Thoughts on Global Energy

Primary Sources of Energy

- Fossil
  - Oil
  - Coal
  - Gas
- Nuclear
  - Fission
  - Fusion
- Solar
  - Hydropower
  - Biomass
  - Photovoltaic
  - Solar thermal
  - Wind
- Geothermal

Non Renewables

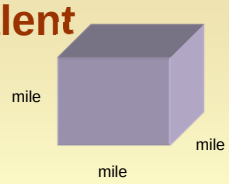
Renewables

How much do we consume?

- Worldwide consumption rate (per second)
  - 37,000 gals of oil
  - 150 tons coal
  - 3.2 Mcf gas
- Units must have come from a veritable tower of Babel!
  - Therms (or BTUs), Quads, MWh, Barrels (bbl), Tons, Tcf …
- Lack of uniform units presents a serious impediment to meaningful discussion
- Further confusion caused by the necessity to use millions, billions, trillions, and quadrillions of whatever

Crane and Kinderman, 2000

Idea: Cubic Mile of Oil Equivalent



- A unit that can be visualized
- 1 cmo ≅ 1 trillion gallons of oil
- Also, 1 cmo ≅ current annual worldwide oil consumption

1 cmo is equivalent to:

- 26 Billion (10^9) bbl oil
- 6 Billion (10^9) tons of hard coal
- 49.5 Trillion (10^{12}) KWh electricity
- 153 Quadrillion (10^{15}) Btu (Quads)
  - 1 Btu ≅ energy from a burning match

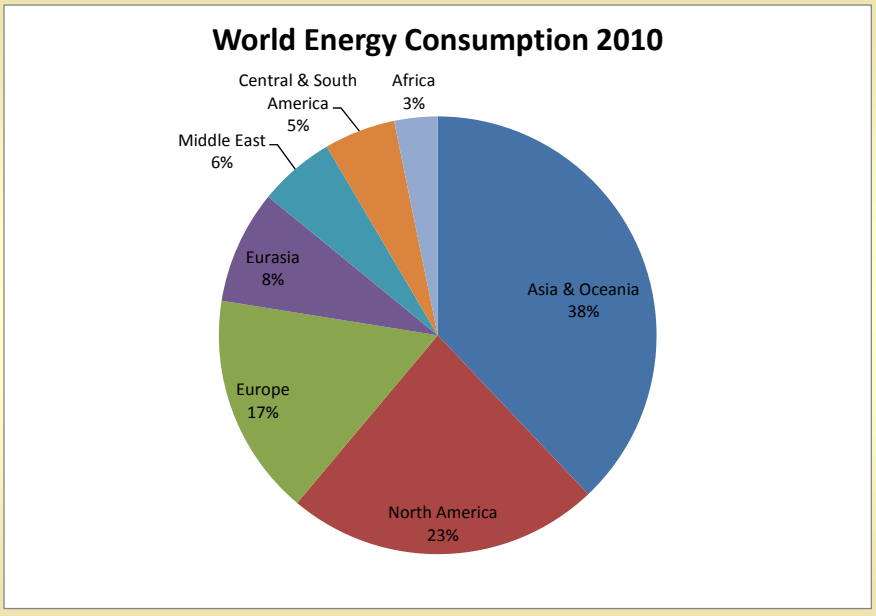
Crane and Kinderman, 2000

Primary Sources of Energy in cmo (2012)

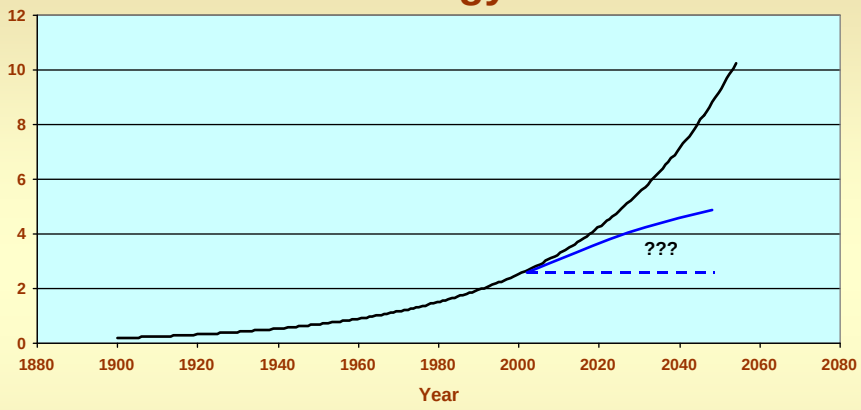
Fossil	**3.02**	
Oil		1.17
Coal		1.04
Gas		0.81
Nuclear	**.14**	
Fission		.14
Fusion		
Solar	**.29**	
Hydropower		.22
Biomass		.03
Photovoltaic		.01
Solar thermal		<.005
Wind		.03
Geothermal	**.004**	
Total	**3.46**	

3.02 out of 3.46 cmo or 87% from fossil sources

Crane and Kinderman, 2000



Historic Trend in Energy Use



- Doubling every 27 years
- Increases in population and living standards drive the exponential increase in energy consumption
- By 2050, the world will need between 2 and 7 additional cmo's!!!
  - Where will this come from??

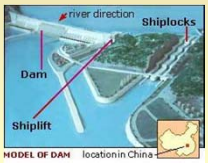
Switching to Non-Fossil Energy

- What do we do?
  - Hydro
  - Nuclear
  - Wind
  - Biomass
  - Photovoltaic

Let's estimate what it would take to get 1 cmo from any of these sources by 2050

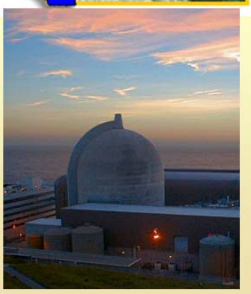
Crane and Kinderman, 2000

Hydroelectric – to get 1 CMO



- Three Gorges Dam is 18.2 GWe
  - 9 times size of Aswan Dam
  - $30 billion (US)
  - 15 years (1994 to 2009)
  - Displaced 1 million people from homes
- 18.2 GWe is .003 CMO!
- Need over 300 such dams to get 1 CMO!
  - By 2050, need 1 completed every 2 months

Nuclear – to get 1 CMO



- Diablo Canyon has two reactors of ~1100 MW each
  - Operating for 15 years
  - Studies on earthquake survivability
  - One of two operating nuclear plants in CA
- Provided 1.72×10^7 MW-hrs of electricity in 2003
- 0.00039 CMO
- Need over 2500 such facilities to get 1 CMO!
  - By 2050, need ~5 facilities completed every month

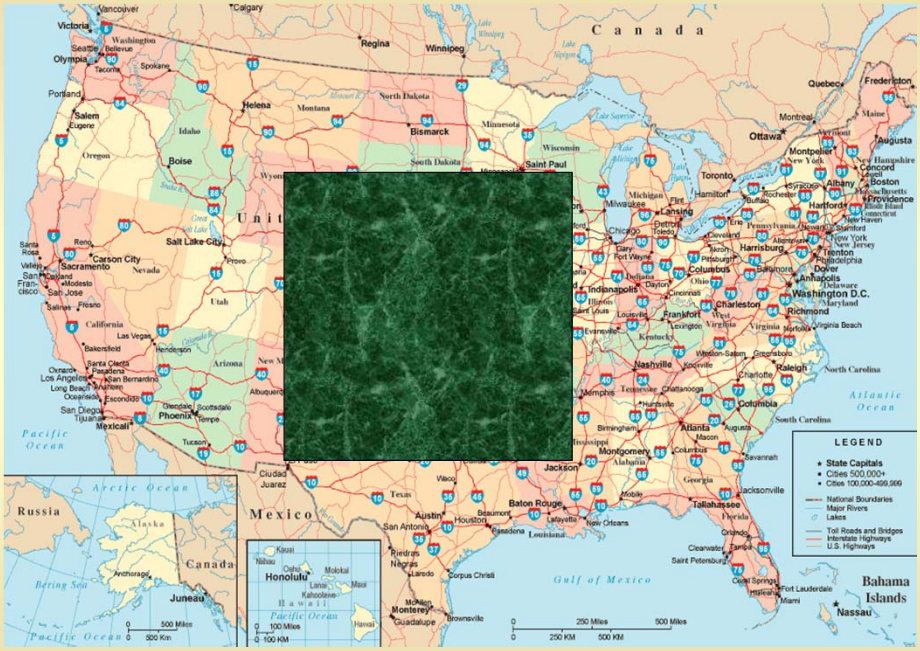
Wind – to get 1 CMO

- Denmark is putting 2 MW windmill/turbines into the North Sea
  - 64 m high at hub, 74 m rotor diameter (210 ft high at hub, 243 ft diameter)
- 10 turbines provided 89×10^3 MW-hrs of electricity for Copenhagen
- 2×10^{-7} CMO per windmill
- Need over 5 million such facilities to get 1 CMO!
  - By 2050, need over 300 such large windmills completed every day!
  - Problems for 2/3 of time wind is not right

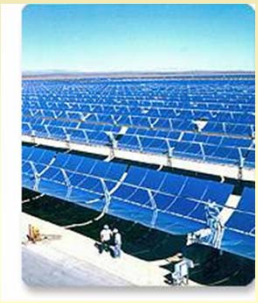
Biomass – to get 1 CMO

Biomass Power Plant - Photo credit: U.S. Department of Energy, Energy Efficiency & Renewable Energy Network (EREN)

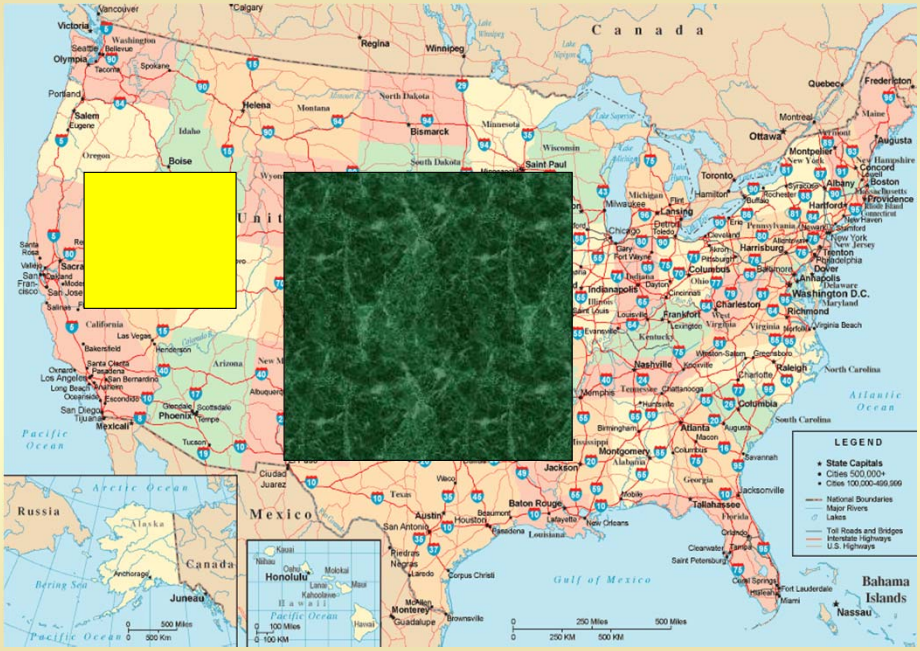
- Average of 15 tons of biomass per acre per year (in U.S.)
- Average energy content of 7500 Btu/lb
  - Small power plants with low conversion efficiency (~20%)
  - Extra ~75% fossil fuel needed to convert to liquid fuels
- 1.5×10^{-9} CMO per acre (not including efficiency of conversion)
- Need over 680 million acres to get 1 CMO!
  - ~1 million square miles, or a square 1000 miles by 1000 miles
  - Impact on food prices (especially meat, wheat, etc.)



Photovoltaic – to get 1 CMO



- Quite expensive to get electricity
- Not bad for hot water
- Average 80 kW-hr/m^2 of power per year
- 1.8×10^{-12} CMO per m^2
- Need over 200,000 square miles of photovoltaics to get 1 CMO!
  - A square 450 miles by 450 miles



This analysis was for 1 CMO by 2050!

The world may need 2-7!

We have an enormous task ahead of us…

What about fossil fuel options?

Coal – to get to 1 CMO

- IPP plant near Delta, UT
  - Two 975 MW facilities
  - Each burns ~1 million pounds/hr of coal
  - All converted to DC power and shipped to the LA basin, then reconverted to AC power
- Assume 36% efficiency, 97% uptime
- 16.6 million MW-hrs of power per year
  - .00103 CMO/yr
- Need 968 such facilities by 2050 to get 1 CMO!
  - 19 plants per year for 50 years, or
  - 1.6 plants per month

This is why we use fossil energy!

- Most projections show that the percentage of fossil fuel use will stay relatively constant
  - We still have to build a lot of facilities!
  - Rapid building in China
  - Construction prices have risen 25-30%
- Increased renewables will keep pace with increased energy use and only increase slightly as a percentage of the overall energy use

What Should Be Done?

- Define goals
  - Cost?
  - Environment?
  - National security?
  - Reduce dependence on unstable/unfriendly countries?
- Continue expanding renewable energy using economic judgment
  - How much extra are people willing to pay for fossil fuel alternatives?
- Make fossil fuel use as clean and efficient as possible
  - Rise in natural gas costs -- home heating costs rise
  - Options for cleaner coal – IGCC, oxyfiring, CO_2 sequestration
  - Alternate liquid fuels – biodiesel, (ethanol), coal-to-liquids, biomass-to-liquids
- Nuclear
  - Projected fuel shortage in ~30 years without breeder technology
  - Wastes from breeder technology much smaller
    - handling large quantities of plutonium is a potential terrorist threat

What Else Should We Do?

- Don't make rash statements or decisions, such as:
  - Eliminate dependence on foreign oil
  - Stop using fossil fuel
  - Require 50% of motor fuel from renewable sources
  - Require H_2 as a fuel for a specified fraction of energy
- Continue to search for economical renewable energy
  - Criteria for use of renewables
    - Must be economic without subsidies
    - Must not increase use of fossil fuels
    - Should not increase prices of other sectors (like food)
    - Must not create additional environmental problems
      - Depleted forest area
      - Oxygen-starved area in Gulf of Mexico at mouth of Mississippi River
- Increase use of unconventional oil
  - Oil sands, oil shale, heavy oil
  - Coal conversion to liquid fuels