GLOBAL ENERGY ISSUES AND ALTERNATE FUELING

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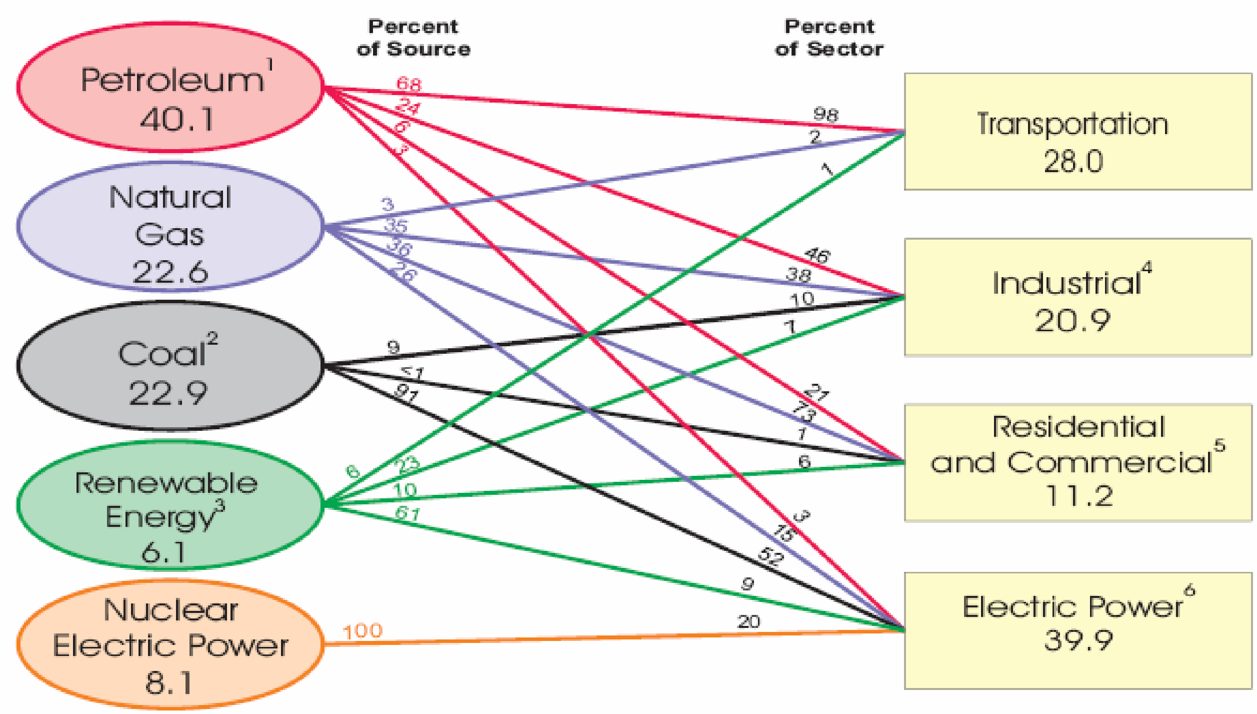
US Uses about 100 Quad/year (1 Q = 10^{15} Btu)
World Energy Use: about 433 Q/yr

U.S. Primary Energy Consumption by Source and Sector, 2005
(Quadrillion Btu)



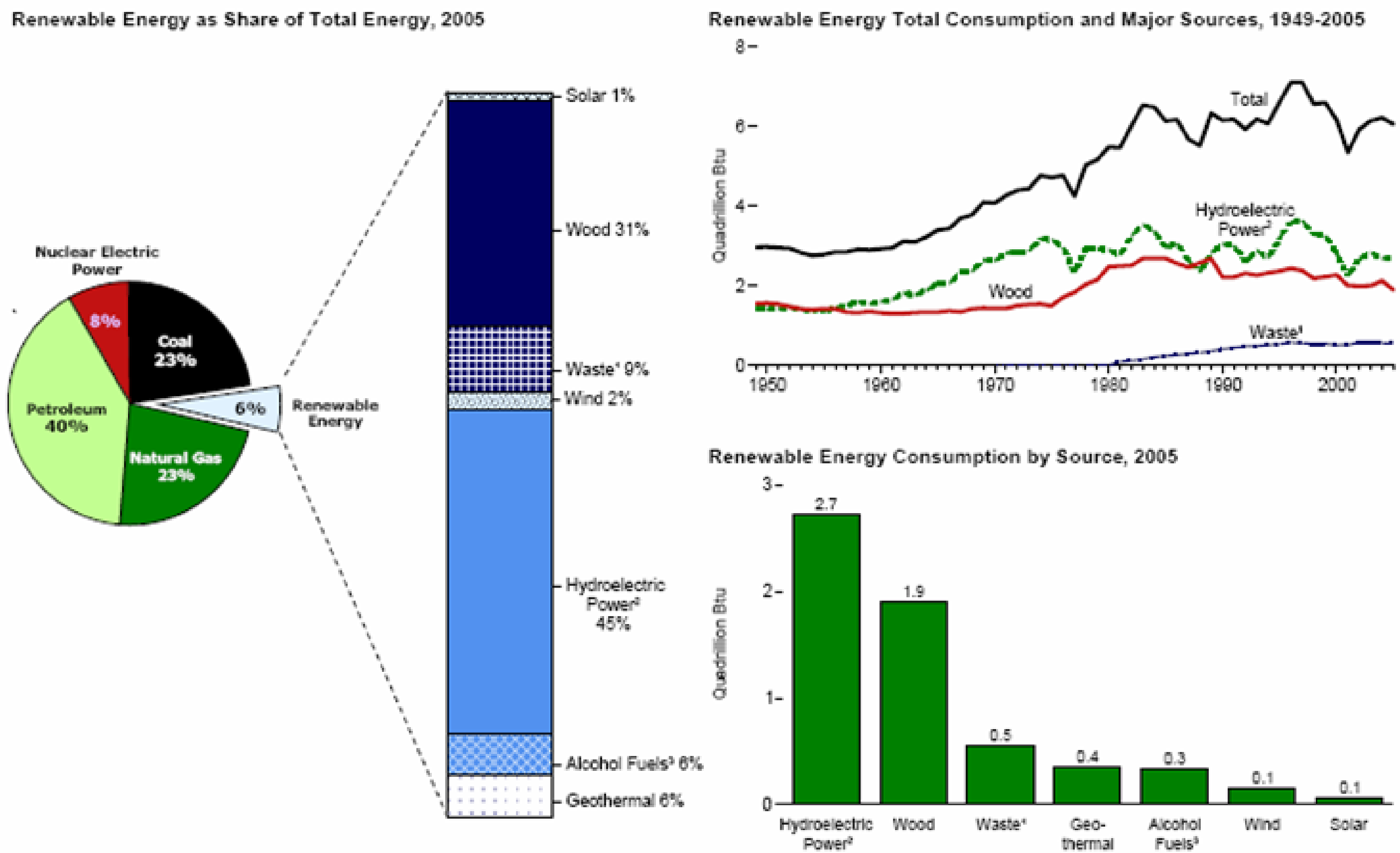
[1]Excludes 0.3 quadrillion Btu of ethanol, which is included in "Renewable Energy."
[2]Includes coal coke net imports.
[3]Conventional hydroelectric power, wood, waste, alcohol, geothermal, solar, and wind.
[4]Includes industrial combined-heat-and-power (CHP) and industrial electricity-only plants.
[5]Includes commercial combined-heat-and-power (CHP) and commercial electricity-only plants.
[6]Electricity-only and combined-heat-and-power (CHP) plants whose primary business is to sell electricity, or electricity and heat, to the public.

Note: Sum of components may not equal 100 percent due to independent rounding.

Source: Energy Information Administration, *Annual Energy Review 2005*, Tables 1.3 and 2.1b-2.1f.

http://www.eia.doe.gov/emeu/aer/pecss_diagram.html

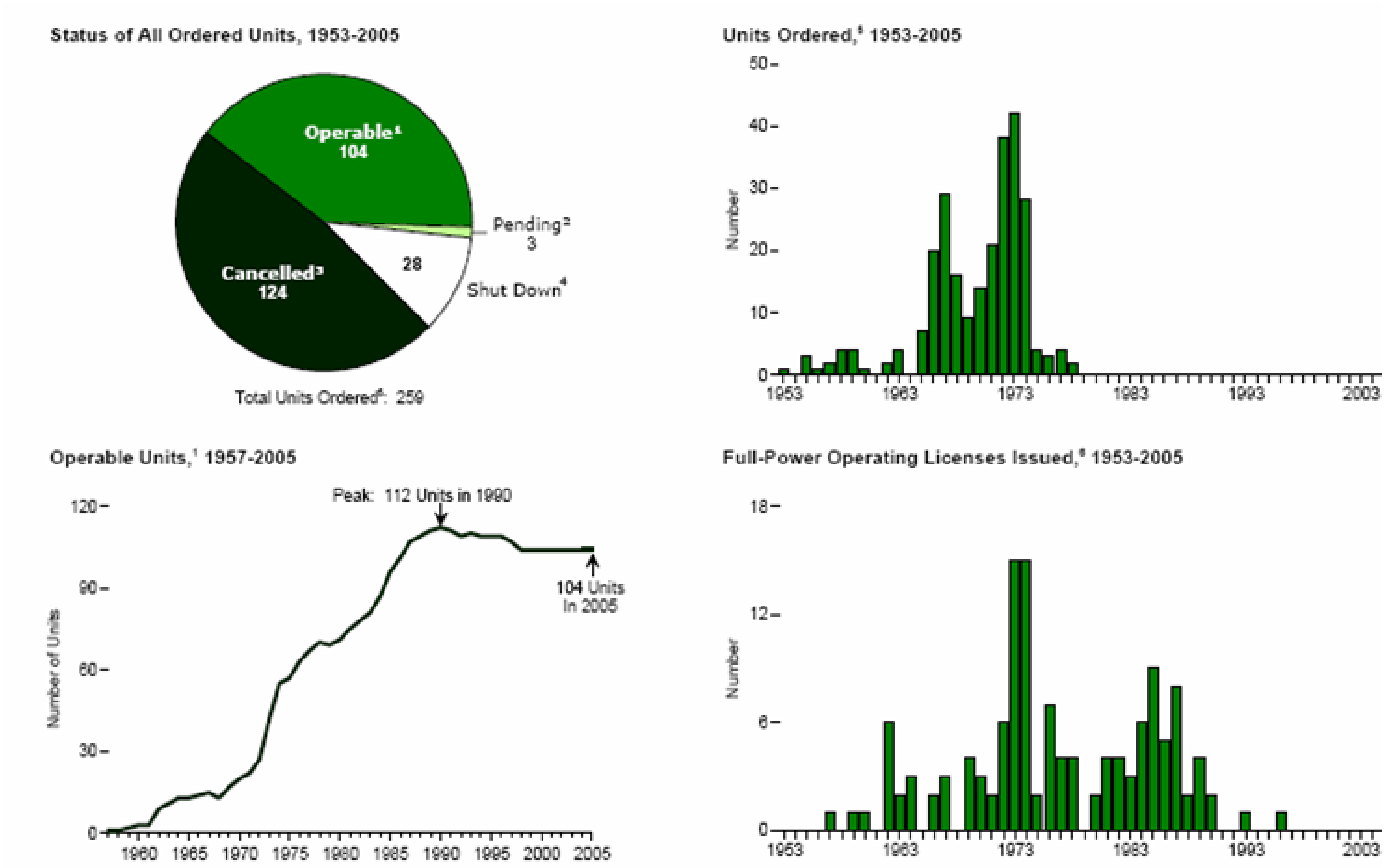
US Renewable Energy about 6%



[1] Municipal solid waste, landfill gas, sludge waste, tires, agricultural byproducts, and other biomass.
[2] Conventional hydroelectric power.
[3] Ethanol blended into motor gasoline.
Note: Because vertical scales differ, graphs should not be compared.
Sources: Tables 1.3 and 10.1.

http://www.eia.doe.gov/emeu/aer/pdf/pages/sec10_2.pdf

Nuclear Could Grow: Has Legacy Problems



[1] Units holding full-power operating license, or equivalent permission to operate.
[2] Bellefonte 1 and 2 and Watts Bar 2, where construction has been stopped indefinitely.
[3] Includes WNP 1; the licensee intends to request that the construction permit be cancelled.
[4] Ceased operation permanently.
[5] Placement of an order by a utility or government agency for a nuclear steam supply system.
[6] Issuance by regulatory authority of full-power operating license, or equivalent permission.
Notes: • Data are at end of year. • Because vertical scales differ, graphs should not be compared.
Source: Table 9.1.

http://www.eia.doe.gov/emeu/aer/pdf/pages/sec9_2.pdf

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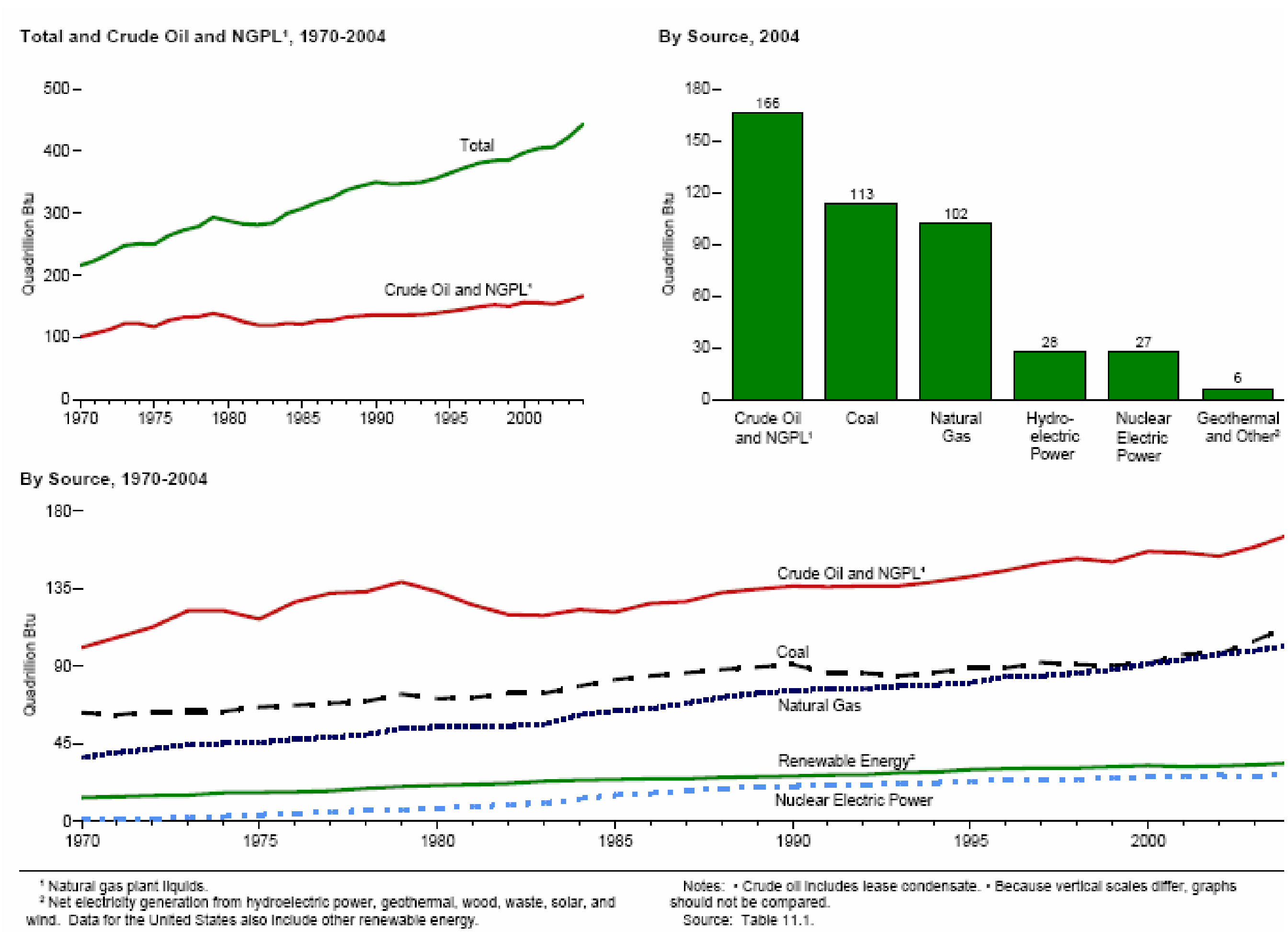
Energy Sources Primarily NonRenewable Hydrocarbon



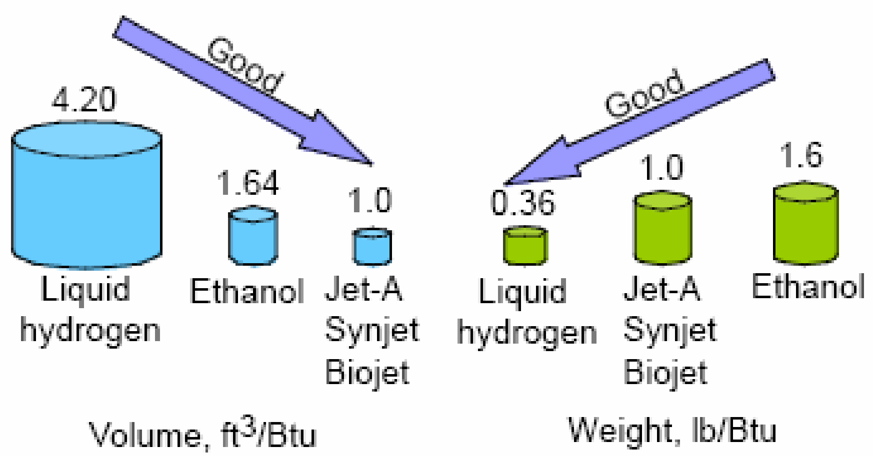
http://www.eia.doe.gov/emeu/aer/pdf/pages/sec11_2.pdf

www.nasa.gov

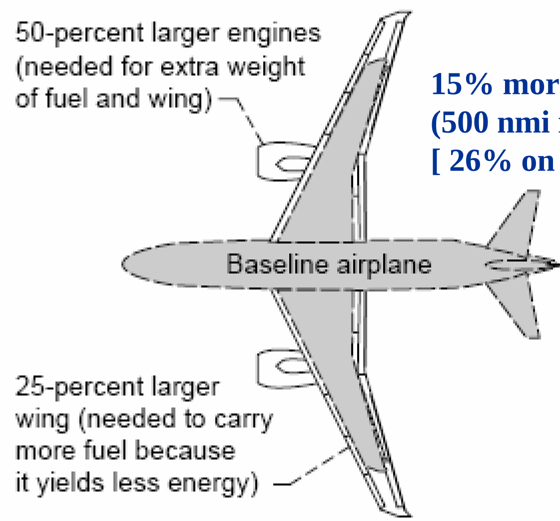
Notes

- Most renewable energy : wood and hydropower
- Small wind, solar and nuclear
- Stagnant nuclear growth, growing massive problem with aging reactor shutdown wastes and costs. Long lead time startup issues
- World Energy sources primarily hydrocarbon
- US: 76% Hydrocarbons only 6% renewable Energy distributed by 4 sectors (transportation, industrial, residential/commercial, electric)
- 28% US energy is transportation energy, 98% of which comes from petroleum
- Hydrocarbons emissions measured as CO2
- Fuels have major impact on aircraft design and use

Alternate Fuels Effect Aircraft Design

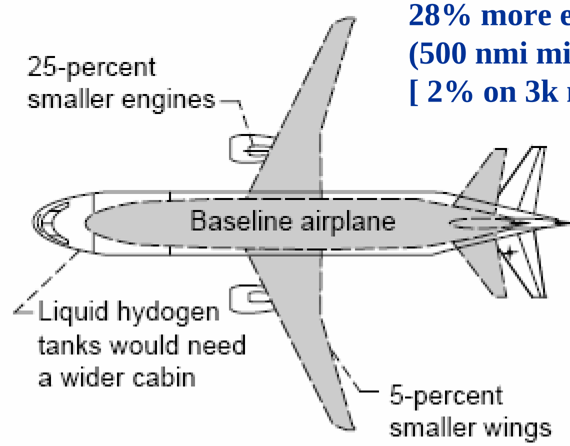


Ethanol



15% more energy use
(500 nmi mission)
[26% on 3k nmi mission]

Hydrogen



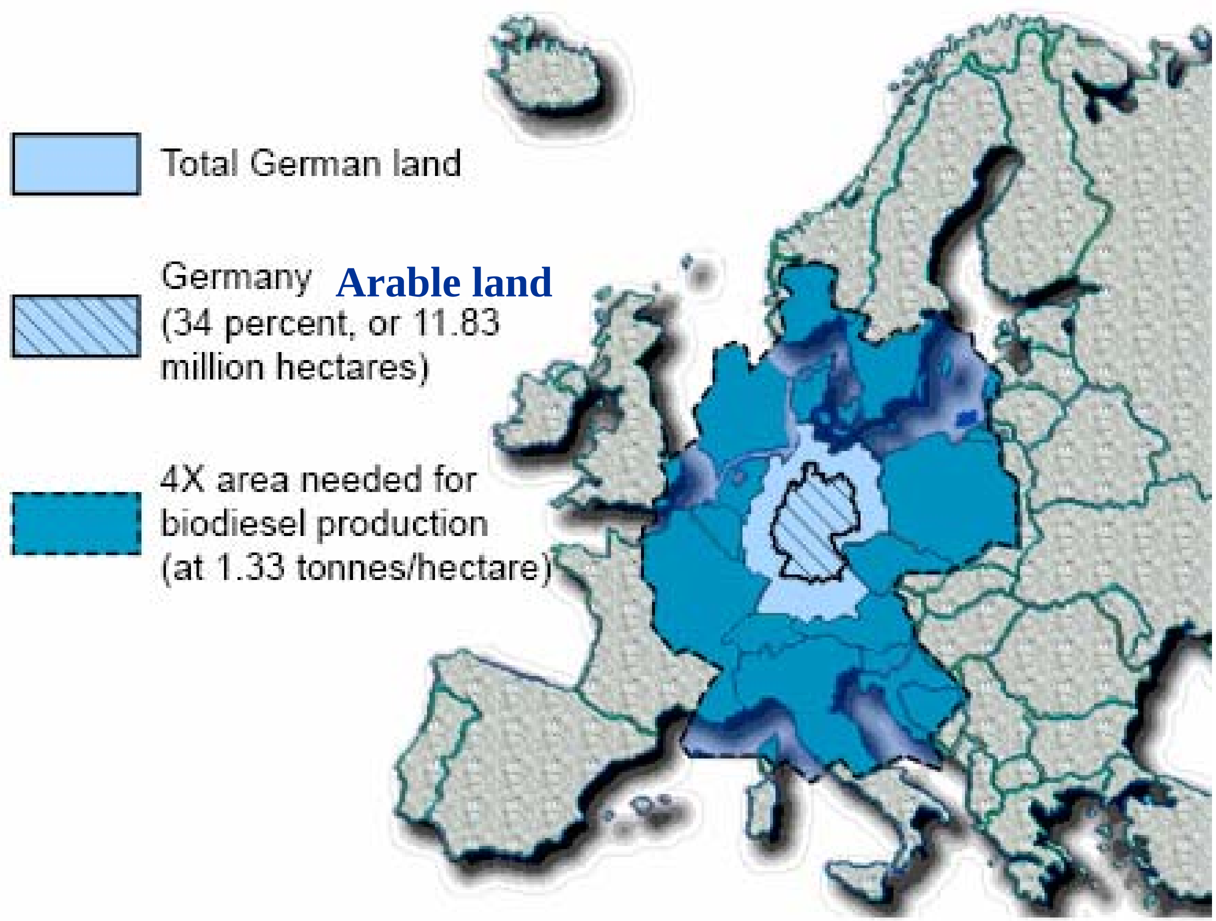
28% more energy use
(500 nmi mission)
[2% on 3k mni mission]

ICAS-2006-5.8.2 / NASA TM-2006-214365

Notes

- Alternate fueling involves trade-offs in aircraft designs
- Renewable ethanol fuel requires larger engines and wings and 15% and 26% more fuel (than Jet A) for 500 nautical mile (nmi) and 3000 nmi missions.
- Hydrogen (liquid fuel) provides for smaller engines and wings yet requires 28% and 2% more fuel (than Jet A) for 500 nautical mile and 3000 nmi missions.
- New Logistics and support systems required
- Aircraft designers seeking drop in fuels suitable for both new and legacy aircraft
- Fuel line sealing becomes major issue to be resolved even for Fischer Tropisch (FT) hydrocarbon fuels
- Alternate fuels as ethanol, biodiesel become arable land intensive (food or fuel issues)

Conventional-Biomass Issue - Food or Fuel ?



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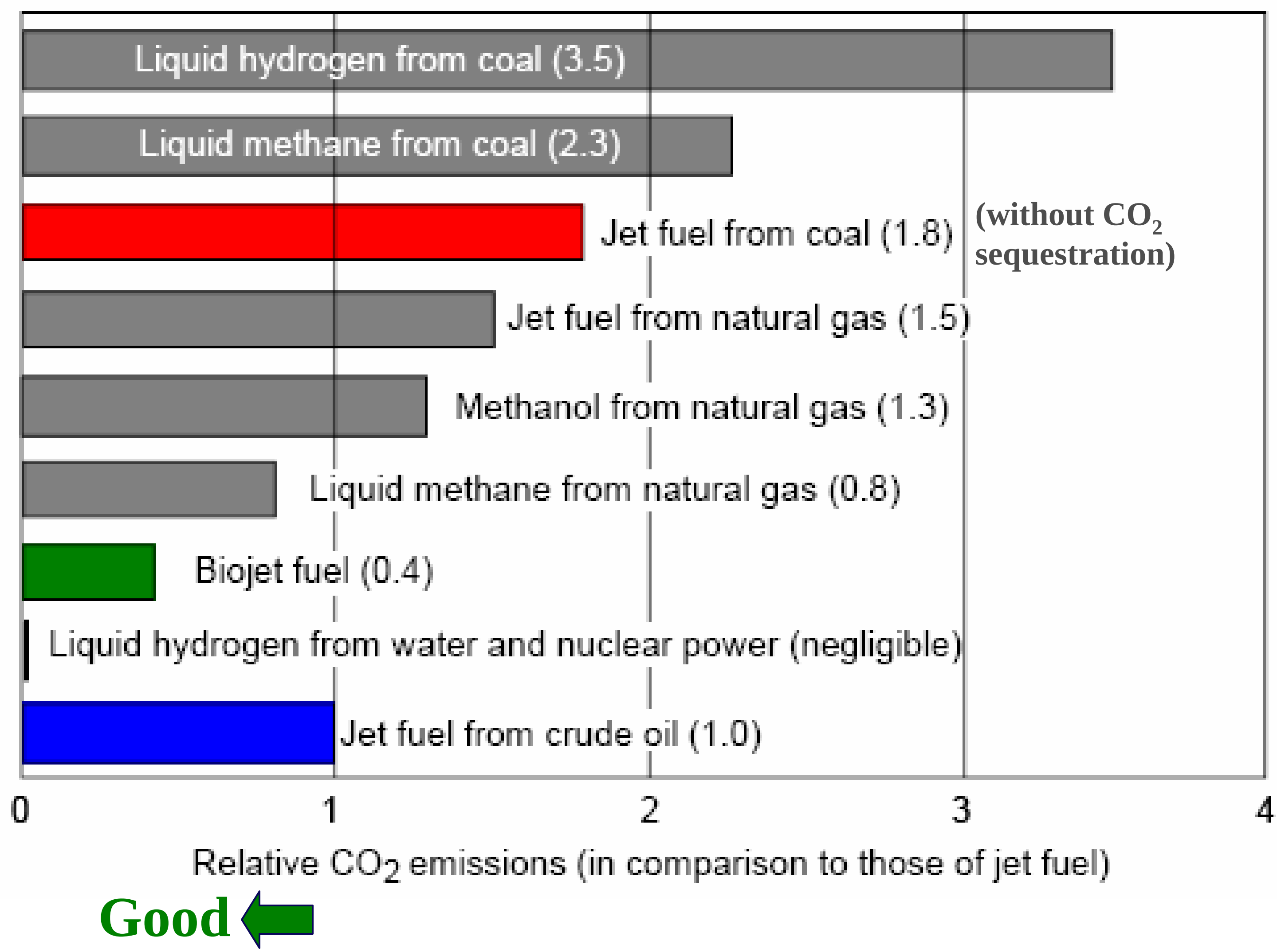
Alternate fuels must be environmentally benign

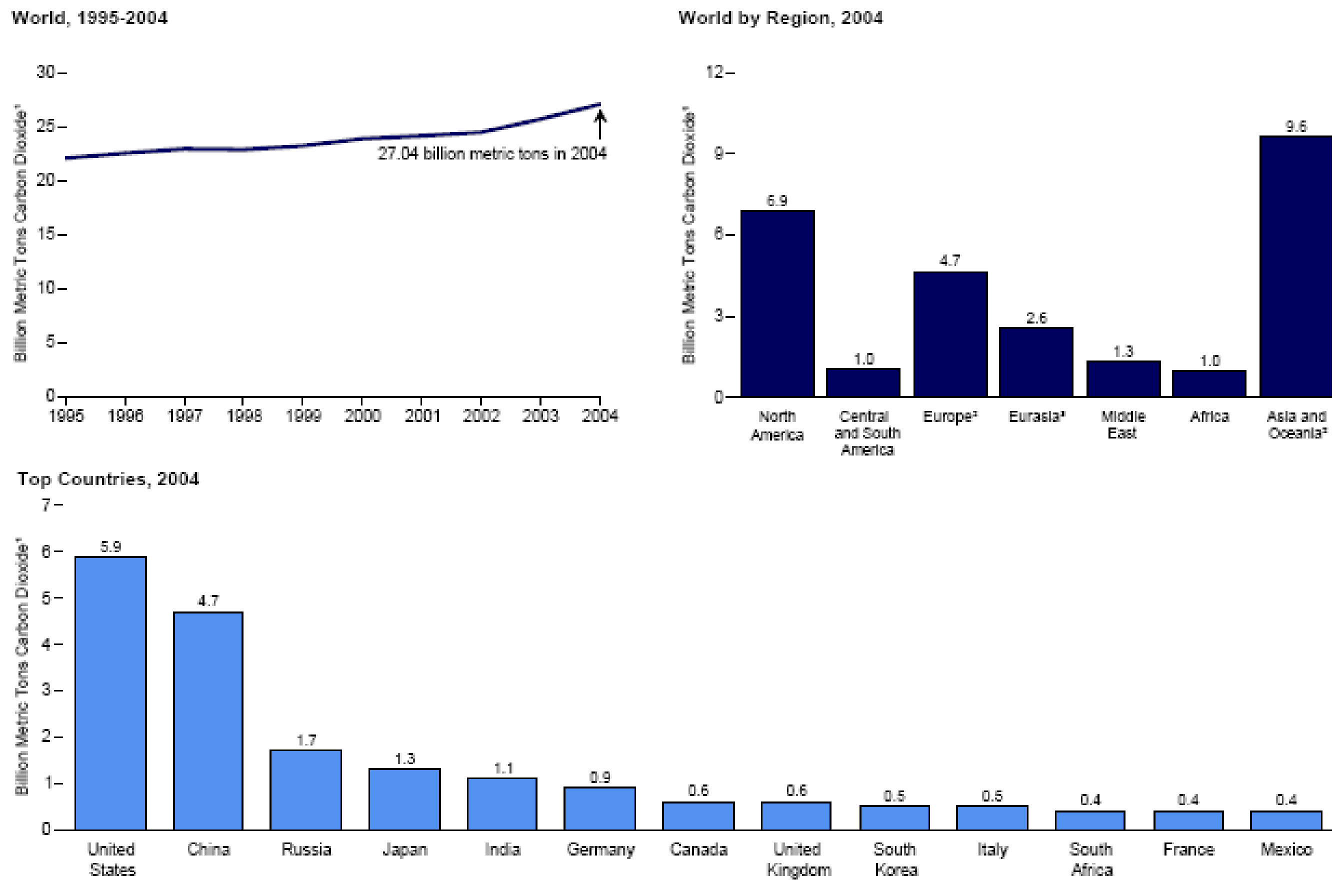


ICAS-2006-5.8.2 / NASA TM-2006-214365

Notes

- Germany mandated 5.75% biodiesel blends yet must import from Brazil to meet demand
- To meet annual diesel demand requires 4X German arable land (not a practical way)
- Emissions depend on methods for generating Alternate Fuels : Hydrogen from coal produces 3.5 x CO_2 than Jet-fuel, yet hydrogen as an alternate aircraft fuel produces negligible CO_2 emissions (but water may become a problem)
- Jet-fuel from coal (e.g., Sasol process) produces 1.6X Jet-fuel from petroleum-CO_2emissions
- World emissions are increasing with hydrocarbon use

World Carbon (CO2) Emissions Problem



[1] Metric tons of carbon dioxide can be converted to metric tons of carbon equivalent by multiplying by 12/44.
[2] Excludes countries that were part of the former U.S.S.R. See "U.S.S.R." in Glossary.
[3] Includes countries that were part of the former U.S.S.R. See "U.S.S.R." in Glossary.

Notes: • Data include carbon dioxide emissions from fossil-fuel energy consumption and natural gas venting and flaring. • Because vertical scales differ, graphs should not be compared.
Source: Table 11.19.

http://www.eia.doe.gov/emeu/aer/pdf/pages/sec11_38.pdf

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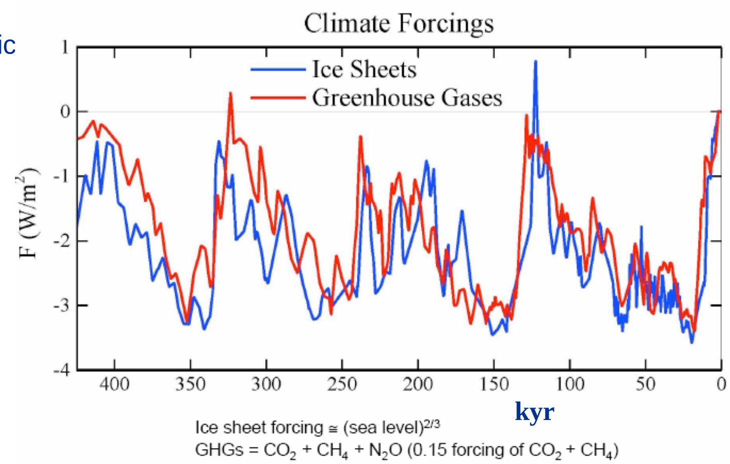
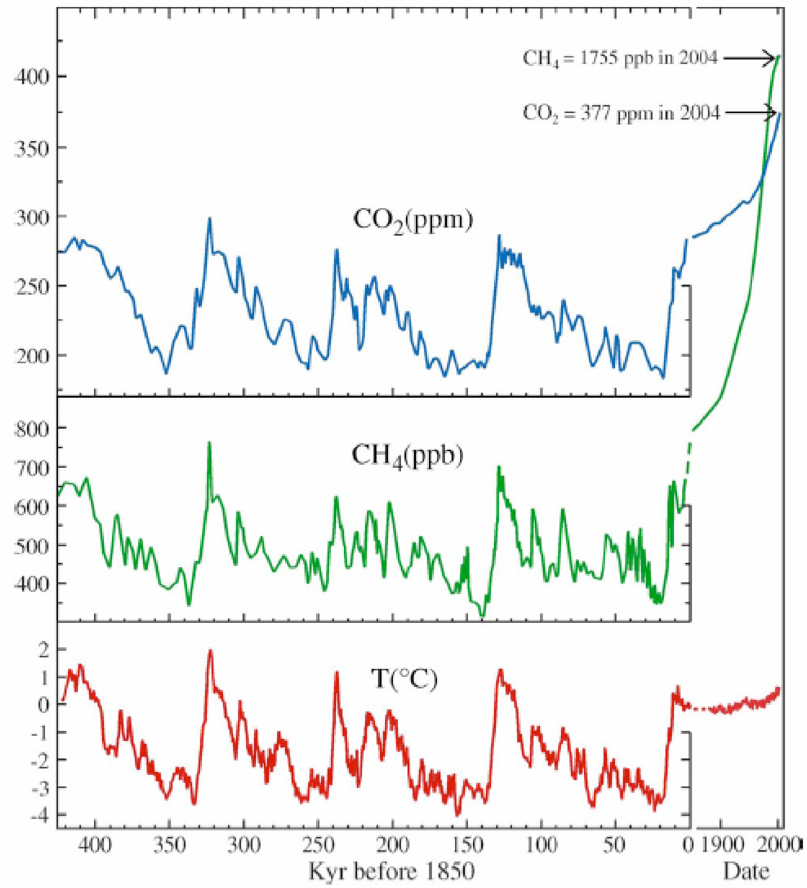
Planet Changing Emissions





Hansen, J., Can We Still Avoid Dangerous Human-Made Climate Change?, World Science Forum, New York, NY, 9 November 2006

Metrics for "Dangerous" Change

Extermination of Animal & Plant Species

1. Extinction of Polar and Alpine Species
2. Unsustainable Migration Rates

Ice Sheet Disintegration: Global Sea Level

1. Long-Term Change from Paleoclimate Data
2. Ice Sheet Response Time

Regional Climate Change

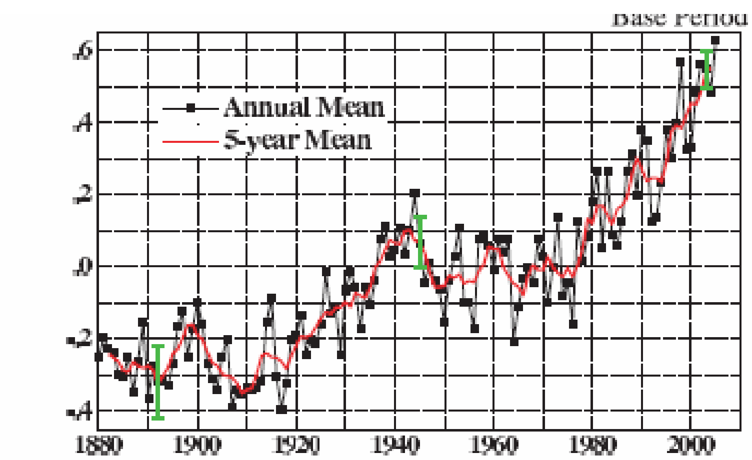
1. General Statement
2. Droughts/Floods

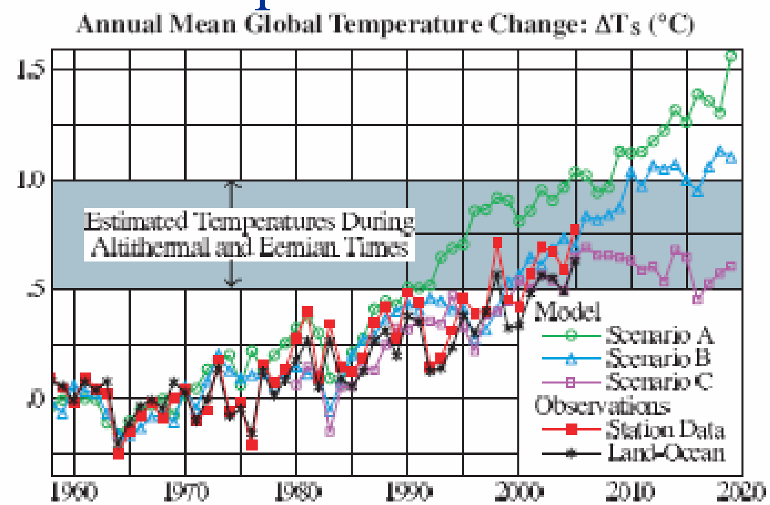
Note Scale Change

www.nasa.gov

Jim Hansen's Global Warming Warnings

$T_{\textbf{Earth-surface}}$ ≈ 1ºC of $T_{\textbf{max}}$ of past 10^6 years
$\Delta T_{\textbf{Earth-surface}}$ = 0.2 ºC/decade for past 30 years
Earth warming +1ºC relative to year 2000 implies **dangerous climate change**, basis: likely effects of sea-level changes, extermination of species





A: Exponential GHG, C: Drastic emissions curtailment, B: Most plausible (close to real world)

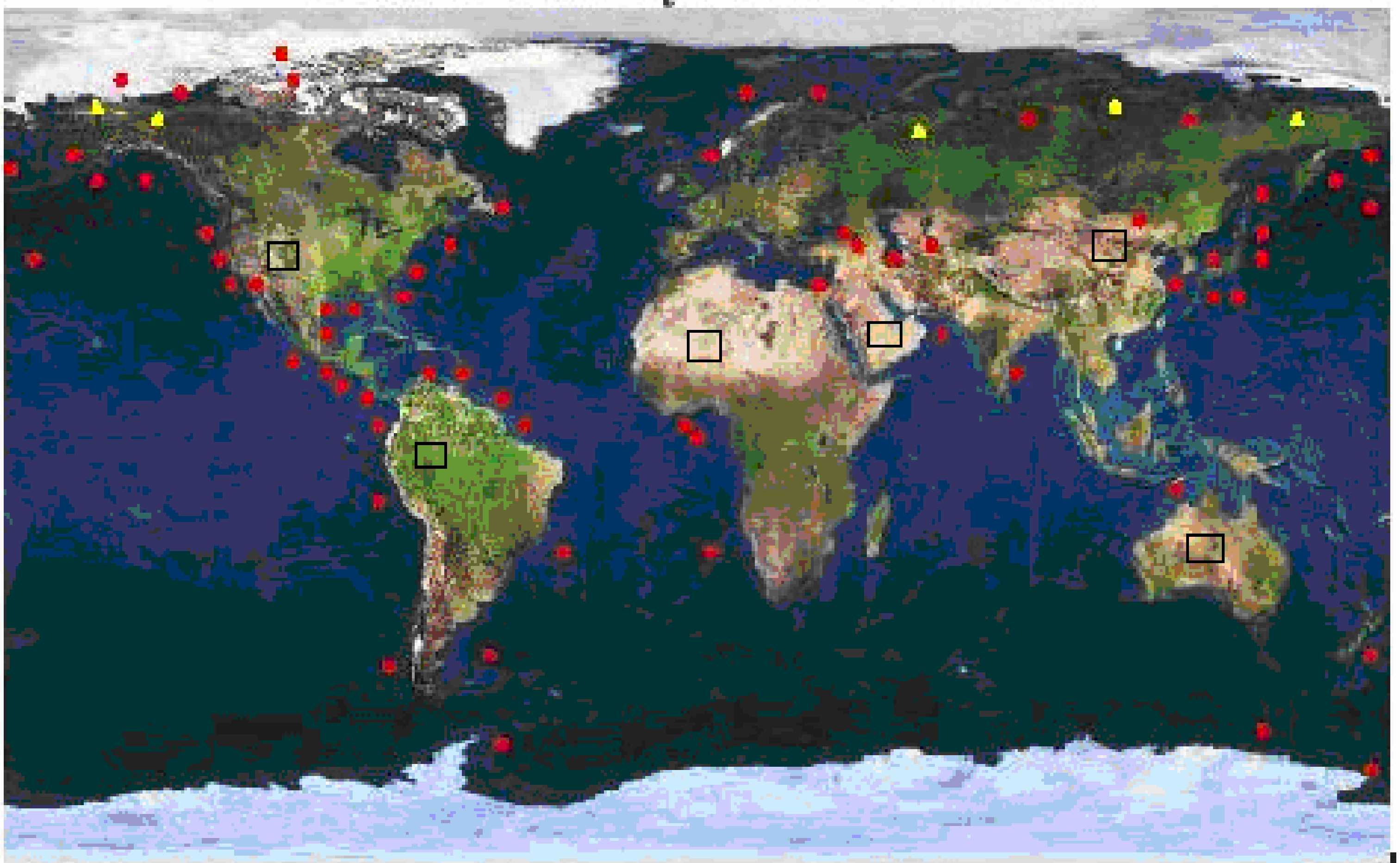
BAU "Business-as-Usual" (between A & B) and AS "Alternate-Scenario" (similar to C)

Hansen, J., Sato, M., Ruedy, R. Lo, K., Lea, D.W., Medina-Elizade, M.; Global Temperature Change, PNAS Sept. 26, 2006, Vol. 103, No. 39, pp 14288-14293.
http://pubs.giss.nasa.gov/docs/2006/2006_Hansen_etal_1.pdf : accessed 25 September 2006

Notes

- 80kyr cycles for CO_2 and CH_4 emissions are dwarfed by those from 1860's onward to present time
- Climate forcing Greenhouse Gases and Ice Sheets go hand in hand (compare the cycle periods) Ice heat of fusion factor in planet thermal response
- Metrics for Dangerous Change in planet Earth sources of data used to determine planet security alert [(Plant, Animal), (Ice, Sea Level), Climate]
- Extinction does not necessarily mean human, but could : Sea floor, ice, permafrost, stability issues
- Business as usual (BAU) is not an acceptable scenario as it impacts land surface and ocean temperatures which in turn impacts planet stability

Gas Hydrates (Clathrates), Solar & Biomass Locations



Gas Hydrate Locations in Ocean Sediment and Permafrost

ΔT_{Earth} Warming most prevalent in Northern Hemisphere

http://www.netl.doe.gov/scngo/NaturalGas/hydrates/databank/HydLocations.htm

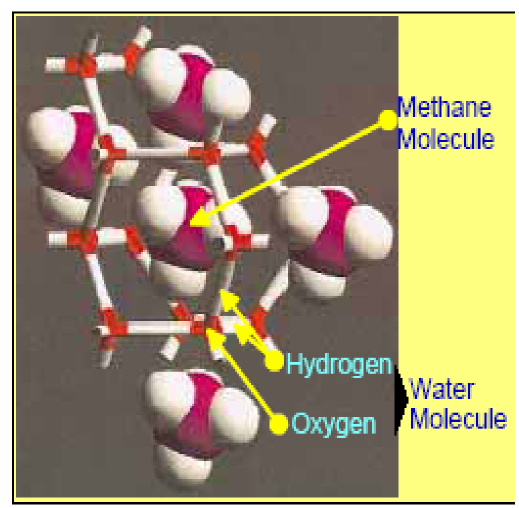
Global Energy Sector Response

Biotic theory petroleum (fossil): limits reserves perhaps 50 years
Abiotic theory hydrocarbon formation supports continuous oil formation deep within earth mantle: no finite bounds

Glaciered ice melts, rise in ocean temperatures and ocean levels impacts stability of methane hydrates, ocean floors, the coastal industrial and aviation complex and specie survival

Methane release (10 to 20 times more detrimental than CO_2)

Figure 1: Burning Methane Hydrate in the Lab. [1]



Notes

- Methane hydrates surround the Americas and Japan coastal regions and are distributed in the permafrost regions of the Northern Hemisphere (and maybe pervasive elsewhere ?)
- Methane hydrates are deep in the ocean or permafrost [150m to 1350m] and are extensive, but shallower or deeper in the Earth, they become gaseous as the temperature-pressure will not support clathrate or ice cage structure.
- At present geological time methane hydrates are stable to marginally stable within rock like structures or domes on ocean floor or permafrost regions
- Current mining (methane recovery) is by warming the hydrate or drilling through a gas dome of unknown pressure [major sealing issues]
- BAU-Global warming will eventually release methane which is 10 to 20 times worse than CO_2 as a greenhouse gas
- Methane Hydrate Stability Impacts Ocean Floor Stability

Ocean Floor Stability Disaster Example: 6200BC, 4000 $(km)^3$ slide off Norway sent 15m tsunami to Scotland and 90 000 $(km)^2$ muddy mid-Atlantic ocean (near shore residents and aquatic life probably would not have survived) http://www.discover.com/issues/mar-04/cover/?page=5 **(access 13Nov06)**

Global Energy Sector Response (cont'd)

- Nobel Laurent Prof. Richard E. Smalley (2005) proposed

• six 3.3 TW-year solar energy sites would meet energy demands of all nations (TW = 10^{12} W) {map squares}

• 100km x 100 km site 10.6 kW-hours/m^2/day at 10% solar cell efficiency and 50 year life

• $3.50/W ($300/m^2) to $1/W ($90/m^2) [10% cells]

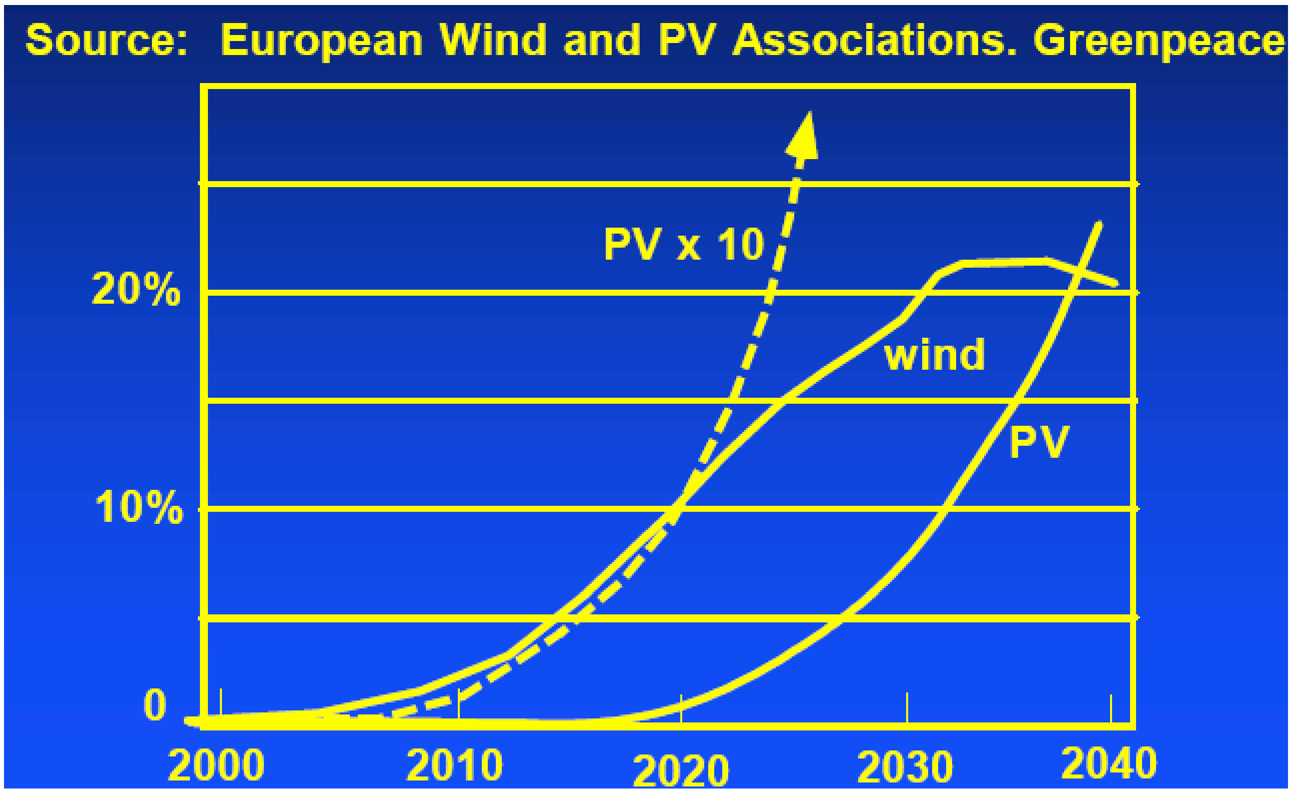
• 3.3 TW-year PV cost ($1 to $3 trillion) or
8.5% < [PV-Cost]/GDP(2001) < 25.5% **(US GDP $11.75 trillion)**

- Oil & Gas industry $6 trillion : Energy Industry $16 trillion, capital investment
- algae beds (20kgal-biodiesel/acre/yr) 20 X Smalley site. Can use brackish or fresh water, pond or column systems

Alternative Renewables

- Alternative Renewable Energy Sources Solar Wind. Diffuse yet pervasive; can supply ALL global energy
- Large land areas required mostly desert type where solar is prevalent (see squares on figure)
- Require less land than Algae Farms growing in fresh or brackish waters (ponds/columns) can capture CO_2
- Less expensive than pursuit of petroleum yet requires will of people of Earth to happen
- Renewable, diffusive PV and Wind energy sources are growing in Europe

Global Energy Sector Response (concl)



Stratospheric Sulfur Injection Global Cooling Switch

- “Pollution particles affect health and lead to more than 500,000 premature deaths per year worldwide. Through acid precipitation and deposition SO2 and sulfates also cause various kinds of ecological damage” Paul J. Crutzen (Nobel Laureate)

- Crutzen’s climate engineering involves
  - Injection of 1-2 Tg S (1 T gram = 10^9 kilogram)
  - SO2 and sulfates formed reflect incident solar, cooling planet

Yet consider these issues.

- Reason for S removal
  - Reduce premature deaths - human and animal
  - Alleviate acid rains that destroy forests – plant matter

- Increasing S decreases biomatter CO2 absorption
  Increasing CO2 increases GHG warming, requiring more S release ?

- “The very best would be if emissions of the greenhouse gases could be reduced so much that the stratospheric sulfur release experiment would not need to take place. Currently, this looks like a pious wish.” Paul J. Crutzen (Nobel Laureate)

- Experiments are to prove concepts - outcome uncertain

Notes

- **Crutzen's climate engineering involves stratospheric injection of 1-2 Tg S over 1-2 year planetary (cooling/warming switch)**
  Estimated costs are $25B-$50 B per injection; no cost basis provided.

- **Anthropogenetic effects are implied heat/cool control, yet unknown**
- **Implication of planet cycle lag response time could prove as extinction spiral.**

- **Freshwater addition and dilution of northern (southern) ocean salinity "stalls" warm equatorial current drivers and alter biomass production in ocean and costal areas. Hatun et al., Curry et al., realclimate.org : Global warming turns Global cooling.**

- **Policy makers Energy options - maintain business as usual (BAU), alternate scenario (AC), investing in solar farms provide long and short term energy. On these issues all life forms are involved; no one, including policy makers will be exempt.**

- **Social policy option, maximize profit or how many lifted from poverty, Energy policy option 6 solar stations supply world energy demand [policy options of Nobel Laureates, Muhammad Yunus (social) and Richard Smalley (global energy)]**

Crutzen, P.J. (2006) Albedo enhancement by stratospheric sulfur injections: A contribution to resolve a policy dilemma?, An Editorial Essay, Climatic Change 77(3-4), Aug , pp 211-219.

Hatun H., Sandø A.B, Drange H., Hansen B. & Valdimarsson H. (2005) 'Inlfuence of the Atlantic Subpolar Gyre on the Thermocline Circulation', *Science*, vol 309, 1841-1844

Curry R. & Maurtizen C. (2005) 'Dilution of the Northern North Atlantic Ocean in Recent Decades', *Science*, vol 308, 1772-1774

http://www.realclimate.org/index.php/archives/2005/10/saltier-or-not/

Potential Global Energy Sector Response

1. Remove unstable methane hydrate sources before spontaneous release due to climate changes, convert to useful energy (work). Sequester CO_2 **(Carbon),** spent well injection? Clathrates? Plants ? Other use?
2. Move toward efficient diffuse-energy collection, conversion, storage, transmission systems
3. Increase renewable energy use, solar, wind, algae bio (general) both land and air power systems
4. Decrease hydrocarbon (“fossil” or abiotic) dependence (shift from BAU to AS)
5. Monitor shoreline dependence on global climatic changes with attendant response.

New Sealing and Fluid Flow Challenges

From tapping and capping hydrate domes to synthetic “drop-in” fuels in legacy aircraft, along with synthetic and bio fuels production, transmission, storage and use in transportation and ground based power industries, sealing and secondary flows remain key issues to their success

Different type of sealing issues

- Sequestering and sequestered emissions
- Deep well injection and sea-bed retention and stability
- FT and bio fuels materials compatibility
- Interface coatings, nanoparticulates, catalytic