Energy & Global Security in the 21st Century

Presented to

The Royal Academy of Engineering

Presented by

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Sandia National Laboratories

Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000

2007-6280C

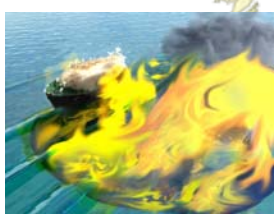
U.S. Energy Security Requires Global Engagement on Many Fronts

High Energy Intensity Economic Development

Energy Security

Terrorism

Science and Technology



Waste

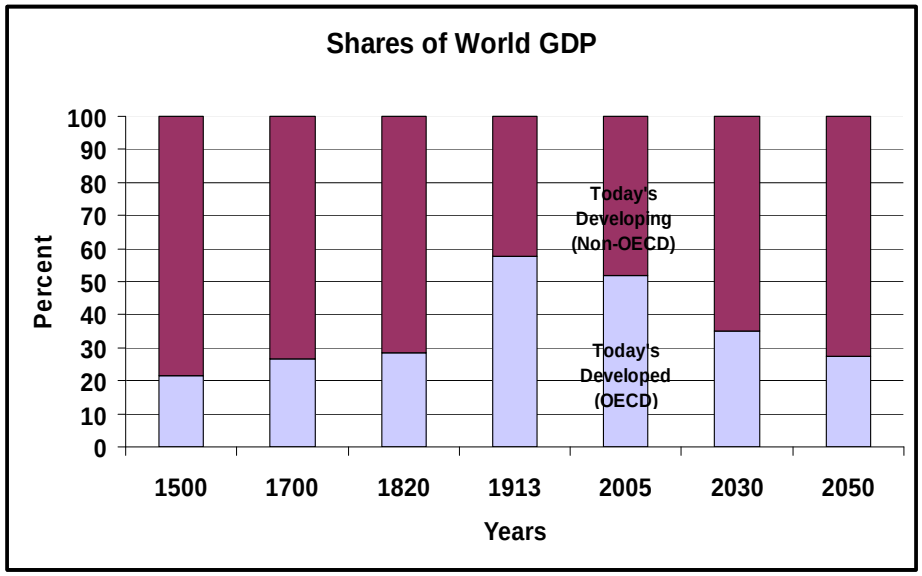
Water

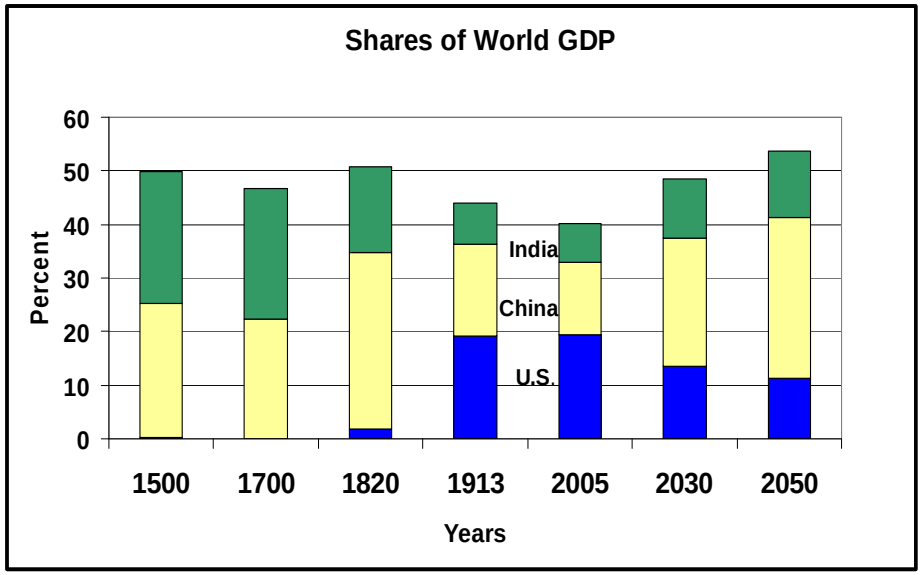
Climate

Energy Disruptions

Proliferation of SNM and Weapon Expertise

Globalization
A Transitional Power Shift





Source: The World Economy, OECD 2001, Angus Maddison; Global Insight Detailed Forecast, September 5, 2008, extrapolated to 2050 , $2000 PPP basis

Geopolitics Have Become More Complex

U.S. Needs Coalitions

Close Democratic Elections
Make Tough Decisions Difficult

China

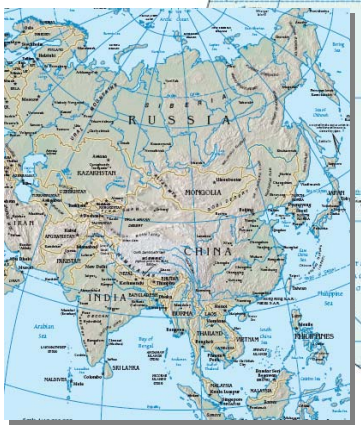
Russia

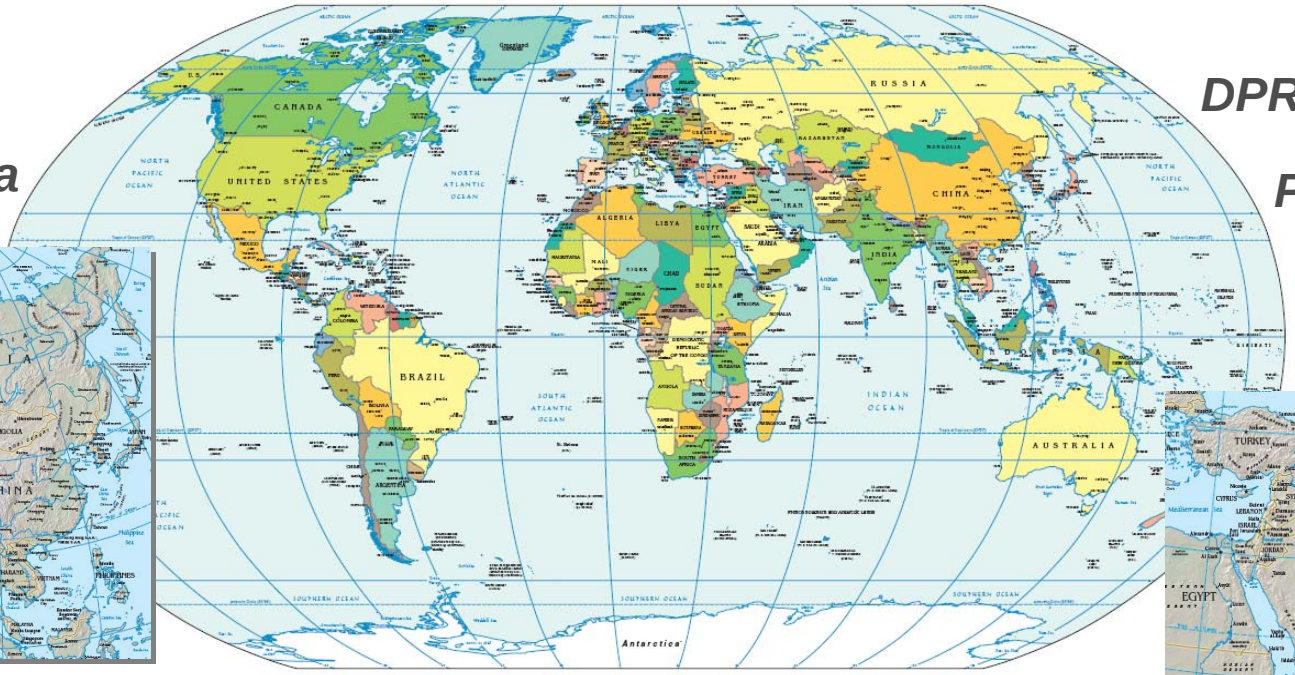
DPRK

Pakistan

Iran

Iraq





Governments Getting More
Into the Marketplace

Middle East Critical to U.S. Security

Trends in Security Perspectives

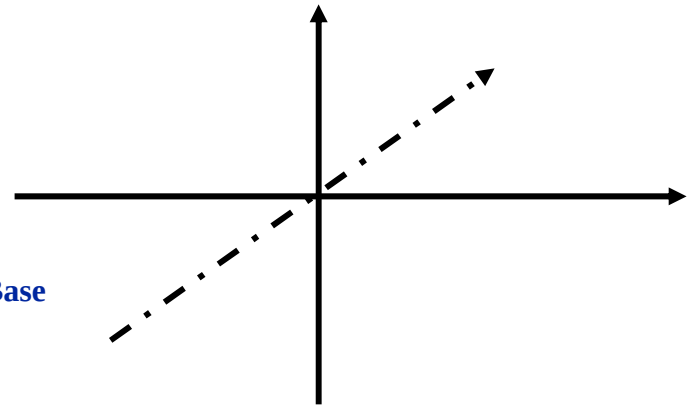
Information Age

Short Time Cycle
New Competencies
Adaptive Planning
Coherently Joint
Interdependent

Character **and** ***Nature*** **of conflict has changed**

Globalization
1947-2001

Developed Rules
Mature Markets
Narrowing Customer Base
Security = Defense



Globalization
Post 2001

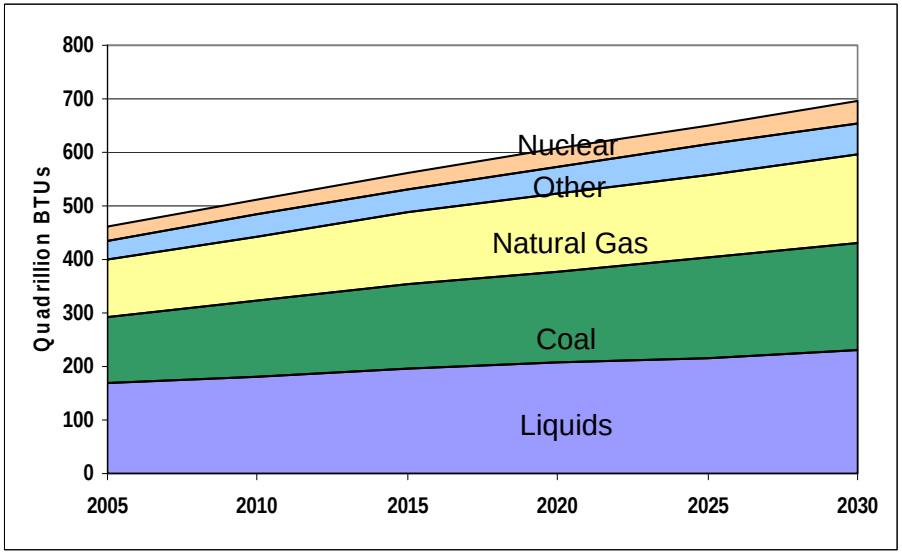
Emerging – Ad Hoc Rules
Market Opportunities
New Emerging Customer Base
Security = All Else + Defense

Industrial age

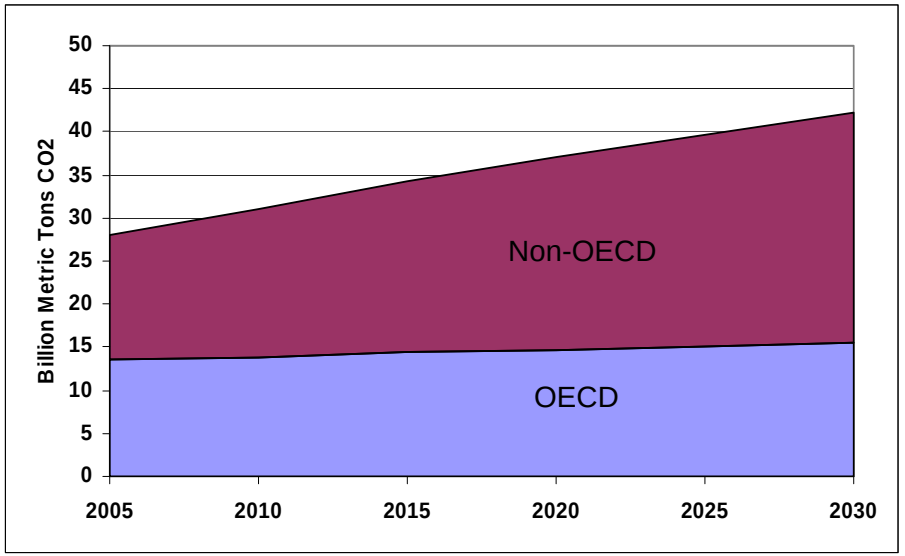
Long Time Cycles
Well Developed Tools, Rules, Processes
Deliberate Planning
Deconflicted Joint Operations - Independent
Tortured Interoperability

Between 2005 and 2030, World Energy Demand and Carbon Emissions Will Grow 51 Percent

Energy Demand



Carbon Dioxide Emissions



and Developing Countries will Account for more than 4/5 of the Increase

Source: USDOE EIA IEO 2008 Reference Case

The World's Proven Fossil Fuel Reserves are Geographically Concentrated

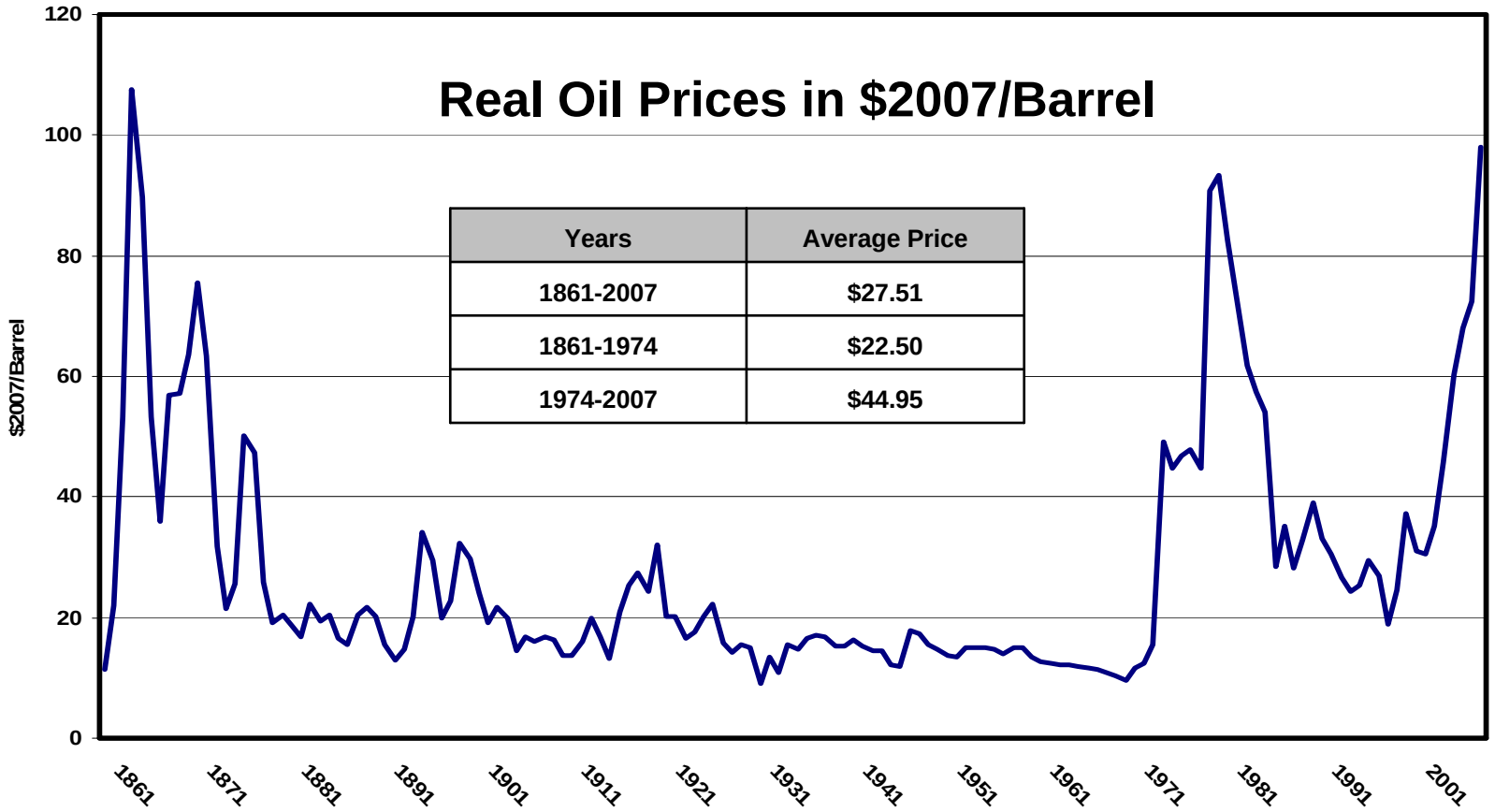
(Percent Share)

Region	Oil	Gas	Coal
Key Persian Gulf	55	40	< 1
Saudi	20	4	0
Iran	10	16	< 1
Iraq	9	2	0
Kuwait	8	< 1	0
UAE	7	3	0
Qatar	1	15	0
Canada	14	1	1
Venezuela	6	2	< 1
Russia	5	27	19
U.S.	2	3	28
Australia	< 1	< 1	9
China	1	1	14
India	< 1	< 1	7
ROW	17	23	23
Total	100	100	100

Source: Oil & Natural Gas, EIA 8/8/2008; Coal EIA 10/17/2008.

And National Oil Companies Own 70-80% of Proven Oil Reserves

How Will Real Oil Prices Play Out?

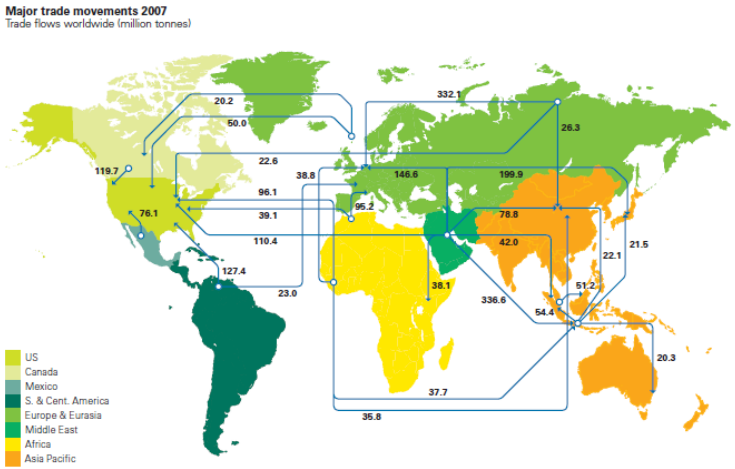


Years	Average Price
1861-2007	$27.51
1861-1974	$22.50
1974-2007	$44.95

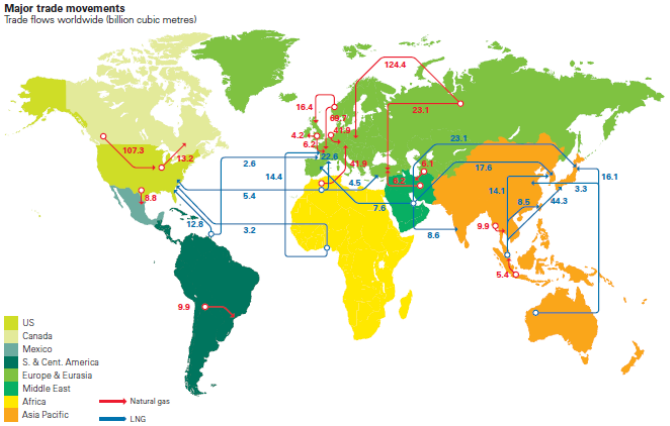
Source: BP Statistical Review of World Energy June 2008. 2008 price is estimated

Physical Protection of the Energy Infrastructure Presents Unique Security Challenges

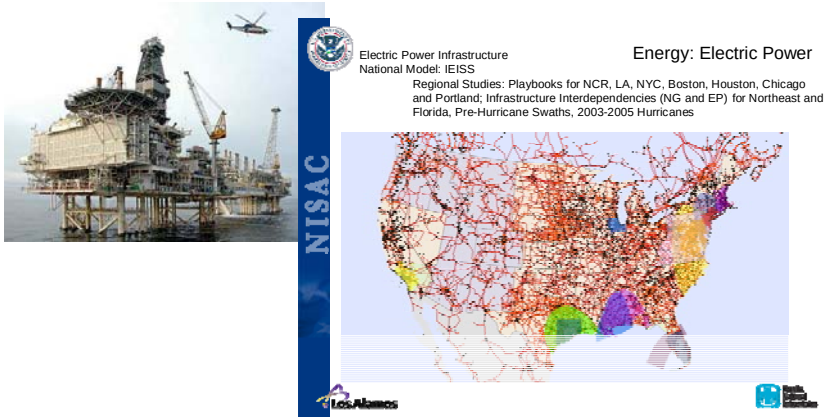
Oil



Natural Gas



Source: BP Statistical Review Of World Energy 2008 (Oil and Natural Gas Trade Flows)

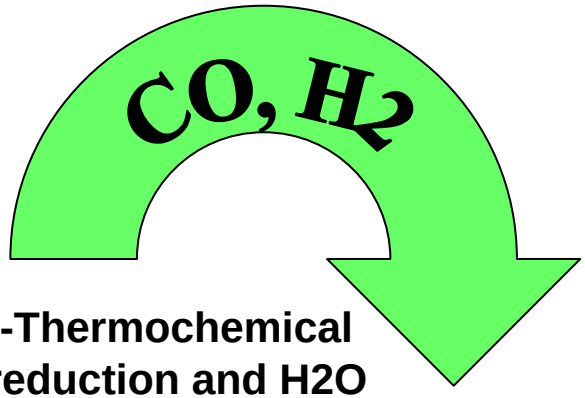


“Tools” Exist or Are Being Developed and Improved to Help Protect the Energy Infrastructure

"S2P: Sunshine to Petrol"
Carbon-Neutral Renewable Gasoline or JP8

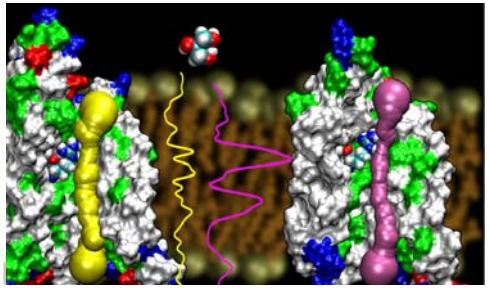
Proof of Concept demonstrated for **Splitting CO2** & **H2O** with a **Solar-**driven Chemical "**Heat Engine**" – Needs R&D to further investigate viability

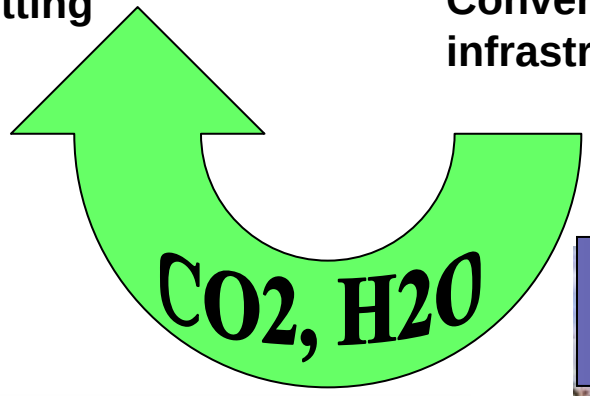
Chemical synthesis of **Gasoline** from the Solar Products and **Conventional Chemistries**.



Solar-Thermochemical CO_2 reduction and H2O splitting

Conventional infrastructure

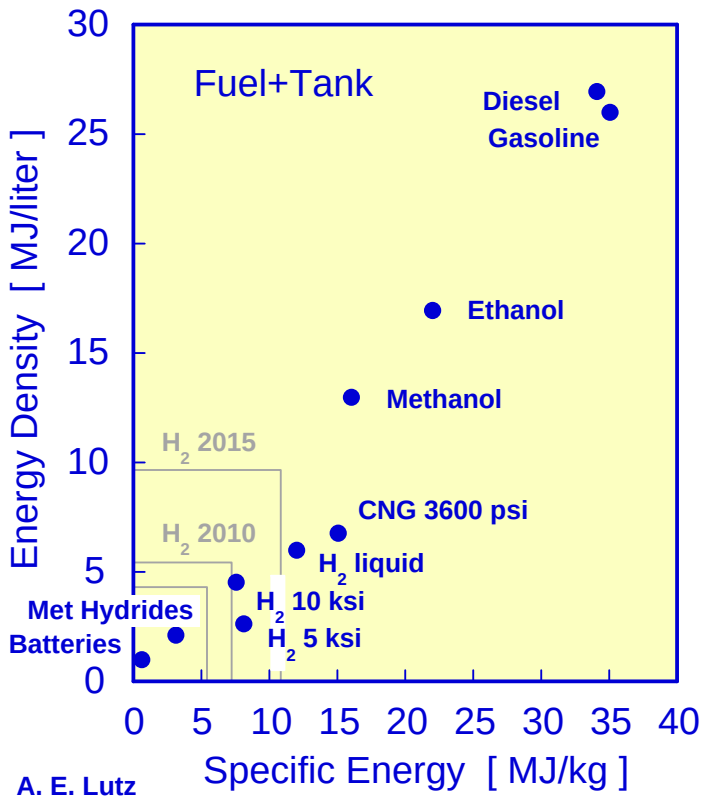


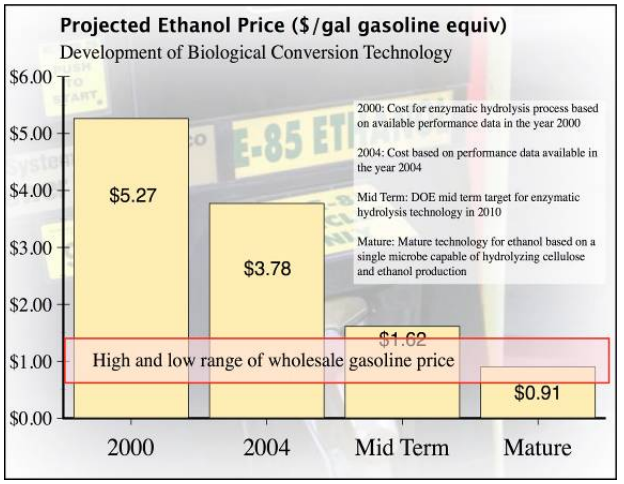


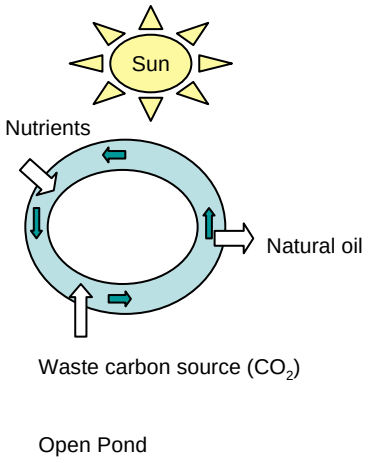
Selective absorbers recover CO_2 from the Atmosphere
(needs invention for economic viability)

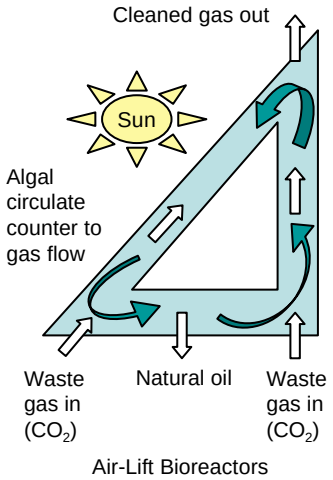
Net 10% of Solar Energy Stored in Chemical Bonds of Gasoline

Making Biofuels Cost Competitive

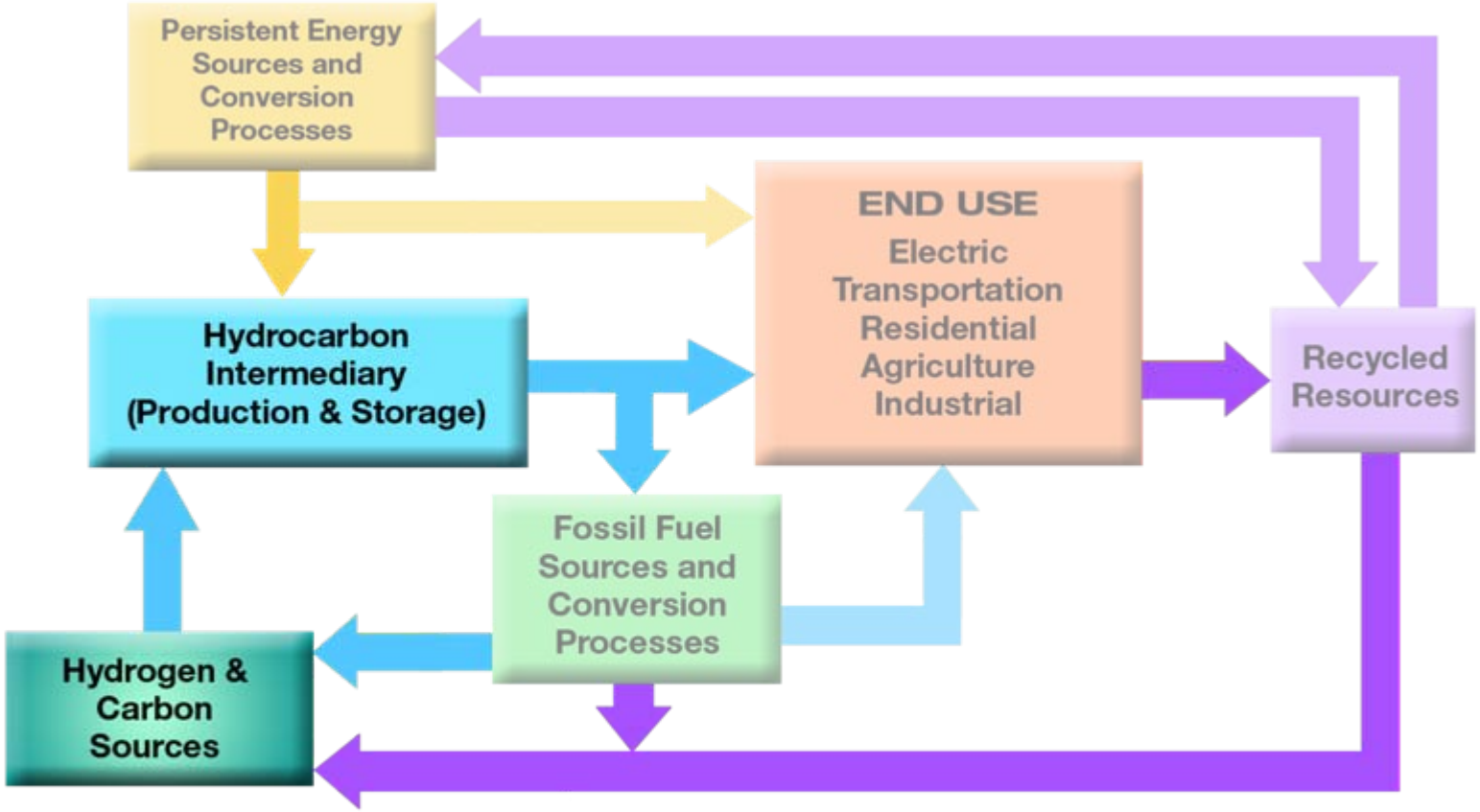


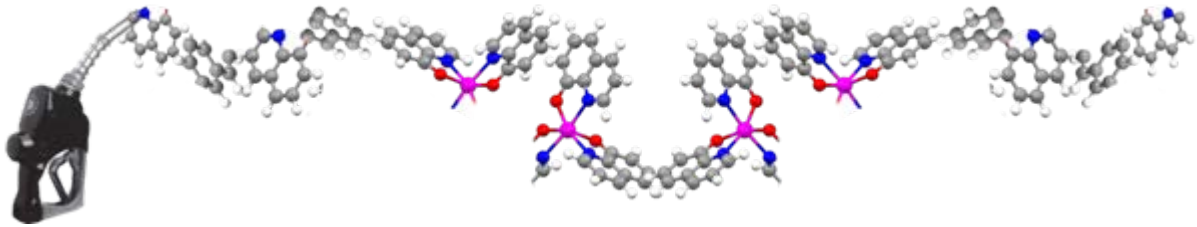




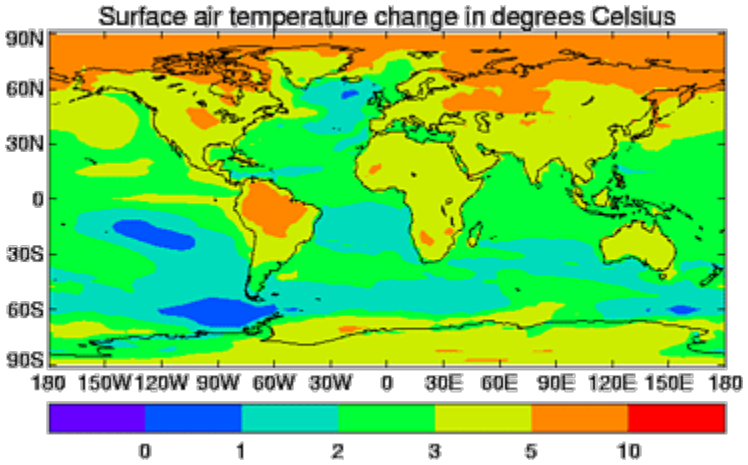


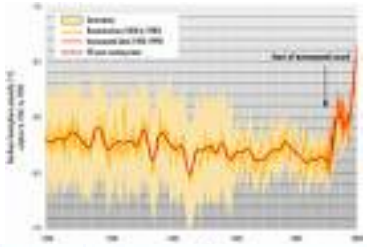
Closing the Energy Cycle

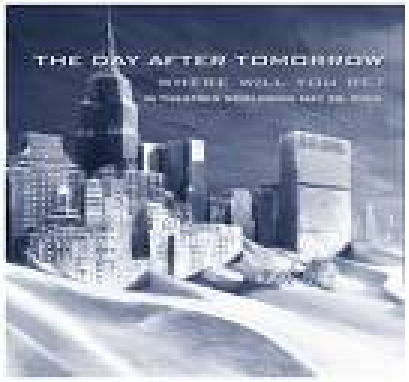




Climate Change Policy is an Enormous Problem



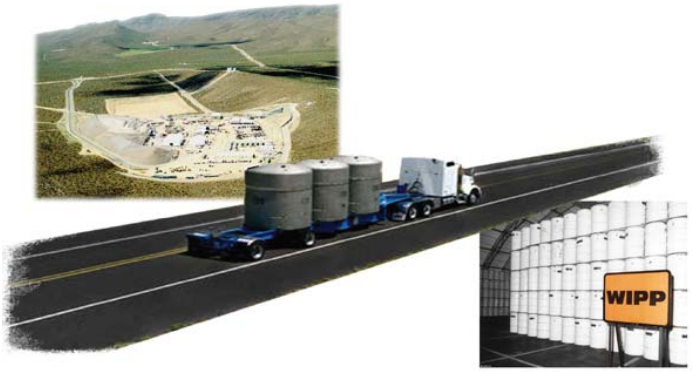




We Support the Integrated Nuclear Power Enterprise

Ensuring Nuclear Facilities are Safe and Secure

Solving the Nuclear Waste Problem



Improving Nuclear Power through Innovation

Preventing Nuclear Proliferation

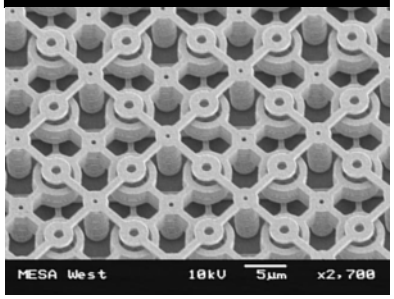
As Nuclear Power Grows, Nonproliferation Will be a Growing Concern

A Range of Technology Innovations Will Enable Advances in Energy Security, Including Infrastructure Protection, Energy Supply, and Consumption

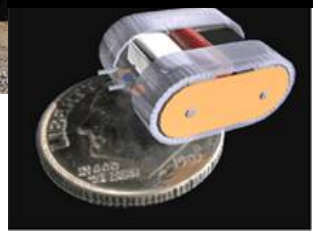
For example:

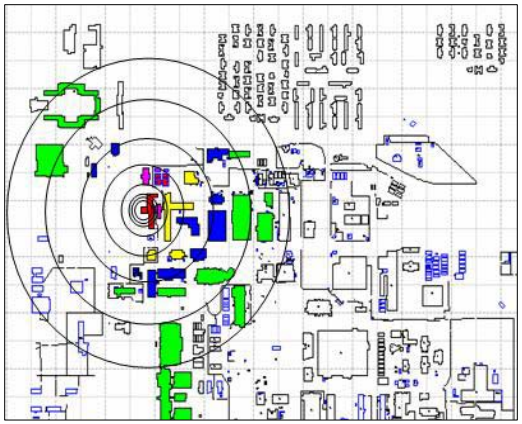
- **High performance computing, including quantum computing for ultra-secure communications**
- **Advanced robotics**
- **Advanced modeling and simulation**
- **Micro-electronic machines and systems**

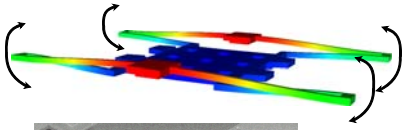
Quantum information processing

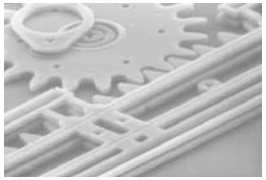


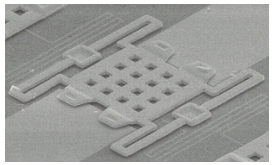
Micro-robot











Some Governments and Car Companies are Aiming for a Hydrogen Economy

Hydrogen could solve key problems:

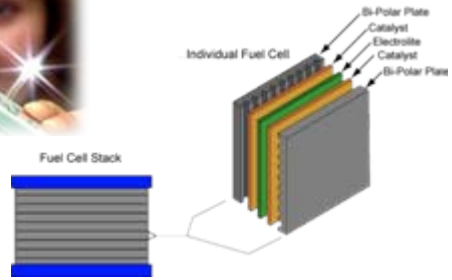
- Reduced (perhaps zero) carbon emissions
- Energy security
- Limited fossil fuels and uneven distribution

Many hurdles to overcome:

- On board hydrogen storage
- Lifetime of fuel cell
- Hydrogen production economics
- Lack of hydrogen infrastructure
- Sequestration of carbon if hydrogen derived from fossil fuels
- Unlikely to be cost competitive until at least mid 2020s

Over Several Decades, Advanced Energy Technologies Could "Disrupt" The Current System

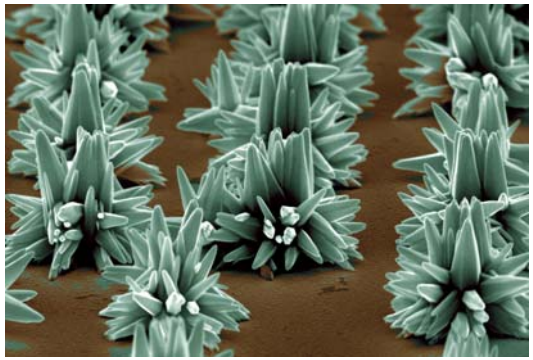
- **Nanotechnology has the potential to fundamentally change energy supply and demand**



Hybrid organic-inorganic solar cells using nano-composite materials

Examples:

- **Solid state lighting using "quantum dots" could cut power for lighting use by 50%**
- **Ultra-high strength lightweight nanophase materials could improve car, airplane efficiency**
- **Nanoparticles and nanoarchitectures for energy conversion and storage may offer solutions to low cost fuel cells and batteries**



ZnO nanostructures - a critical component in low-cost hybrid solar cells

Conclusions

- **The world economy and energy markets will become increasingly integrated and interdependent, though "pull back" risk remains**
  - **Energy use and carbon emissions will grow substantially, driven by the developing world**
  - **The potential for oil and natural gas supply shocks and price instability will increase**
  - **Nuclear power will grow and nuclear technology will spread, increasing the risk of proliferation**
  - **Defense and military complexity will grow, as will requirements for sound, timely intelligence**
  - **Major new energy technology platforms that transform economies and energy could emerge**

Conclusions (continued)

- **As economic competition and cooperation intensify, the scope for national public policies with major economic impact will become increasingly limited**
  - **Need for clear domestic consumer-producer energy price signals and consistent energy security, environmental and economic objectives and policies will grow**
  - **Pressure for policy and regulatory harmonization will increase, as will requirements for decision-making speed, and the cost of mistakes will grow**

Conclusions (continued)

- **Energy infrastructure protection will continue to be a critical component of ensuring national security**
  - **Infrastructure components are widespread, highly visible, and accessible**
  - **Many transportation and delivery nodes and links are exposed and in unstable and/or unfriendly regions**
  - **Growing energy markets and integration will stretch infrastructure systems and add complexity to their operation and security**
  - **Tools are being developed and improved to help provide protection**
  - **Systems analysis, enhanced intelligence, and, as a last resort, military force may be brought to bear**
  - **New technologies will enable additional creative solutions**

Conclusions (continued)

- **International flexibility, cooperation and partnering on many fronts, including defense, intelligence, non-proliferation, public policy and science & technology investment, will be critical to**
  - **Avoid bumps in the road**
  - **Support international economic and political security**
  - **Improve the health and well being of the developing world**
  - **Provide a foundation for global and regional economic prosperity and environmental sustainability**