Technological Progress and Environmental Challenges for Energy Production and Use

Presented to:
China-Montreux Energy Roundtable
Beijing, China

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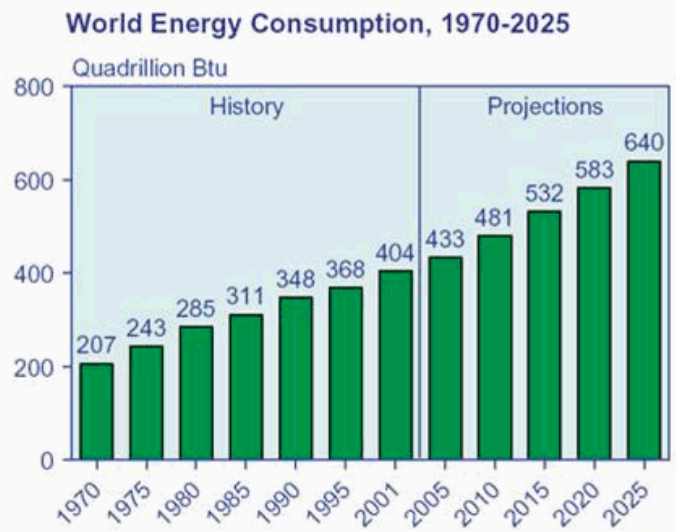
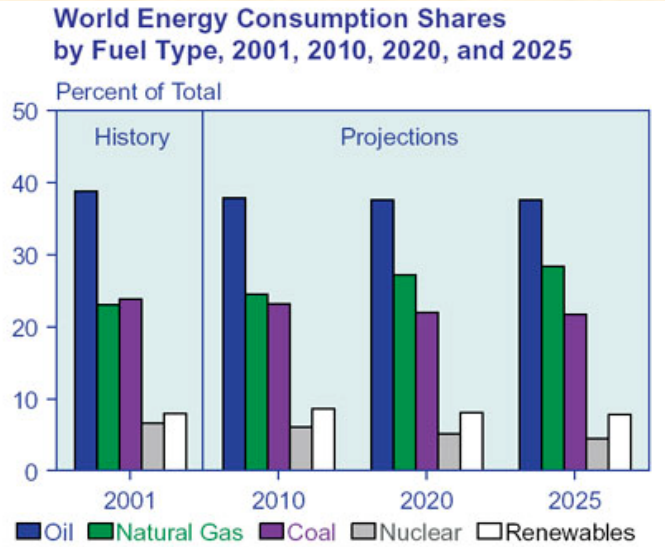
Fossil Fuels are Our Most Important Primary Energy Resources (but are they environmental villains)

- Fossil fuels are our principal energy sources, but they are depletable on a time scale relevant to human history
- Fossil fuel use may be changing the environment of the planet locally, regionally, and globally
- Our developing society demands more energy for more people
- Technology and policy intervention are required so that fossil fuels are used to the net benefit of society and its environment

World Energy Consumption is Projected to Grow with not Much Change in the Fuel Types



Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003), web site www.eia.doe.gov/iea/. **Projections:** EIA, System for the Analysis of Global Energy Markets (2003).



Sources: **2001:** Energy Information Administration (EIA), *International Energy Annual 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003), web site www.eia.doe.gov/iea/. **Projections:** EIA, System for the Analysis of Global Energy Markets (2003).

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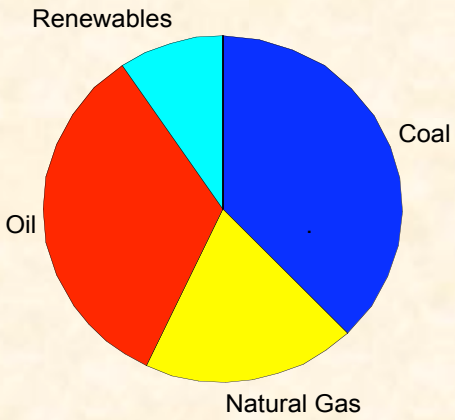
The Fossil Fuel Percentage of Total Energy Production in the U. S. has not Changed Significantly in Over Fifty Years*



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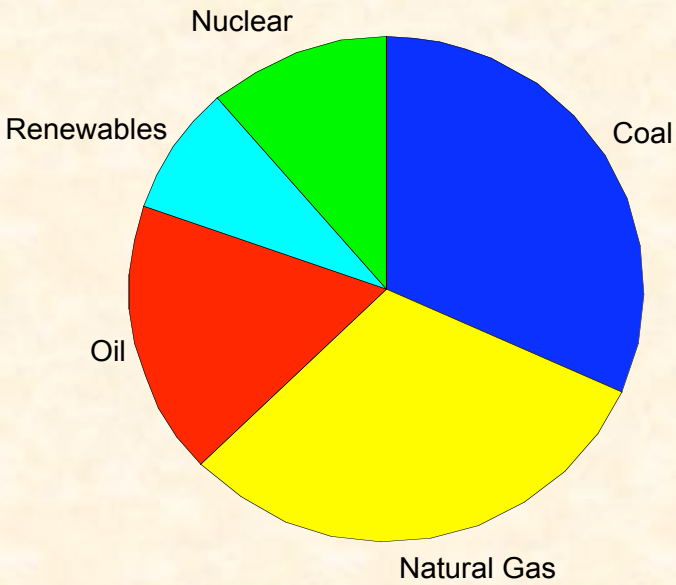

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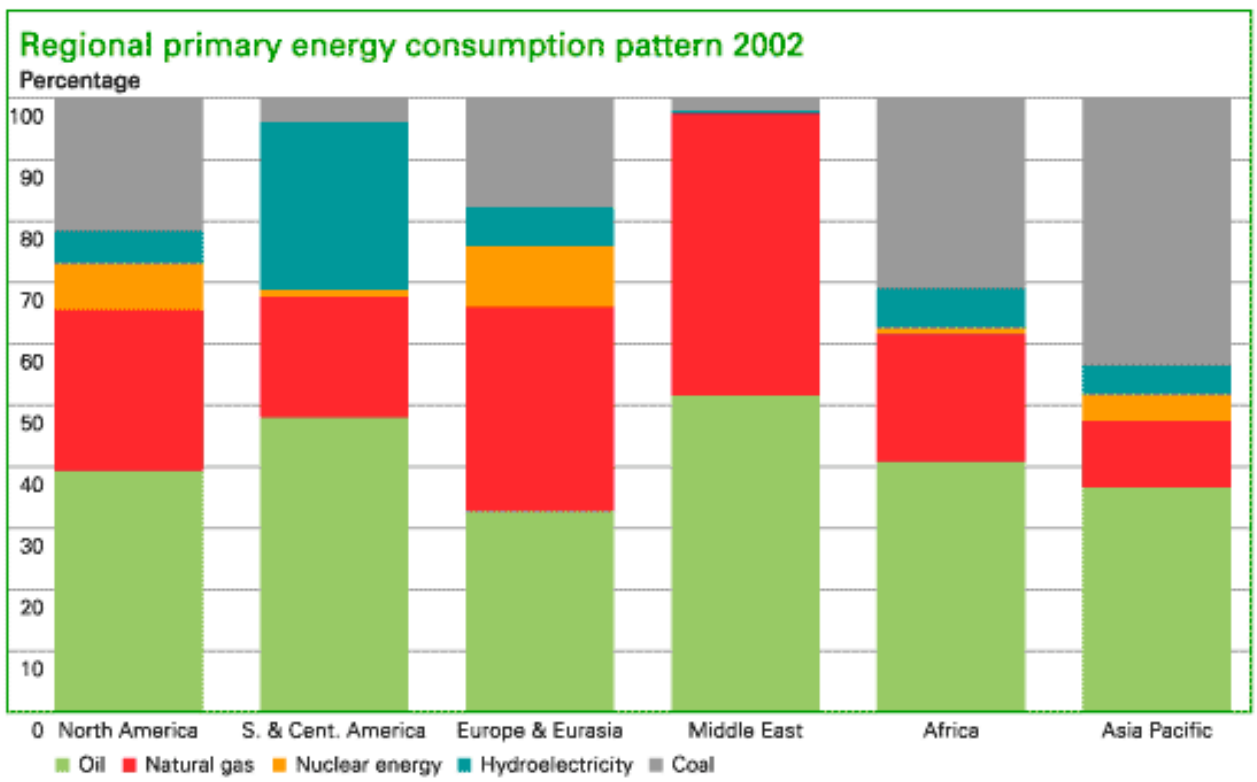
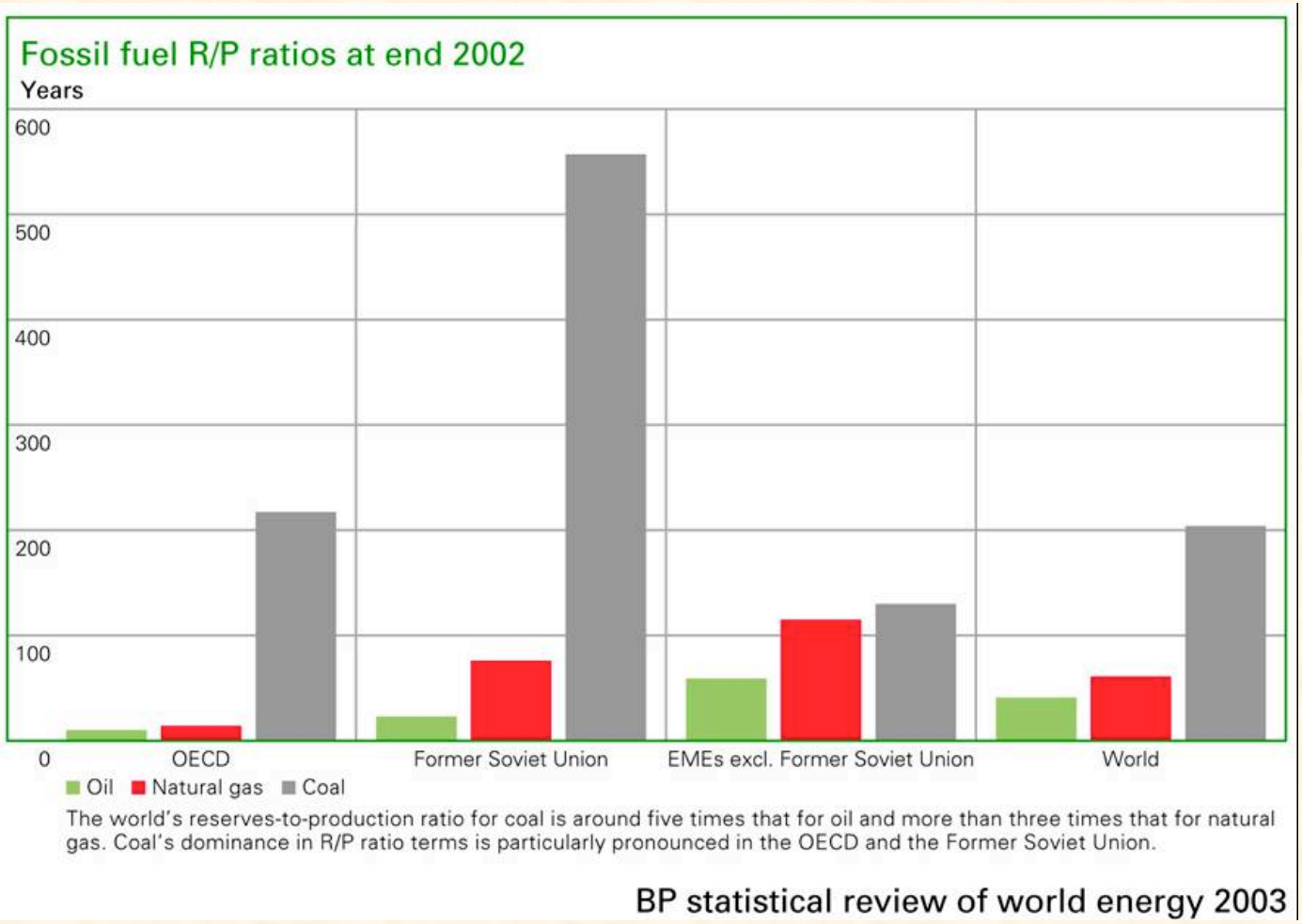
*** And probably won't for the next fifty years.**

Oil Remains the Largest Single Source of Energy in Most Parts of the World



Oil remains the largest single source of energy in most parts of the world. The exceptions are the Former Soviet Union, where gas dominates and Asia Pacific where coal is the dominant fuel.

Reserves of Coal are Large Compared to Other Conventional Fossil Fuels



Why are Fossil Fuels so Popular?

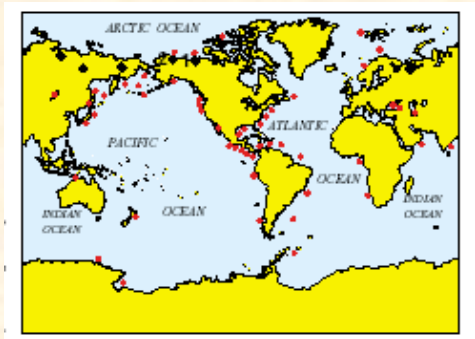
- They are marvelous energy sources
- They are ubiquitously distributed, and most are readily transportable
- Fossil energy resources are very large
- We have learned to use fossil fuels very effectively
- Nonfossil energy resources are not ready to substitute for fossil fuels on a grand scale (although some, e.g., nuclear power generation, are significant)

Fossil Fuel Resources Could Last Many Hundreds to Several Thousand Years

- Coal is our most abundant and recoverable fossil fuel resource and could last for hundreds of years
- Oil is fairly abundant and widely distributed; supplies could last on the order of decades
- Conventional natural gas supplies are sufficient for several decades
- Unconventional natural gas, particularly from methane hydrates, could extend resources for many hundreds of years
  - More carbon as methane in methane hydrates than all other hydrocarbons combined
  - Advanced finding techniques needed
  - Production techniques for methane hydrates must be developed

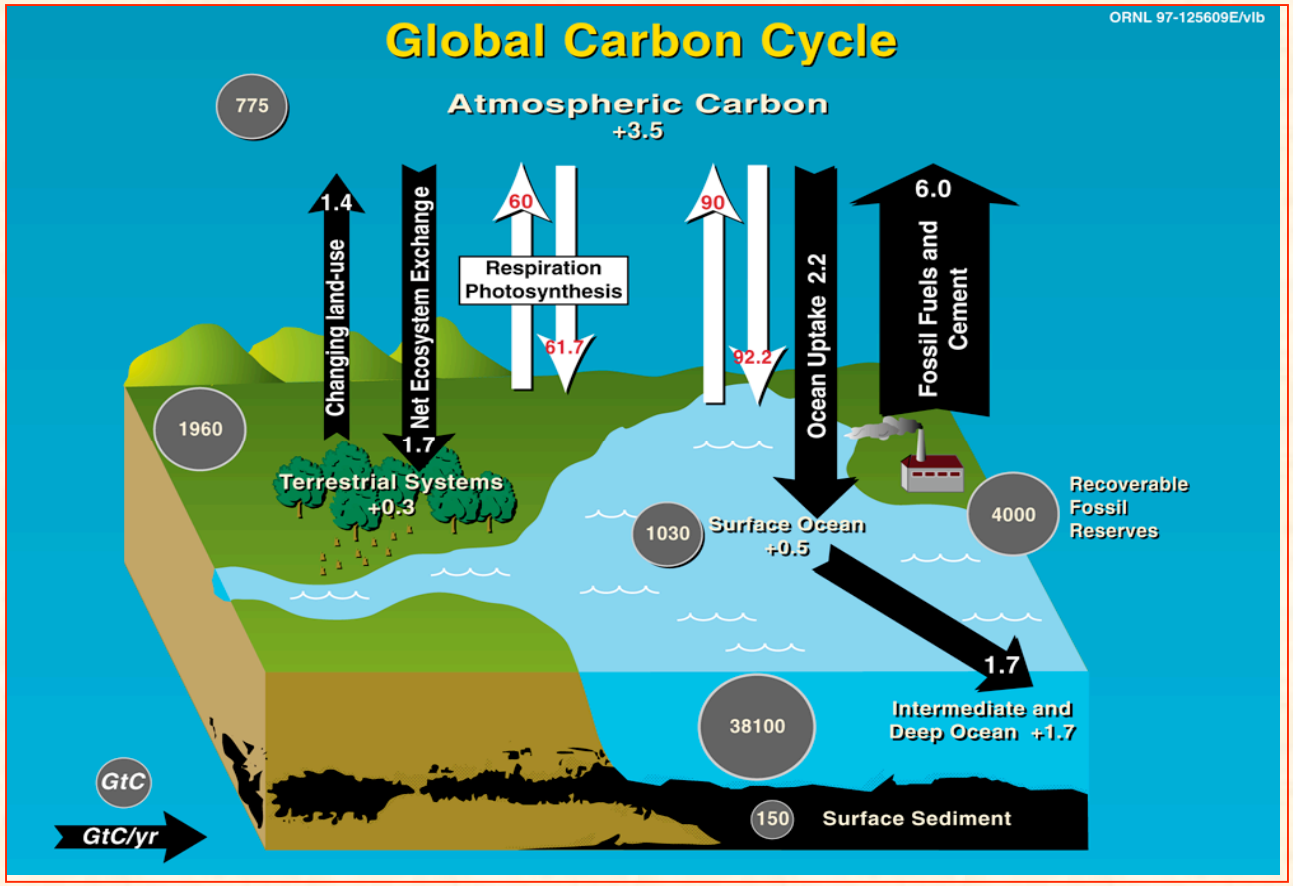
Methane Hydrates form Wherever Appropriate Conditions Exist

- Moderately low temperature
- Moderately high pressure
- Gas near saturation
- Water
- The appropriate conditions are found in the deep sea, usually at water depths greater than 500 m
- In Arctic, i.e., colder, waters, methane hydrates may exist at ~300 m



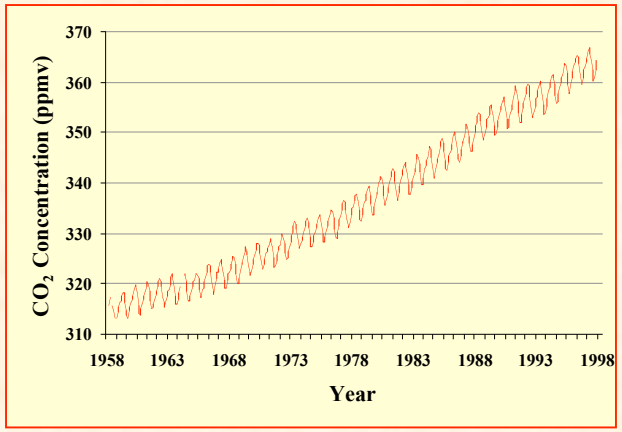
Courtesy DOE

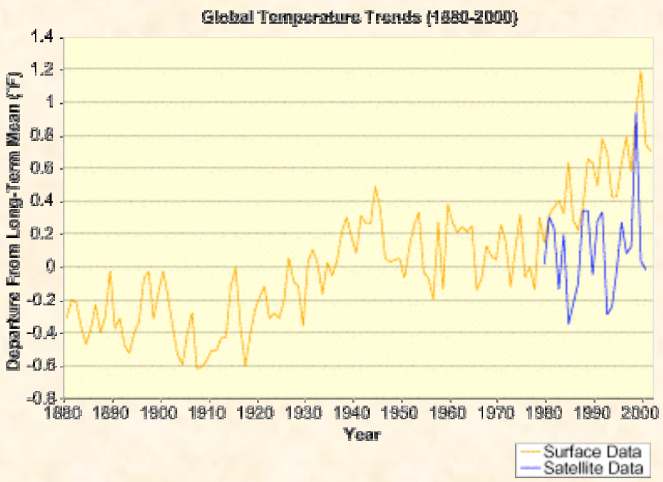
The Most Ominous Issue Related to Fossil Fuel Use is the Possibility of Global Climate Change



The Issue is not the Greenhouse Effect; it's the Changing Greenhouse Effect

- Water vapor is the most abundant and effective greenhouse gas
- Without water vapor and its corresponding greenhouse properties, the earth would not sustain life
- CO_2 emissions are thought to be responsible for about 50% for the enhanced greenhouse effect





Surface Data Source: National Climatic Data Center, 2001.
Satellite Data Source: John R. Christy, University of Alabama in Huntsville, and Roy Spencer, National Aeronautics and Space Administration.

We Know Several Facts That Relate to the Possibility of Global Warming

- The concentrations of "greenhouse gases," particularly CO_2, in the atmosphere are increasing
- CO_2 is the major anthropogenic greenhouse gas
- Fossil fuel burning accounts for more than 75% of the increasing CO_2 in the atmosphere
- Deforestation is the other major source of CO_2
- The average atmospheric temperature is increasing slightly
- Increases in recent average atmospheric temperature correlate well with increasing concentrations of CO_2

Three Primary Approaches are Usually Considered for Mitigation of CO_2 Emissions

- Higher efficiency systems
  - More energy output per unit of fuel
  - Less emissions per unit of energy
- Lower carbon intensity energy systems
  - Energy systems that do not use fossil fuels
  - Fuel switching from coal/oil to natural gas
- Carbon sequestration
  - Isolation of CO_2 emissions from the atmosphere
  - Requires separation and capture
  - Ocean, geologic, and terrestrial ecosystems
  - Using present technology, estimates of sequestration costs are in the range of $100 to $300/ton of carbon emissions avoided

Successful Carbon Sequestration Techniques and Practices Must Satisfy Several Requirements

- Be effective and cost-competitive (goal is to reduce costs of sequestration to $10/ton of carbon emissions avoided)
- Provide stable, long-term storage (desire is permanent isolation from the environment)
- Be environmentally benign (hope is for all environmental impacts to be neutral)

Much of the Developed, i.e., Industrial World Has a Legacy of High Energy Inefficiency

- A significant percentage of CO_2 emissions in developed countries result from older (usually) and more inefficient plants than are currently available
- Significant benefits would accrue if developing countries installed the best of energy producing technologies
- Developing countries could achieve the level of affluence of Western Europe at perhaps only one-fourth the energy consumption per capita*

* This is not to suggest that implementation of efficient energy production schemes alone will cause this affluence

Fuel Cells Using H_2 as Fuel and CO_2 Avoidance are Essential to Achieving a Hydrogen Economy

- Fuel cells directly convert chemical energy to electrical energy
- Fuel cell efficiencies are very high compared to thermal processes
- Hydrogen is the preferred fuel for all fuel cells (and is the only acceptable fuel for some fuel cells)
- Exploitation of fuel cells has a huge dependence on hydrogen production and infrastructure
- Only economical approach to large-scale hydrogen production at present is via conversion of fossil fuels
- Transition to a hydrogen economy appears to be inextricably linked to CO_2 capture and sequestration

Hydrogen as a Fuel Presents a Complexity of Issues

- Hydrogen is the most abundant of elements, but it is always in a combined form
- The most economical approach to producing hydrogen is by hydrocarbon reforming processes, i.e., natural gas reforming and coal gasification
- Economical hydrogen production from sustainable renewables and electrolysis of water is virtually impossible in the near term and hydrogen from fossil fuels will be cheaper for perhaps 50-100 years
- Present challenge is the development of a hydrogen infrastructure that handles hydrogen now and in the future

Hydrogen Based Power Generation with CO_2 Sequestration will be Feasible Soon

- Technology for producing hydrogen is well developed
- Concentrated point sources of hydrogen and carbon dioxide minimize complexity of systems
- Offers tremendous opportunity for clean use of coal through gasification
- Energy, environmental, and economic benefits are positively linked
- Capacities and efficiencies are increased with concomitant reduction of carbon dioxide as well as traditional emissions
- Provides time for addressing the larger challenges of hydrogen based transportation
- Investment in carbon sequestration provides the necessary insurance that transition can be accomplished

Fossil Fuels are Plentiful Enough to Provide for the Projected Growth in the World's Energy Needs

- We must be smarter in the way we use fossil fuels, particularly in the way we address the carbon emissions issues
- Fossil fuel substitution toward the lower carbon emission factor fuels (natural gas versus oil or coal) will help
- Methane hydrates could be a salvation
- Hydrogen production coupled with carbon sequestration is the ultimate future, using carbon fuels first and non-carbon sources (renewables, etc.) later