



#### 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







# 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  $1.72 \times 10^7$  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<sup>3</sup> MW-hrs of electricity for Copenhagen
- 2 × 10<sup>-7</sup> 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 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 $1.5 \times 10^{-9}$ CMO per acre (not including efficiency of conversion) CMO!

- Need over 680 million acres to get 1
- ~1 million square miles, or a square 1000 miles by 1000 miles Impact on food prices (especially meat,
- wheat. etc.)









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

# 16.6 million MVV-r .00103 CMO/yr

- Need 968 such facilities by 2050 to get
- 1 CMO!
- 19 plants per year for 50 years, or1.6 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 (1 plant completed per week!!!)
  - 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 dependent
- Reduce dependence on unstable/unfriendly countries?
   Continue expanding renewable energy using economic judgment
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   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<sub>2</sub> sequestration
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     Alternate liquid fuels biodiesel, (ethanol), coal-to-liquids, biomass-toliquid fuels – biodiesel, (ethanol), coal-to-liquids, biomass-to-
- liquids
  - 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

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