar power tower	 Spain	Seville	Europe's first commercial solar tower

2. Solar Photovoltaics

Federal lands, lower 48 States, with solar photovoltaic resource potential of 5 or greater



'hard' vs 'soft' energy paths

Hard =

1. Big plants
2. Centralized production

Soft =

1. Decentralized
2. units per household

Big Plants



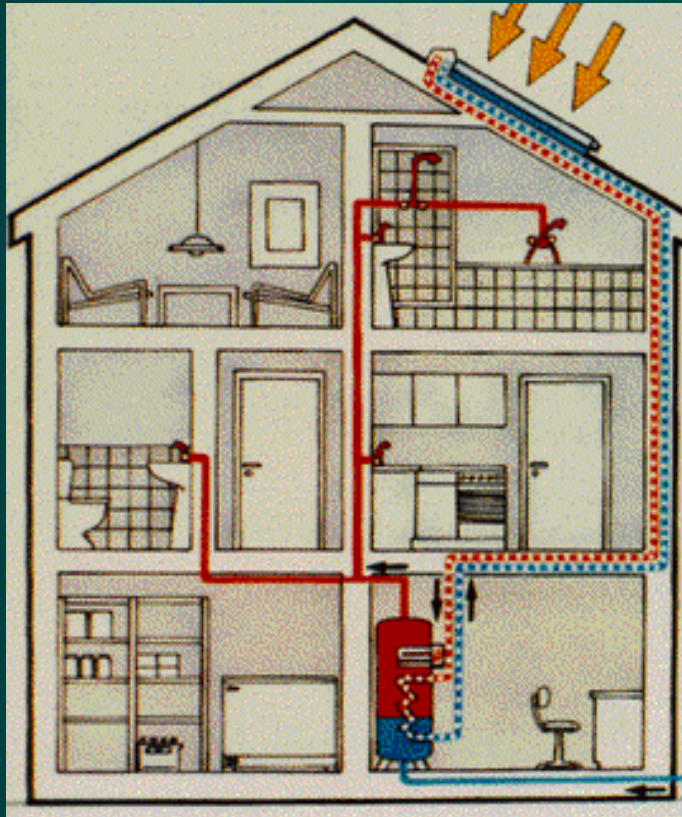
Decentralized

Energy efficient house; wind power on roof. Solar panels for heat and electricity.

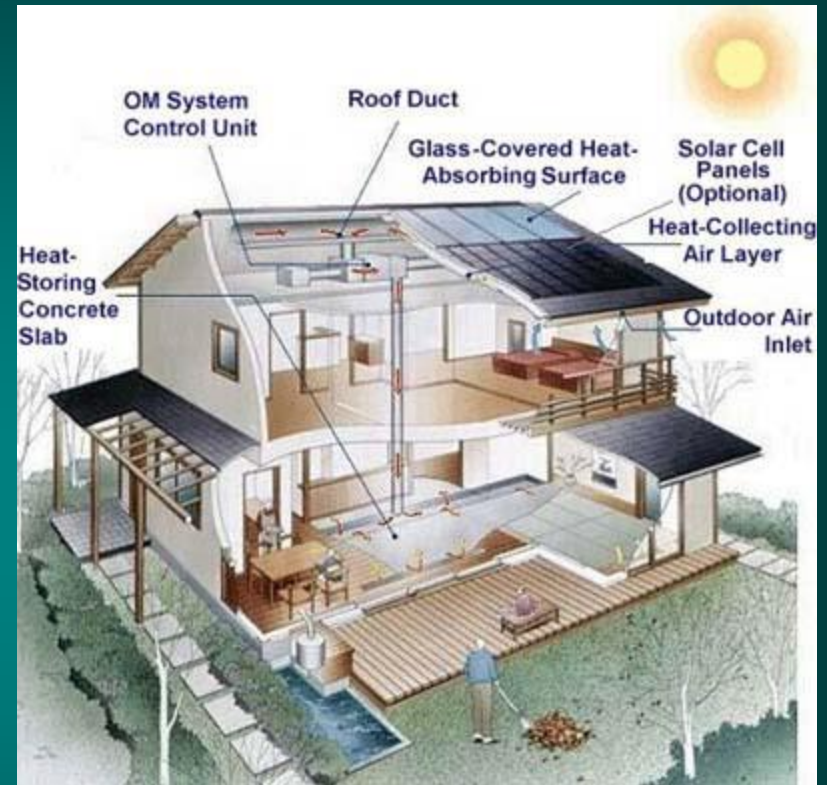




Solar electricity generation



Solar water heating



solar air heating

Solar house problems

- The Los Angeles air = smog
- Retrofitting- very expensive
- Hard for big hotels, Walmarts, etc.

Solar house economics

- Add \$16,000 to price of house
- Pay back - \$1500 per year in energy costs
- 15 years to break even

Federal tax incentive; 40% of investment can be written off. Discontinued in 1986