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A Global Perspective on Energy Markets, Climate Change & Economic Integration: Problems and Prospects

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Dr. Arnold B. Baker
Chief Economist
Sandia National Laboratories
505-284-4462
abbaker@sandia.gov

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Global GDP 2007
(Current Exchange Rates)

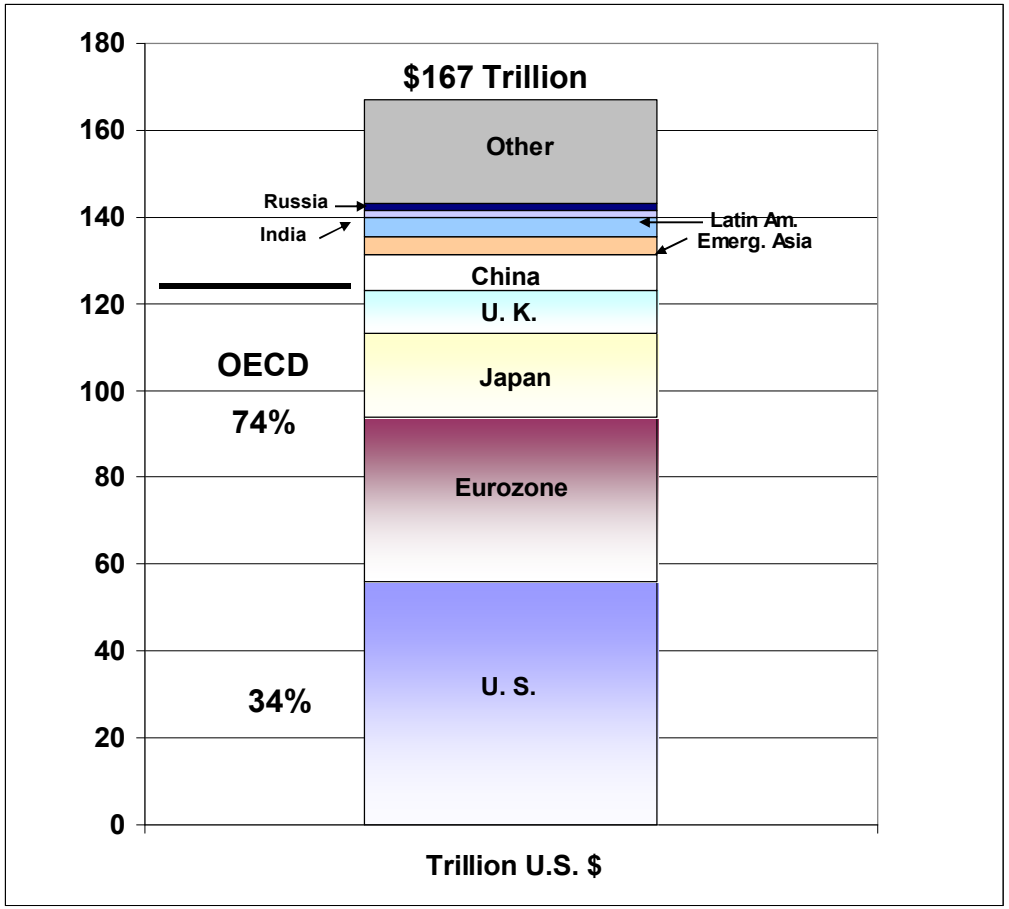
Country (Rank)	$ Trillion
U.S. (1)	13,843
Japan (2)	4,379
Germany (3)	3,329
China (4)	3,242
U.K. (5)	2,774
France (6)	2,555
Italy (7)	2,110
Spain (8)	1,437
Canada (9)	1,423
Brazil (10)	1,321
India (11)	1,137
Russia (12)	1,288
S. Korea (13)	970

Country (Rank)	$ Trillion
Australia (14)	907
Mexico (15)	892
Netherlands (16)	766
Turkey (17)	499
Belgium (18)	456
Sweden (19)	454
Indonesia (20)	435
Switzerland (21)	421
Poland (22)	420
Norway (23)	385
Taiwan (24)	382
Saudi Arabia (25)	376

World	54,396
OECD	40,304

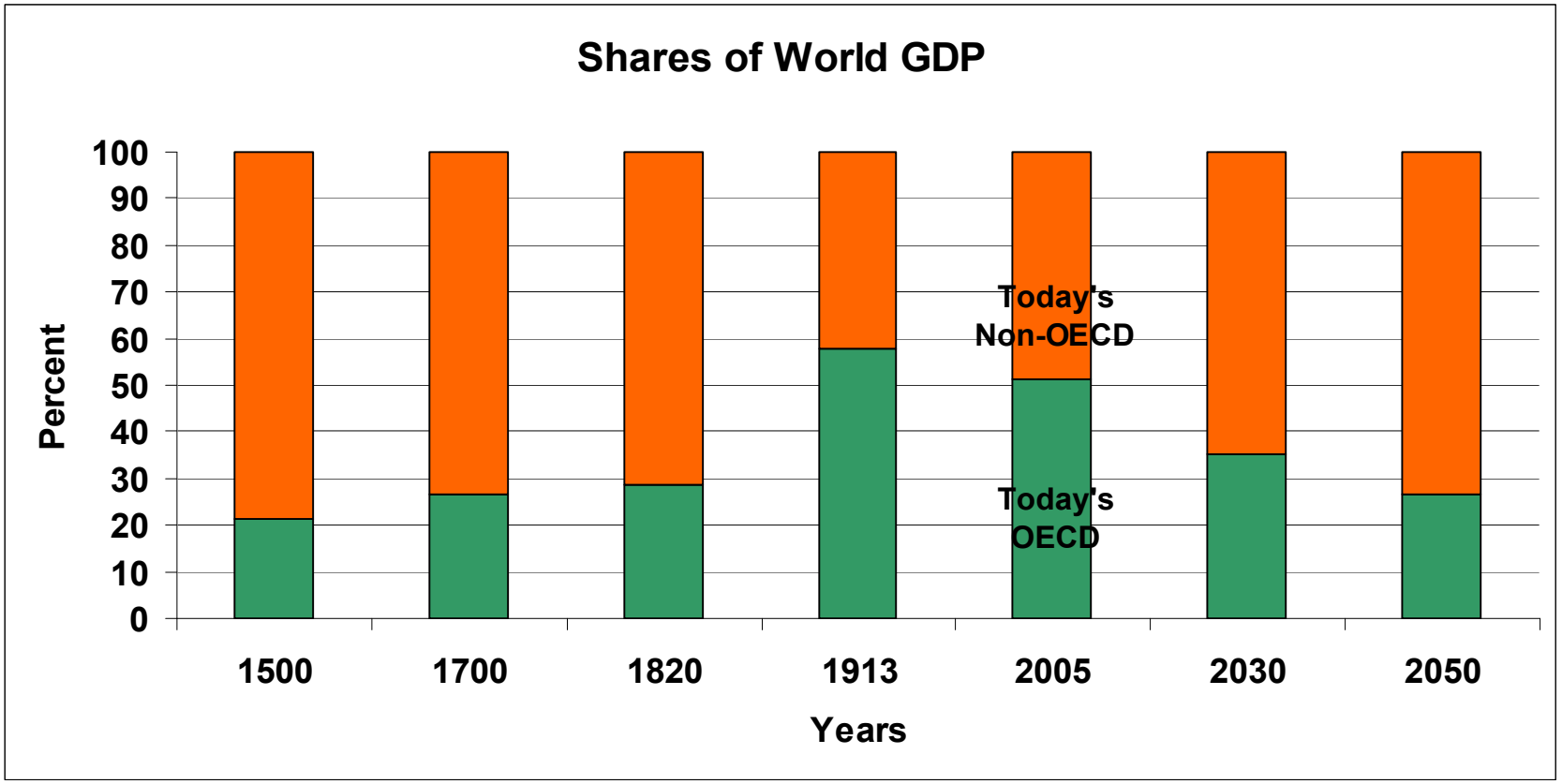
Source: Global Insight, February, 2007

Global Financial Assets 2007



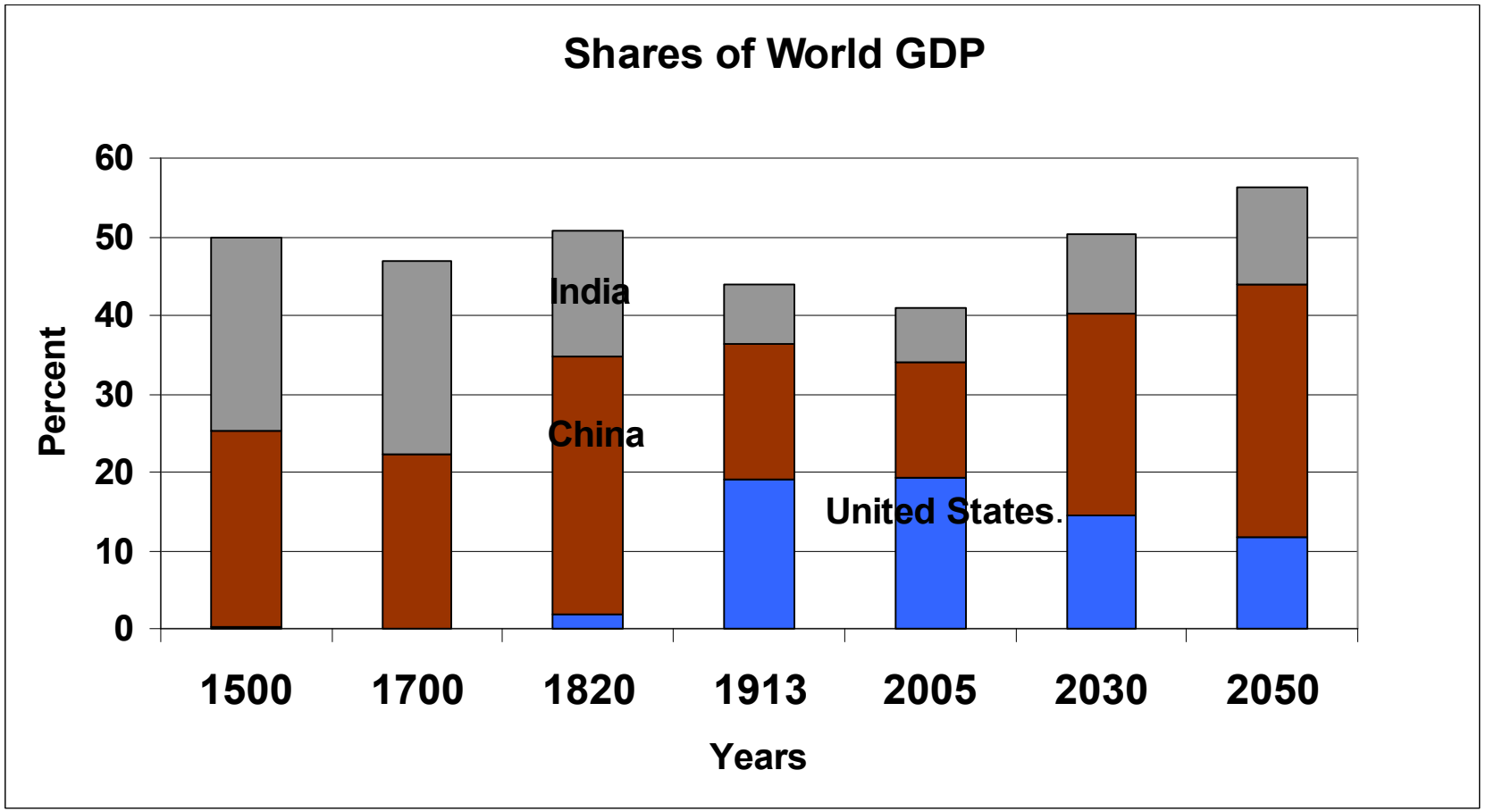
Source: Mapping Global Capital Markets, Fourth Annual Report, McKinsey Global Institute January 2008. Includes equities, private debt, government debt and bank deposits

A Transitional Power Shift



Source: The World Economy, OECD 2001, Angus Maddison; DOE/EIA International Energy Outlook, 2007, extrapolated to 2050

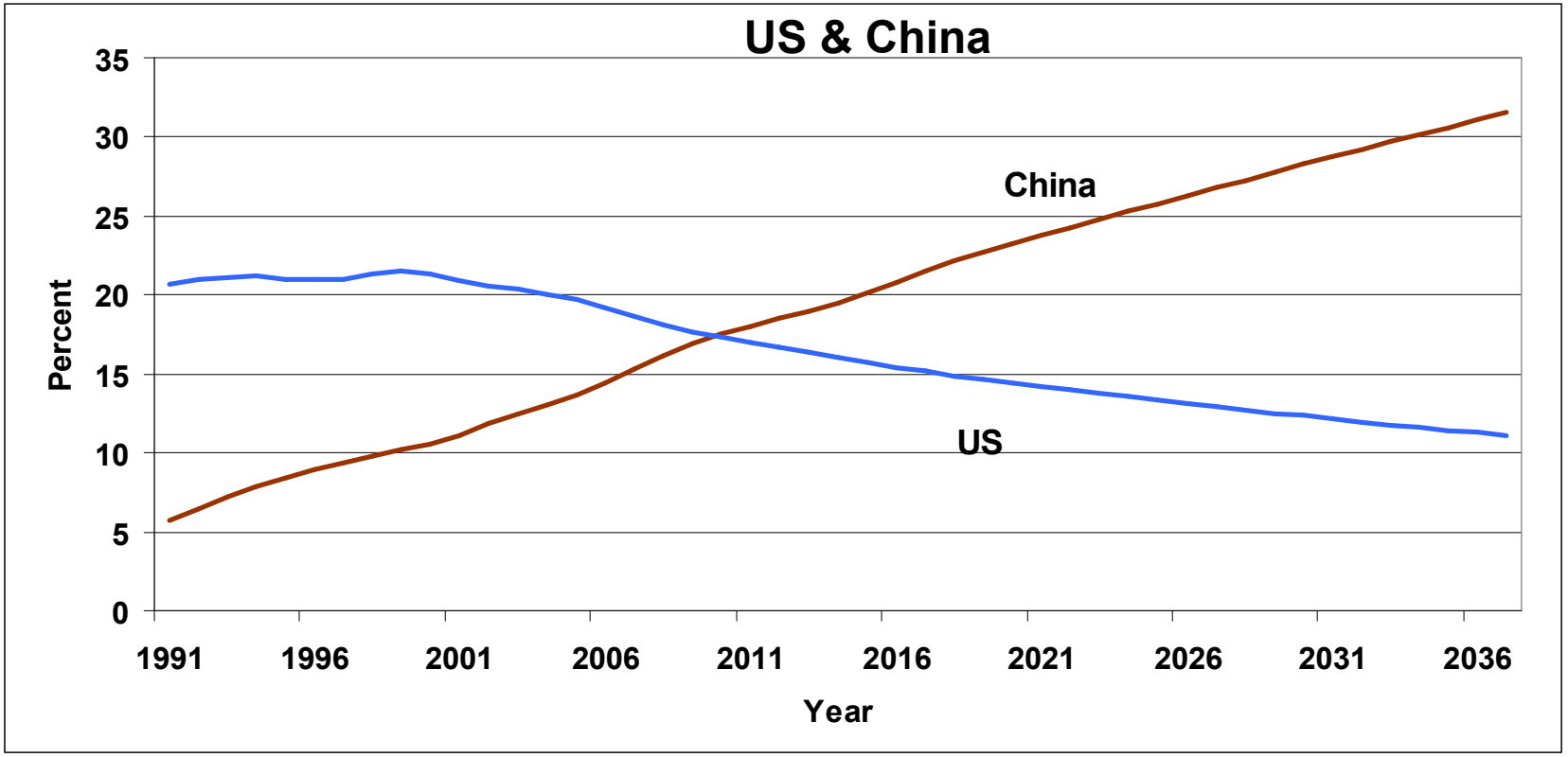
A Transitional Power Shift
(Continued)



Source: The World Economy, OECD 2001, Angus Maddison; DOE/EIA International Energy Outlook, 2007, extrapolated to 2050

A Transitional Power Shift
(Continued)

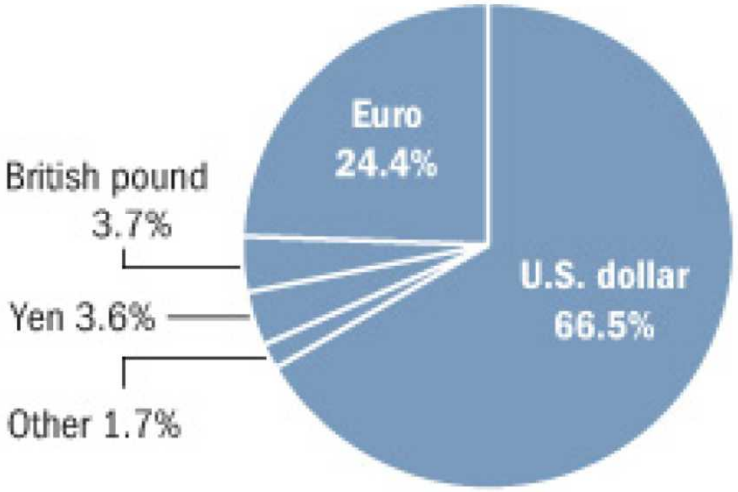
Shares of World GDP



Source: Global Insight, January 2008, $2000, PPP Basis

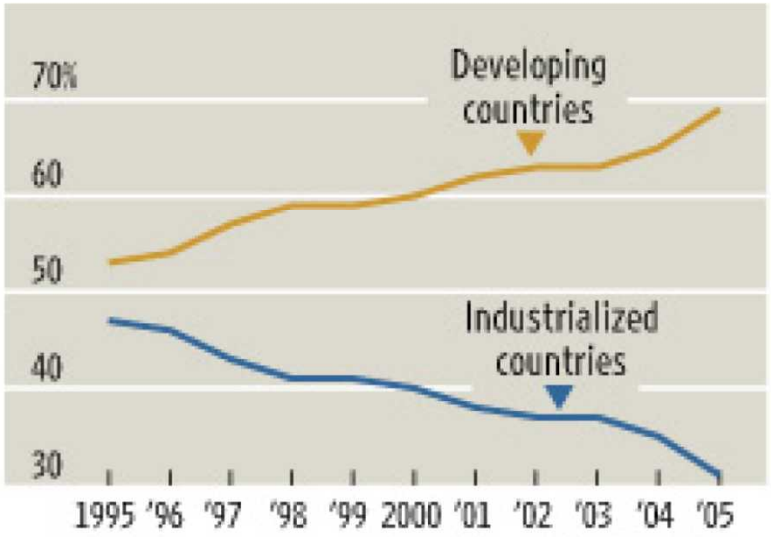
A Transitional Power Shift
(Continued)

Share of global foreign exchange reserves for 2005, by currency



Source: IMF; Investment Strategies Group at Bank of America

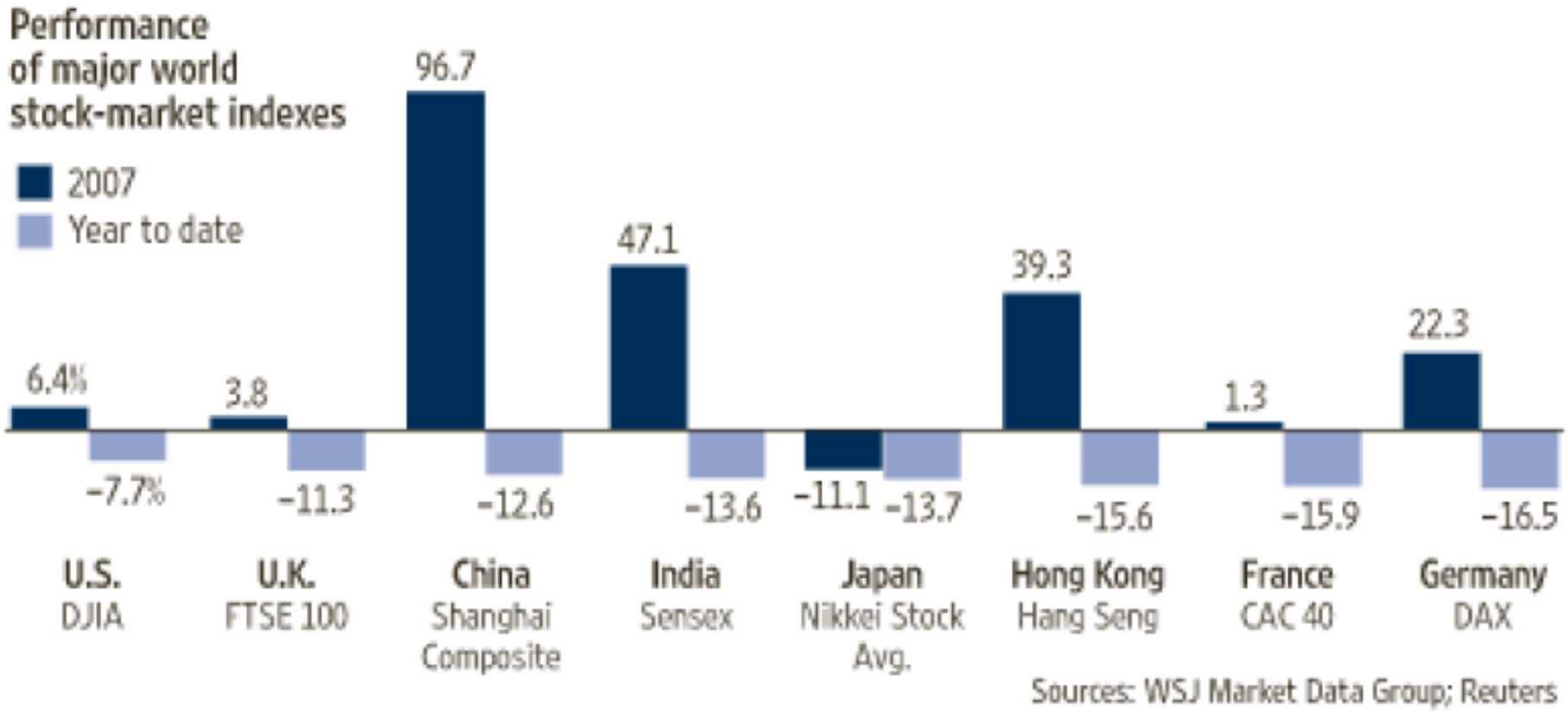
Official reserve holdings as a share of the global total



Our national economies are becoming increasingly intertwined

Source: Wall Street Journal, May 9, 2006, P. 8

World Financial Markets Have Become Increasingly Integrated



Source: Wall Street Journal, February 8, 2008, P. C3

The "Subprime Mortgage" Flu: Financial Markets Get The Fever

- **Financial institutions are creative, competitive and outgrew well intended regulations in pursuit of profit**
  - U.S. mortgage lending--with low interest rates, rising housing prices became a "sure thing" and lending standards were ignored
  - "Securitization" and "bets" extended to other debt/financial instruments
    - » Lack of transparency (how many loans were "bad")
    - » Inaccurate risk pricing/ market value (some "securities" didn't trade in open markets, so the companies valued them themselves)
    - » Rating agencies may have violated standards
- **Companies and financial institutions became afraid to lend to each other, which in the extreme, could shut down the financial system**
- **Fed has two worries**
  - Subprime failure would lead to recession (with falling housing prices and mortgage defaults, consumers would quit spending)
  - The US and global financial system would freeze (the major fear)
- **Fed-USG solutions**
  - Add high quality liquidity to the markets (reduce discount rates)
  - Reduce short term interest rates (Federal Funds rates), add fiscal stimulus (USG)
  - Attempt to reduce mortgage defaults (USG/banks)

The "Subprime Mortgage Flu": The Road to Recovery

- **Financial community knows it must improve regulations and transparency--it will**
  - Federal Reserve support; European leaders pushing for tougher global bank/financial market regulations, utilizing Swiss Financial Stability Forum and IMF
  - U.S. probes by FBI, SEC, DOJ & some states; S&P/rating agency bond/security downgrades
  - Losses will have to be recognized and written off

- **Seeds of inflationary cycle potentially sown**
  - All else equal, increasing money supply (reducing short term interest rates) stimulates inflation; monetary policy works with 6-9+ month lag
  - US stimulus package will put funds into economy by summer

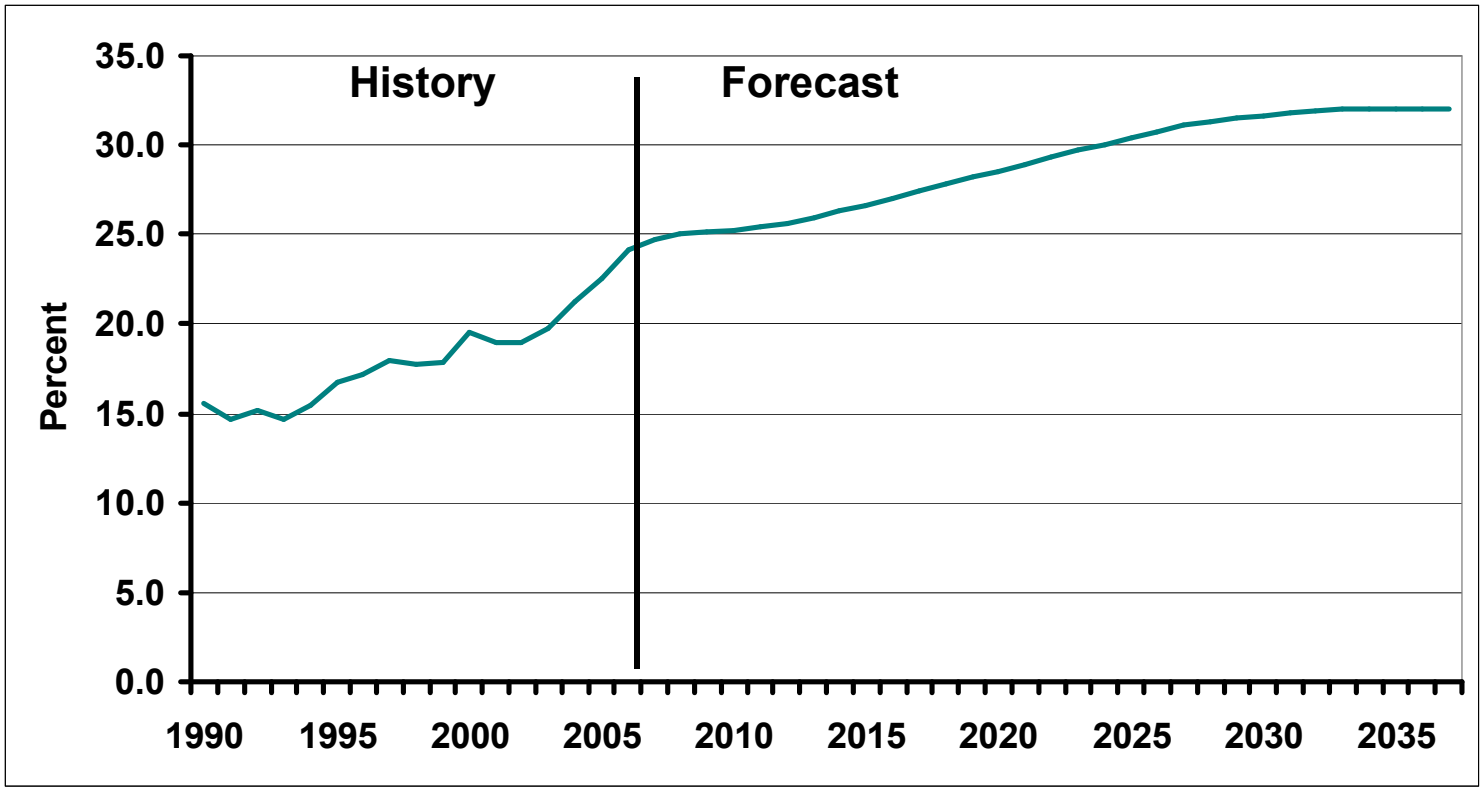
- **The US dollar can fall further**
  - Reducing short term US interest rates can reduce relative dollar value
  - Fear of longer term inflation can reduce dollar (shift from dollars to more stable currency)
  - Central bank coordination important (ECB, BoE, etc.)

- **Monetary policy management will be very complex over the next couple of years**
  - Especially given the new US President and Congress in 2009 that may want to make changes the fiscal policies of the last eight years

- **Further downside risks remain**
  - Risk of adverse feedback - "deleveraging": financial losses, tight credit standards, slow economy, financial losses….

World Economy Has Become Increasingly Integrated

World Merchandise Exports As A Percent of GDP



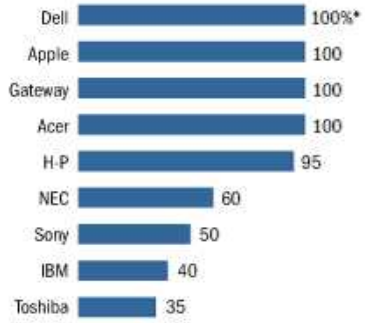
Source: Global Insight, January 12, 2008

As Have Manufacturing Supply Chains

All Over the Map

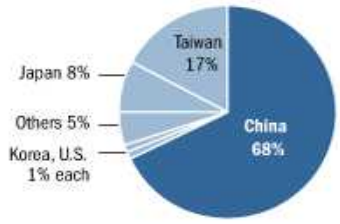
When a U.S. customer orders an H-P Pavilion laptop, the request travels all the way to China in just days. A look at the process, and China's increasing role not just as manufacturer, but supplier of more sophisticated laptop parts

Outsourcing ratio for world's top laptop PC brands, 2004:



*Dell takes care of final assembly in its factories.
Source: Merrill Lynch

World-wide laptop PC production by country, 2005:



Source: IDC

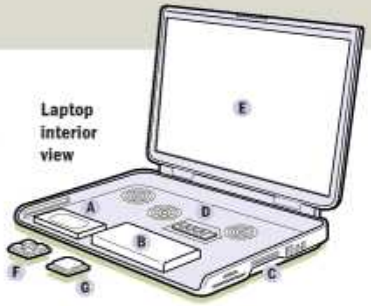
Filling the order

1. **Order** placed online in the U.S.
2. **Validated** order transmitted to Taiwanese-owned Quanta plant in Shanghai
3. **Laptop assembled** from parts from China and all over the world
4. **Computer shipments** consolidated at Shanghai airport and flown freight to the U.S.
5. **Individual laptops** sent to customers

Putting it together

A	**Hard-disk drives**	Japan, China, Singapore, U.S.
B	**Power supplies**	China
C	**Magnesium casings**	China
D	**Memory chips**	S. Korea, Taiwan, U.S., Germany
E	**Liquid-crystal display**	S. Korea, Taiwan, Japan, China
F	**Microprocessors**	United States
G	**Graphics processors**	Designed in U.S., Canada; made in Taiwan

Note: List does not include every country that manufactures a given part.
Sources: Hewlett-Packard; WSJ research



Source: Wall Street Journal, June 9, 2005, p. B1

And Universities and Boardrooms

For example, Singapore has courted top-tier schools:

- 1998: French business school INSEAD
- 2000: University of Chicago
- 2003: Johns Hopkins Singapore
- 2003: Duke
- 2005: MIT

Boardrooms

- 90% of Europe's largest concerns have one or more directors from outside their home country
- 35% of 149 large U.S. businesses have at least one non-American director

Source: Wall Street Journal, July 12, 2005, p. B1

This Trend Toward Interdependency Will Accelerate

- **The Internet and silicon revolution will continue to break down communication and economic barriers**
  - More countries will participate in world economy and financial markets
  - Integrated supply chain logistics of service & manufacturing industries will seamlessly cross national borders
    - » As will distance education and technology transfer
- **Both global economic competition and global economic cooperation will intensify**
- **Scope for national public policies with major economic impact will become more limited**
  - Can't afford to have costs out of line with competitor countries
  - Will affect energy/environment/social/defense-security policies
  - Driven toward greater policy/regulatory harmonization (lowest common denominator?)

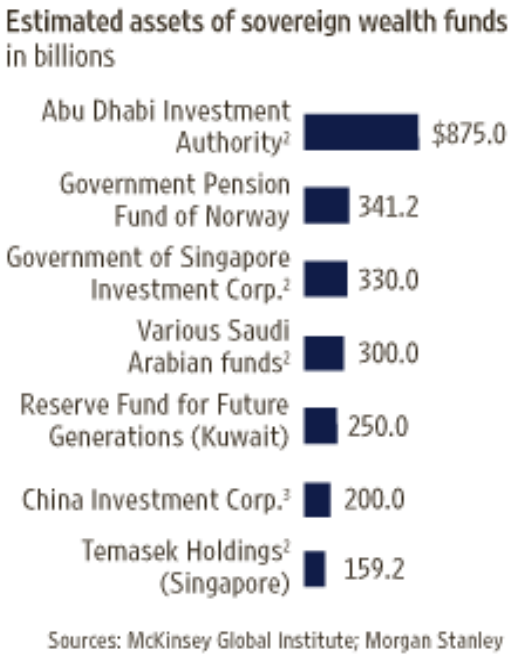
But Protectionist Seeds Are Sprouting

- European "national champion" utility company mergers
- U.S. ChevronTexaco—UNOCAL (CNOOC); Dubai Ports World; Bain Capital/Huawei—3Com
- China/emerging markets competitive threats
  - Low cost manufacturing, "low value" Yuan "management"
- Export fees (food)
- U.S. and Europe considering carbon import fees
- Sovereign wealth funds

Domestic Politics vs.

International Competition and Economics:??

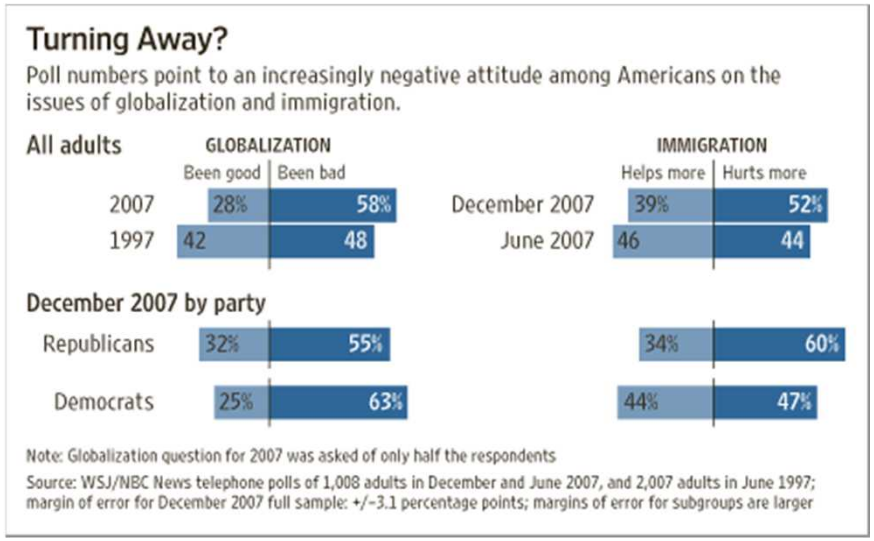
Sovereign Wealth Funds

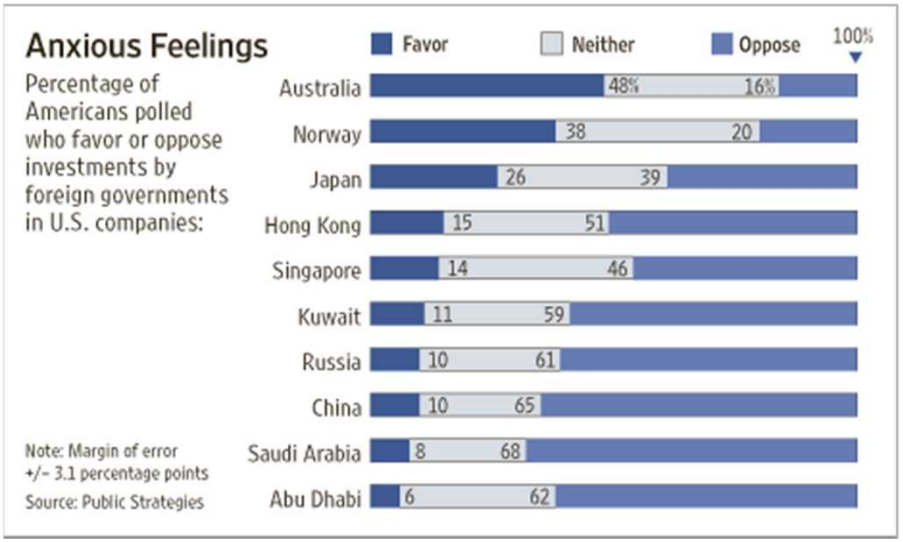


Source: Wall Street Journal, January 28, 2008, p. A2

Source: Wall Street Journal, January 10, 2008, p. A1

But Protectionist Seeds Are Sprouting (Continued)

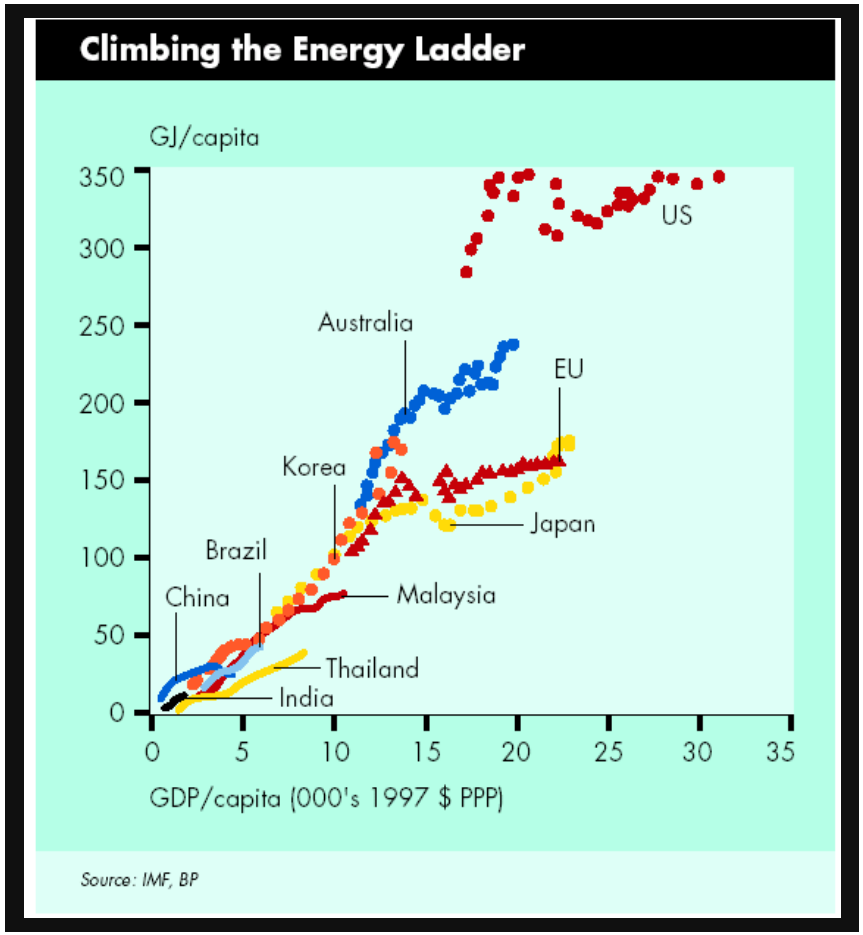




Source: Wall Street Journal, December 20, 2007, P. A13

Source: Wall Street Journal, February 21, 2007, P. A9

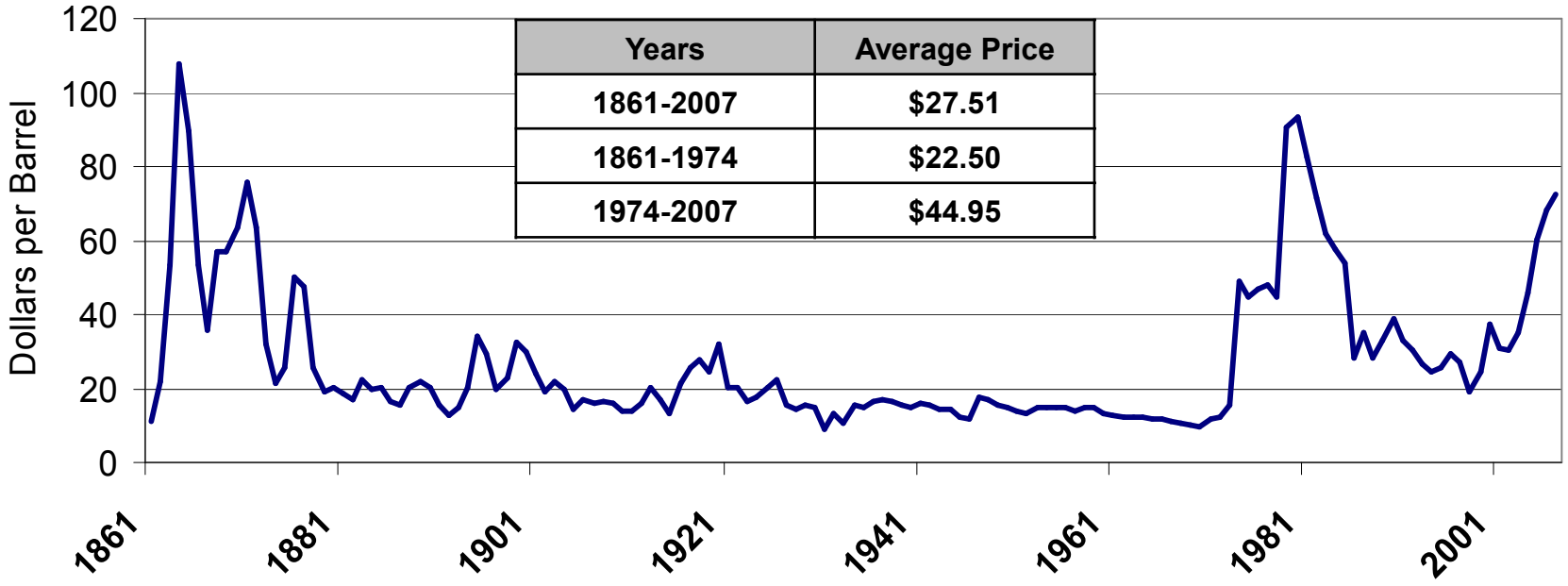
Economic Prosperity and Stability Require Access to Reliable and Affordable Energy



Source: Royal Dutch Shell, "Exploring the Future – Energy Needs, Choices and Possibilities", 2001

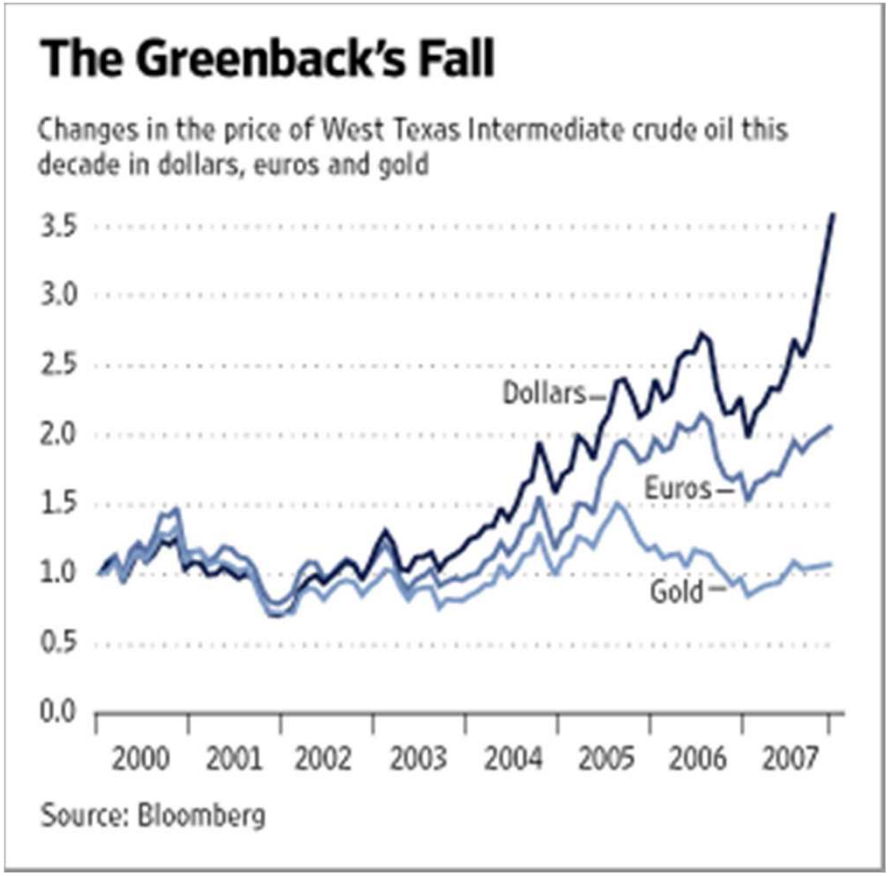
Real Oil Prices Have Varied Considerably

Real Oil Prices in $2007/Barrel



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

Oil Prices in Dollars, Euros and Gold



Source: Wall Street Journal, January 4, 2008, p. A 10

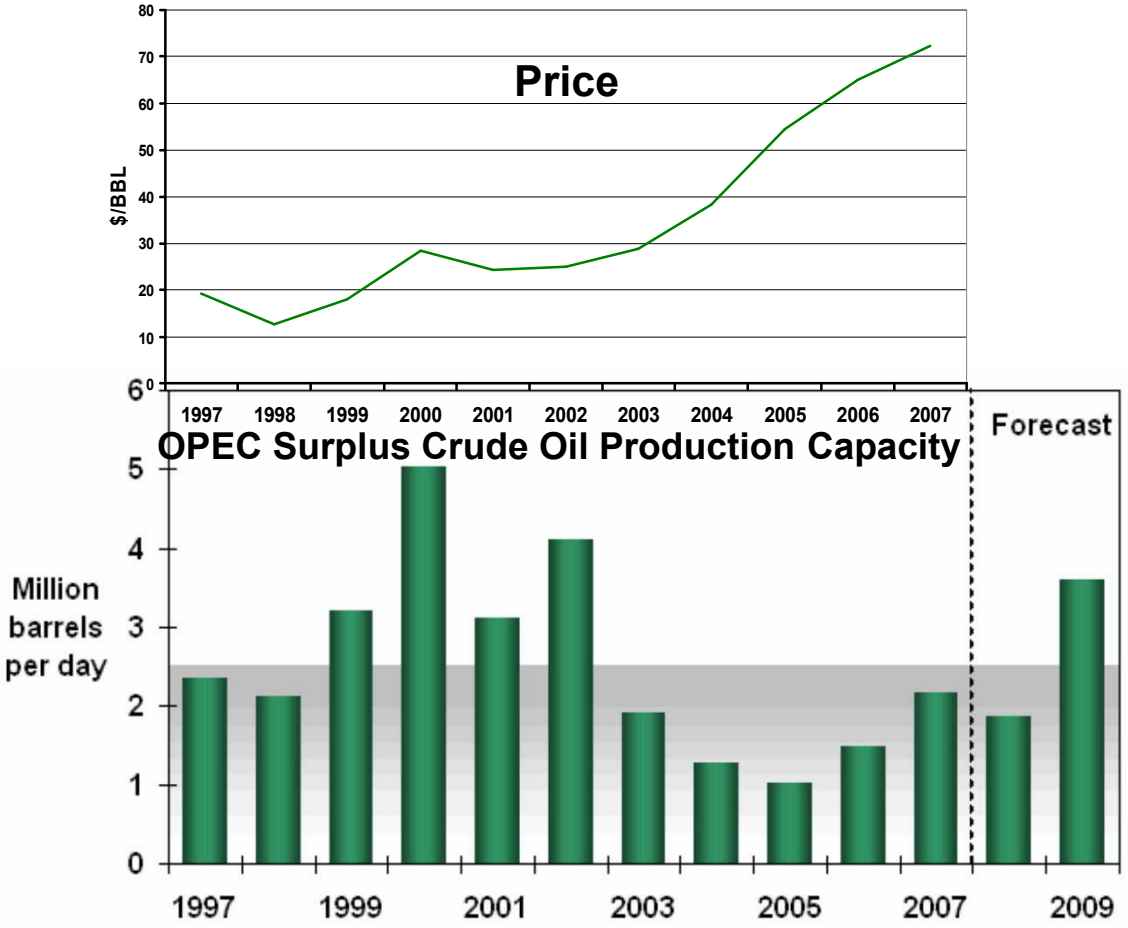
Top Oil Producers and Consumers 2006

	Country	Total Liquids Production MMBD
1	Saudi Arabia*	10.72
2	Russia	9.67
3	U.S.	8.37
4	Iran*	4.15
5	China	3.84
6	Mexico	3.71
7	Canada	3.29
8	UAE*	2.94
9	Venezuela*	2.80
10	Norway	2.79
11	Kuwait*	2.67
12	Nigeria*	2.44
13	Brazil	2.16
14	Algeria*	2.12
15	Iraq*	2.00

	Country	Total Liquids Consumption MMBD
1	U.S.	20.58
2	China	7.27
3	Japan	5.22
4	Russia	3.10
5	Germany	2.63
6	india	2.53
7	Canada	2.22
8	Brazil	2.18
9	South Korea	2.16
10	Saudi Arabia	2.07
11	Mexico	2.03
12	France	1.97
13	U.K.	1.82
14	Italy	1.71
15	Iran	1.63

Source: EIA topworldtables

Surplus OPEC Oil Production Capacity Drives Market Prices



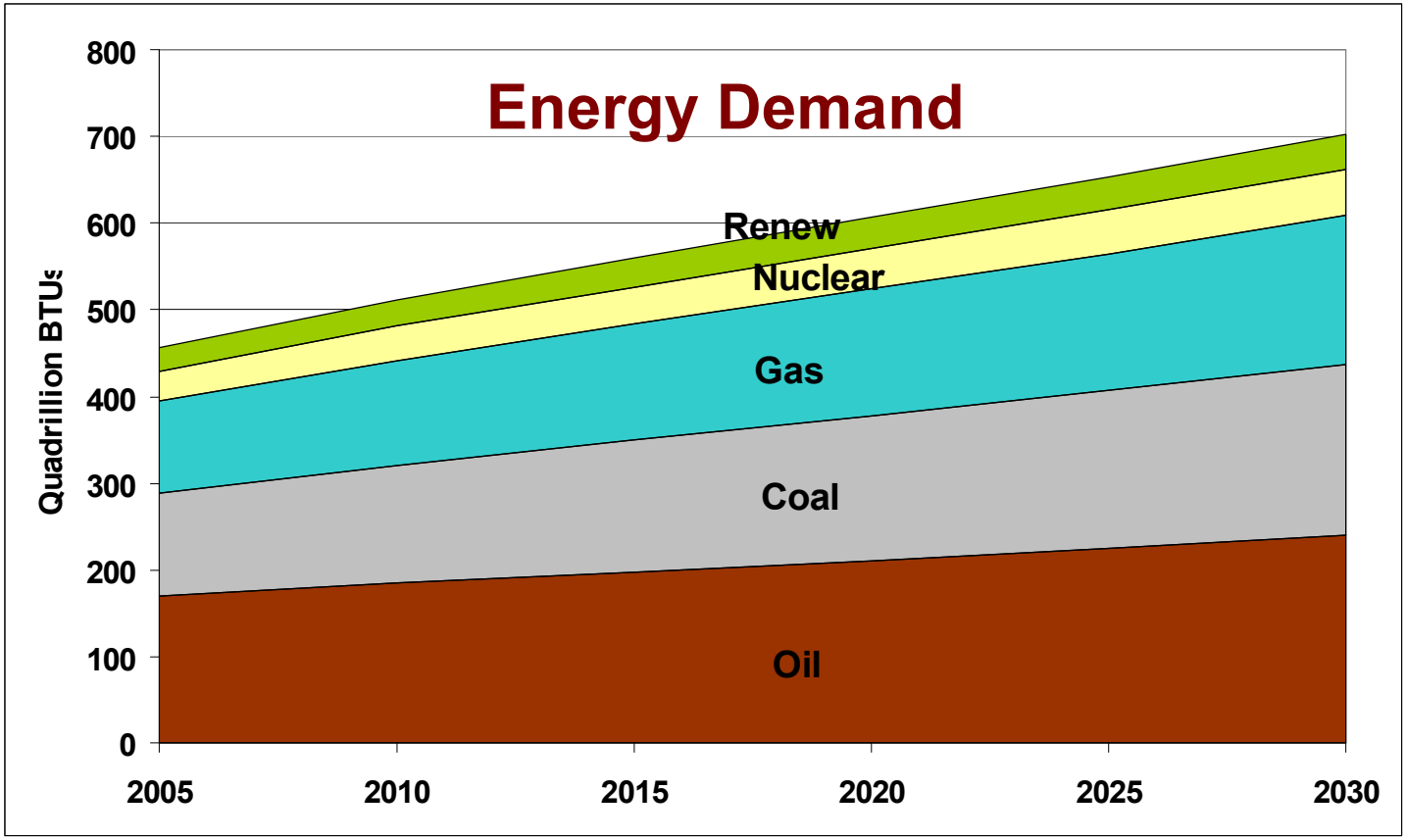
Note: Shaded area represents 1997-2007 average (2.5 million barrels per day)

Source: Short-Term Energy Outlook, January 2008 *and BP Statistical Review of World Energy 2007*

Over the Near to Medium Term, Oil and Gas Markets Face Many Uncertainties

- Iraqi domestic instability on Iraqi oil production
- Negotiations for Iranian nuclear technology on Iranian oil supplies
- Saudi commitment to expanded oil production
- President Putin's policies on Russian oil and natural gas supplies
- President Chavez's policies on Venezuelan oil supplies
- Instability in Nigeria
- High oil price/financial turbulence effect on world economic growth
  - Effect of economic growth on oil demand in China, India, U.S., etc.
- Effect of high oil prices on non-OPEC oil supplies
- Siting of LNG facilities

Between 2005 and 2030
World Energy Demand Will Grow Over 60 Percent

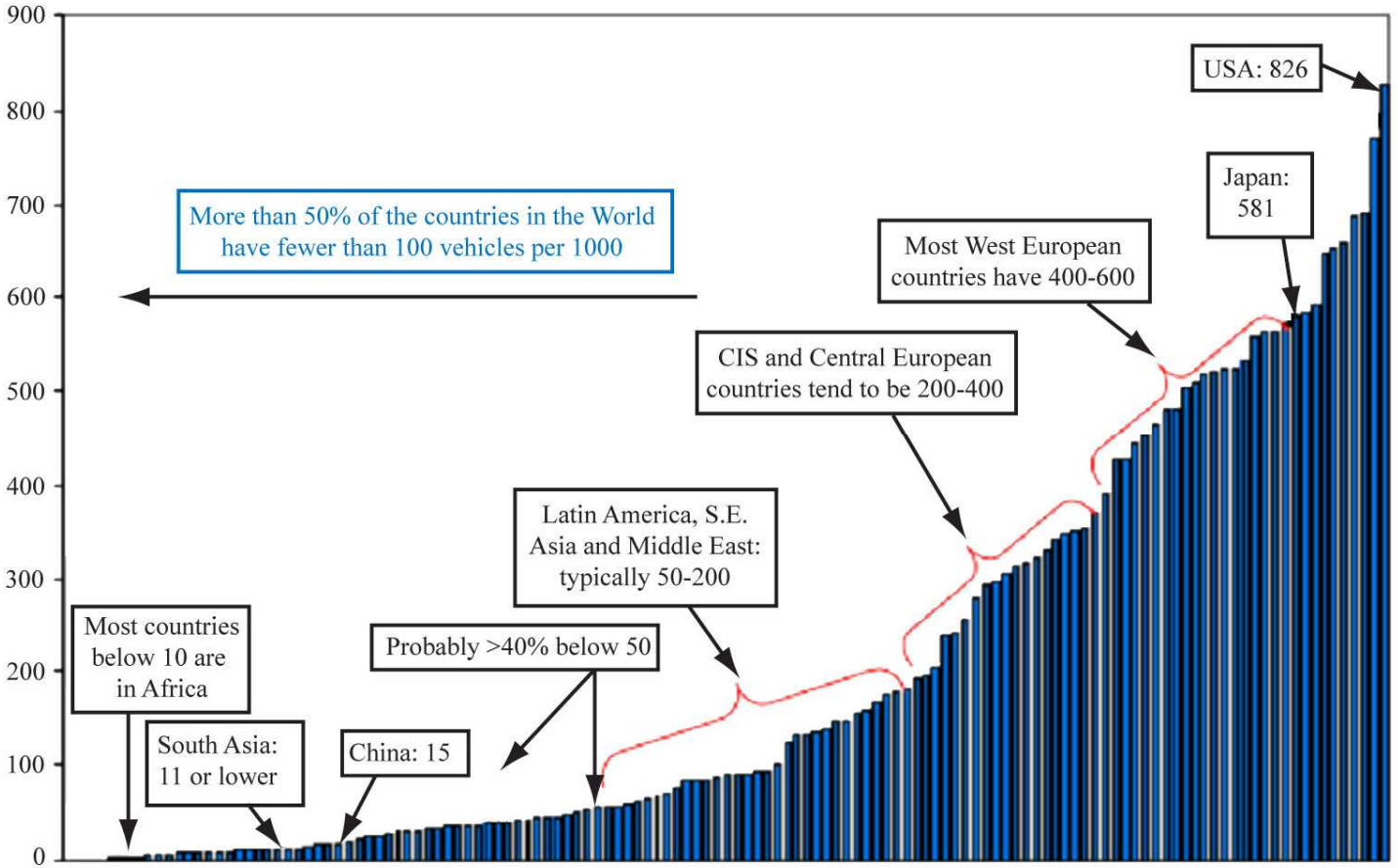


and Developing Countries will Account for 3/4 of the Increase

Source: USDOE EIA IEO 2007 Reference Case

Developing World Vehicle Ownership May Grow Considerably

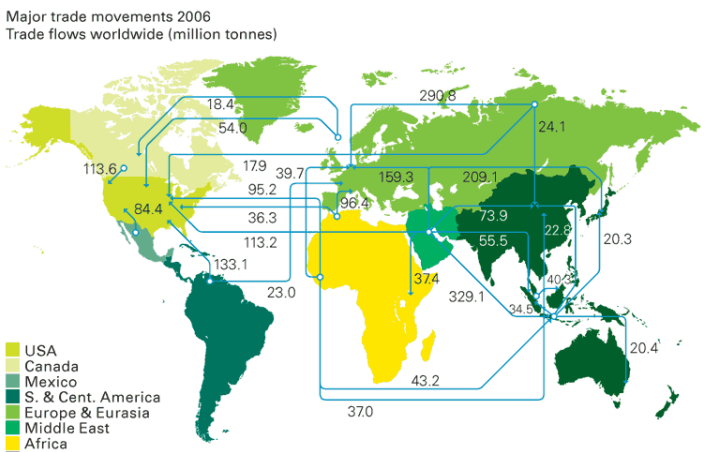
Vehicle ownership in 2003, per 1000



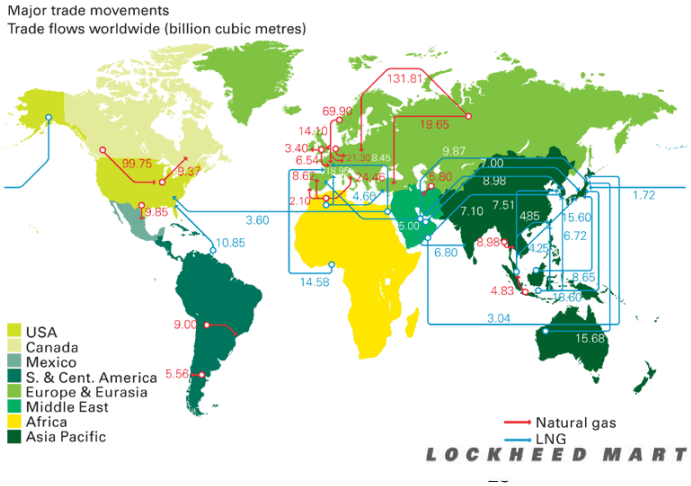
Source: "Oil Outlook to 2025," OPEC Secretariat Paper, 10th International Energy Forum, Doha, April 22-24, 2006, figure 2.4, p. 11

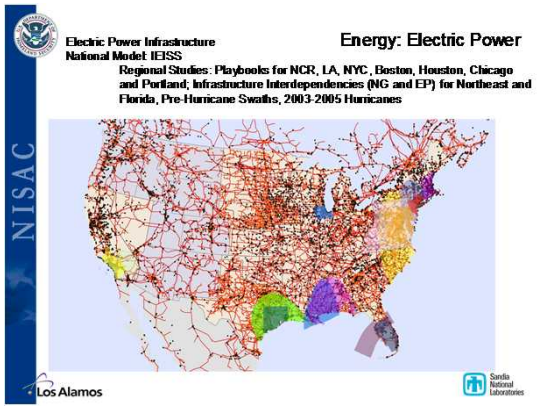
Energy Trade and Infrastructure Will Grow, Presenting Unique Security Challenges

Oil



Natural Gas





The World's Proven Fossil Fuel Reserves are Geographically Concentrated

(Percent Share)

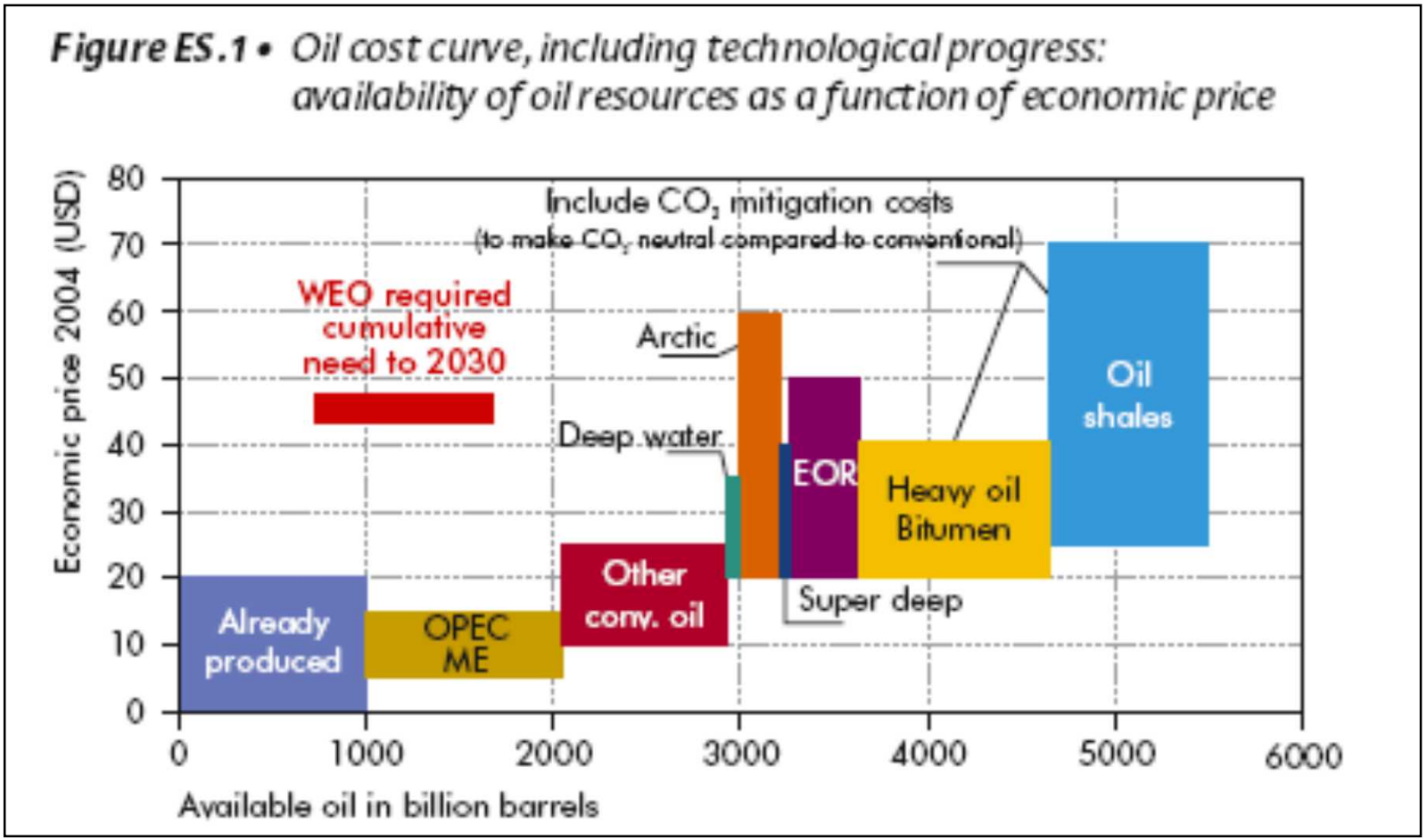
Region	Oil	Gas	Coal
Key Persian Gulf	55	41	< 1
Saudi	20	4	0
Iran	10	16	< 1
Iraq	9	2	0
Kuwait	8	< 1	0
UAE	7	3	0
Qatar	1	15	0
Canada	14	< 1	< 1
Venezuela	6	2	< 1
Russia	5	27	17
U.S.	2	3	27
China	1	1	13
India	< 1	< 1	10
ROW	17	24	32
Total	100	100	100

Source: Oil & Gas Journal 1/1/07; EIA Int. Energy Ann. 6/21/07.

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

A Wide Range of Prospects for Alternative Liquid Fuels, But They Will Take Time to Develop

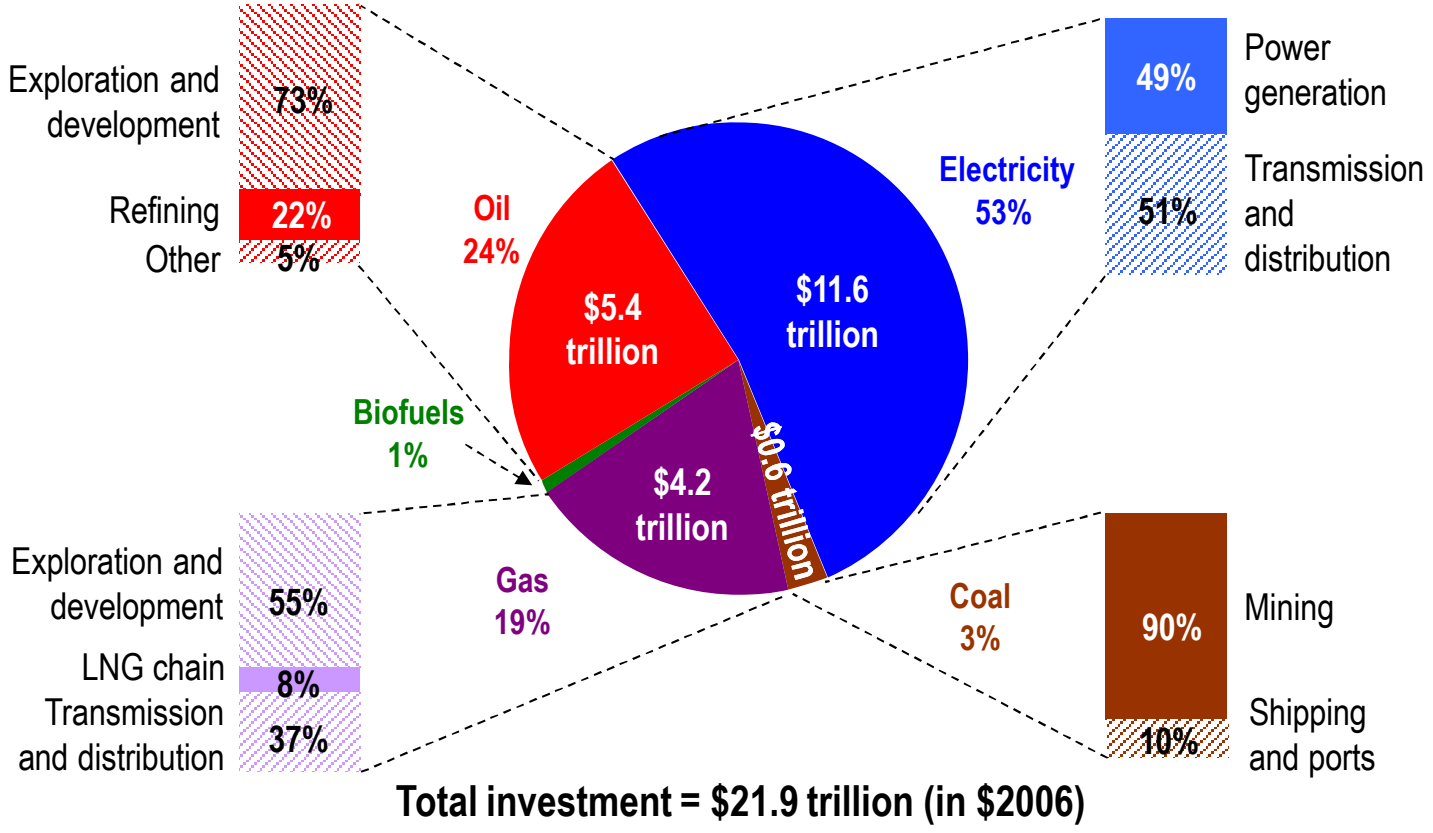
IEA's Oil Cost Curve



Source: Resources to Reserves, Oil and Gas Technologies for the Energy Markets of the Future, OECD/IEA 2005, P. 17

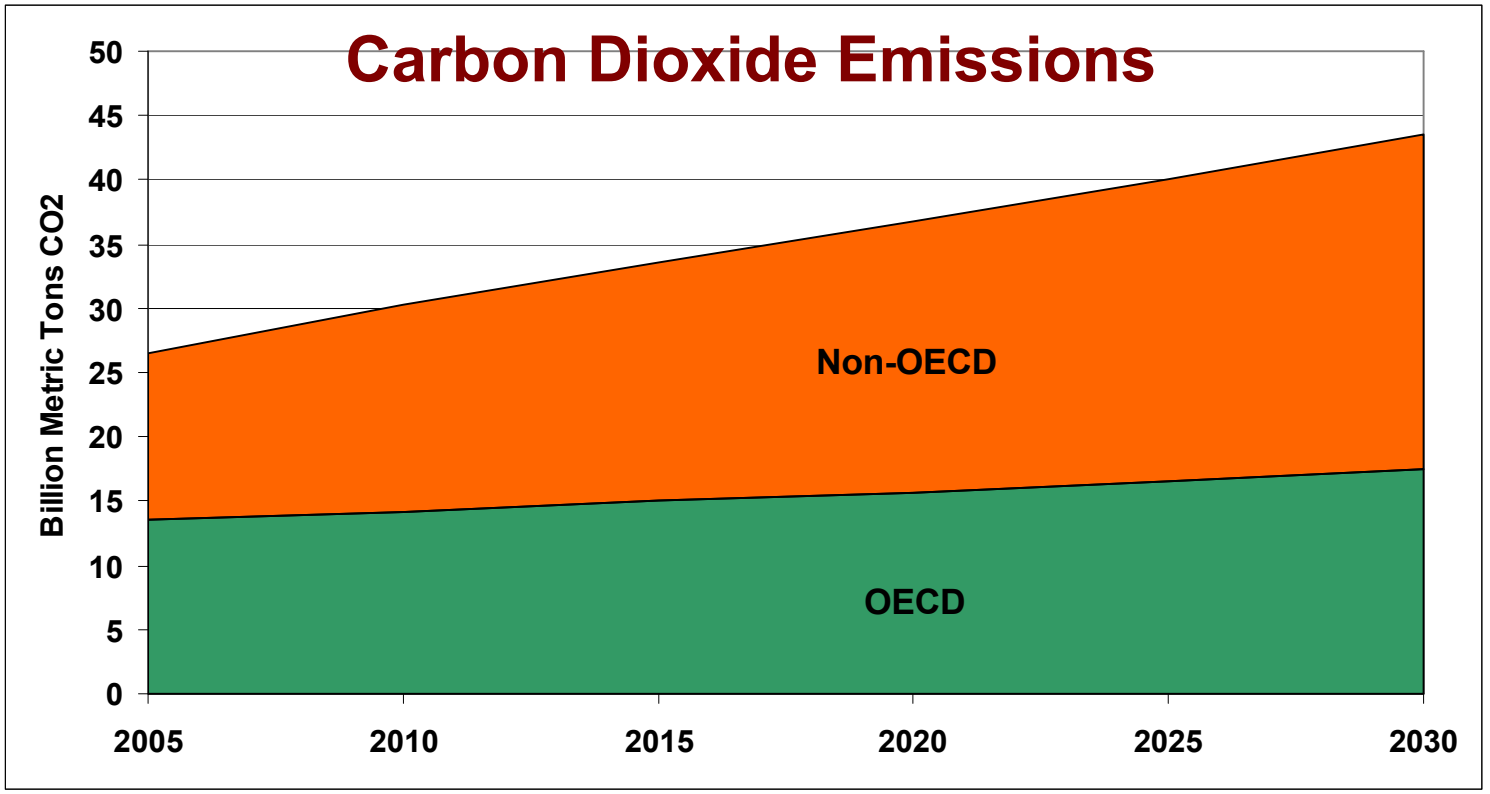
IEA WEO 2007 Reference Scenario:

Cumulative Investment in Energy-Supply Infrastructure, 2006-2030



Half of all investment needs to 2030 of $22 trillion are in developing countries, 17% in China & another 6% in India alone

Between 2005 and 2030 World Carbon Emissions Will Grow 55 Percent



and Developing Countries will Account for 80 % of the Increase

Source: USDOE EIA IEO 2007 Reference Case

Typical Fossil Fuel Carbon Content

	MMT C/ Quad Btu	% More Than Natural Gas
Natural Gas	14.5	0
Gasoline	19.4	34
Diesel	20.0	38
Crude Oil	20.2	40
Resid	21.3	47
Coal (Electricity)	25.8	78

Source: EIA, Emissions of Greenhouse Gases in the US, 1998

The Climate Change Policy Problem is Enormous

- The theoretical climate change relationship is between atmospheric concentrations of GHG and climate change, not annual emissions
- According to the Intergovernmental Panel on Climate Change, stabilizing atmospheric concentration of GHG at current levels would require permanent emissions reductions of 60% or more below current levels
  - Kyoto Protocols: Industrialized countries agreed to reduce emissions, on average, 5.2% from 1990 levels by 2008-2012
  - UN Climate Conference in Bali (12/2007) looking for a follow-on path forward

The Climate Change Problem Framework

- **Carbon emissions (C), energy (E), and economic output (GDP) are directly related:**

$$C_{net} = E/GDP \times C/E \times GDP - S$$

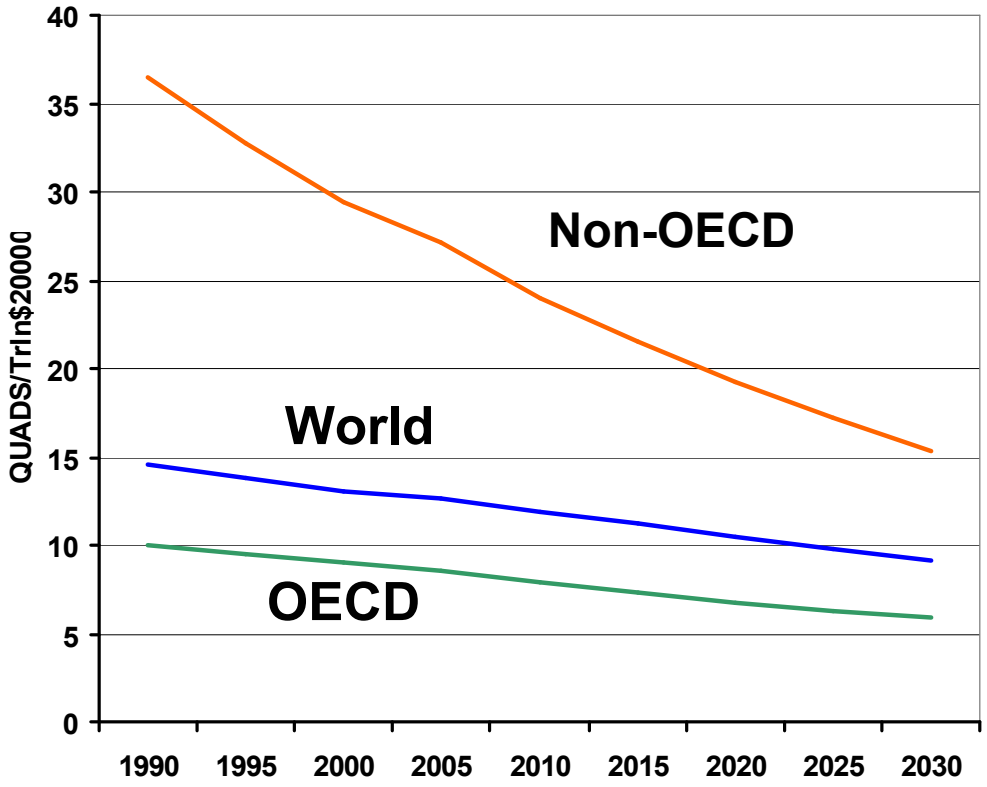
where

  - E/GDP is the "energy intensity" of the economy
  - C/E is the "carbon intensity" of the energy system
  - S represents carbon sequestered

Source: Professor Kaya, Japan

Energy Efficiency—How Much More Is Feasible?
Carbon Emissions Trend Already Assumes The World Uses 28 Percent Less Energy Per Unit of GDP by 2030

Energy Intensity



2005-2030	
% Improvement	
Non-OECD	44
OECD	31
World	28

Source: USDOE EIA IEO 2007 Reference Case

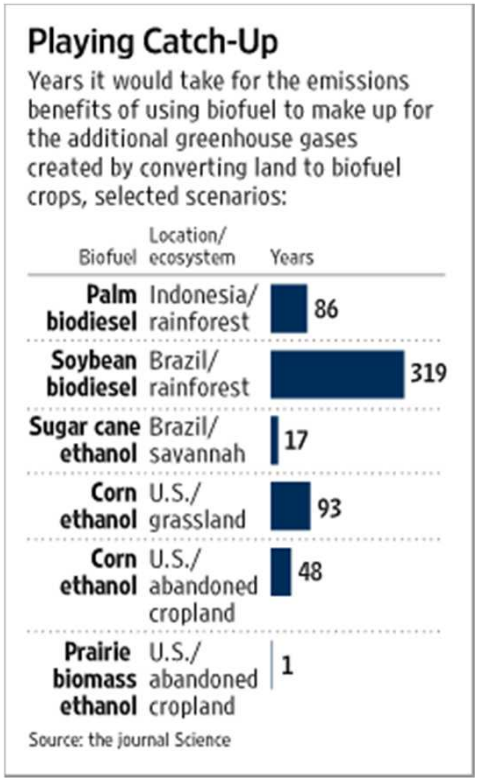
Carbon Sequestration Technologies Will Add Costs to Fossil Fuels But Are Feasible

Electricity Cost Without/With Carbon Sequestration

Power Plant Systems	Natural Gas Combined Cycle (US$/kWh)	Pulverized Coal (US$/kWh)	Integrated Gasification Combined Cycle (US$/kWh)
Without Capture (Reference Plant)	.03 - .05	.04 -.05	.04 -.06
With Capture and Geological Storage	.04 - .08	.06 - .10	.05 - .09
With Capture and EOR	.04 - .07	.05 - .08	.04 - .07

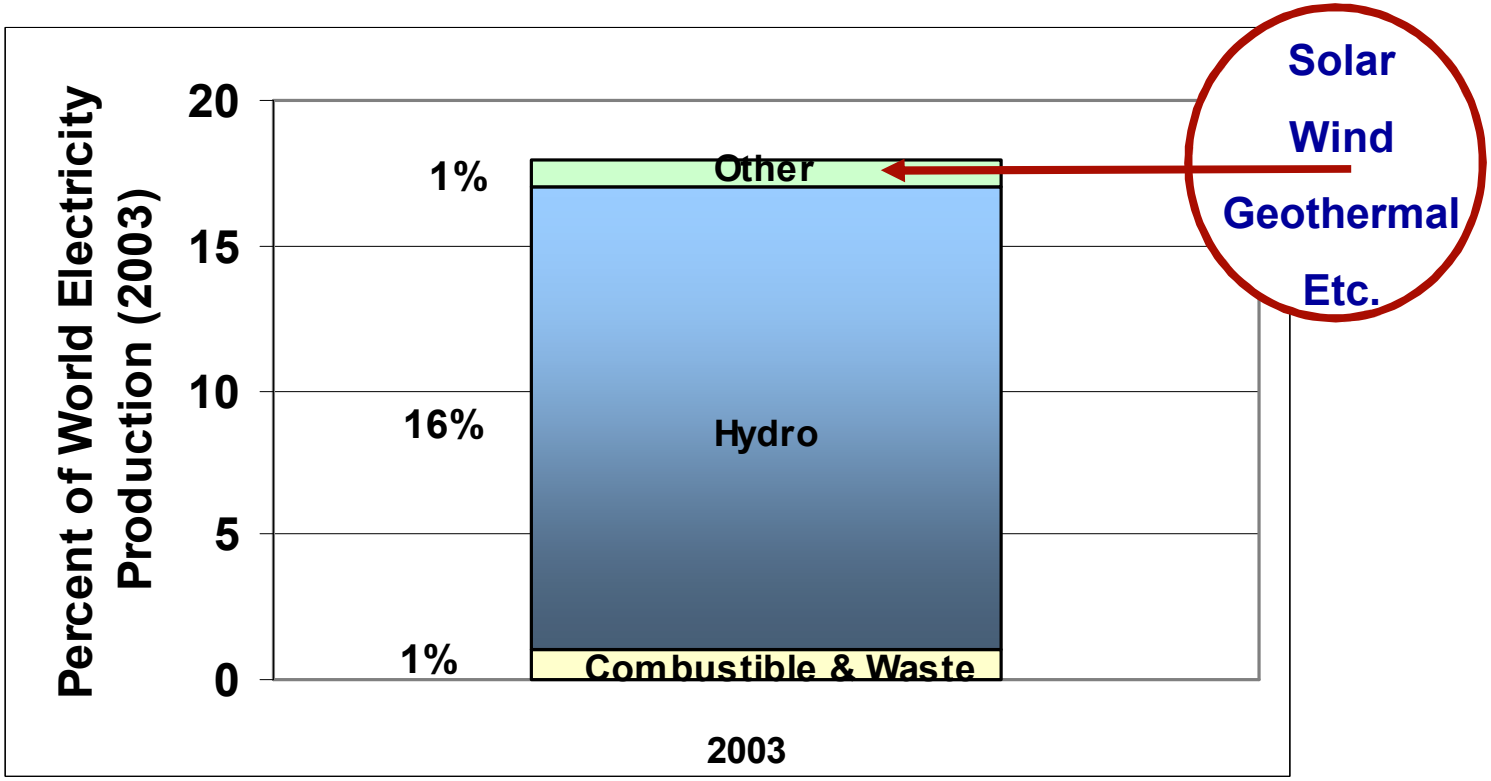
Source: IPCC Special Report on Carbon Dioxide Capture and Storage, Summary for Policymakers, September 25th 2005. Table S. 3.

Biofuels May Increase CO2



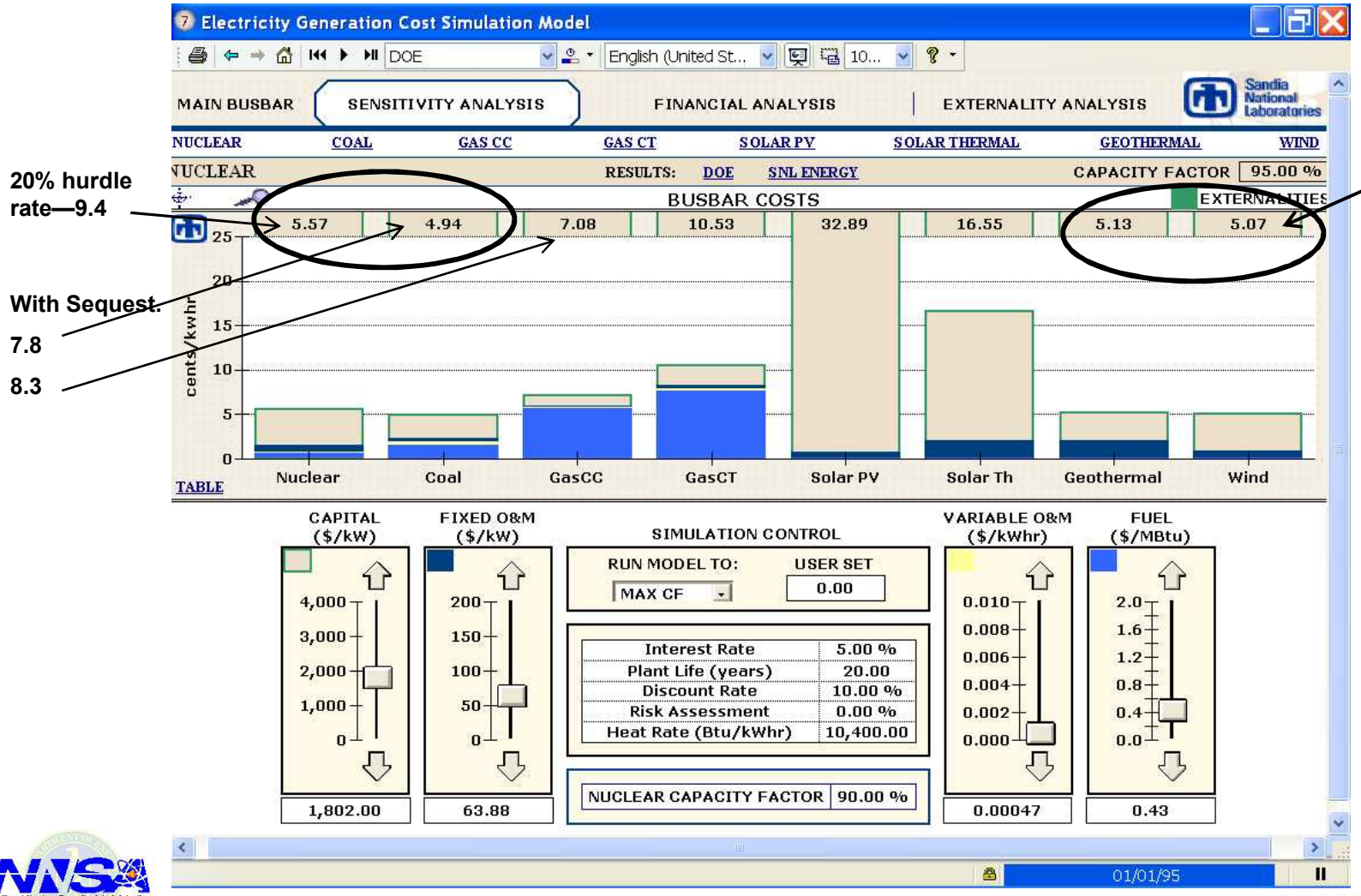
Source: Wall Street Journal, February 8, 2008, P. A4

Current Renewable Electricity is Largely Hydro



Source: Renewables In Global Energy Supply, IEA Fact Sheet 2006

New Nuclear Electricity Plants are Cost Competitive in US, Depending on Capital Cost and Perceived Risk



20% hurdle rate—9.4

With Sequest.

7.8

8.3

44% Wind

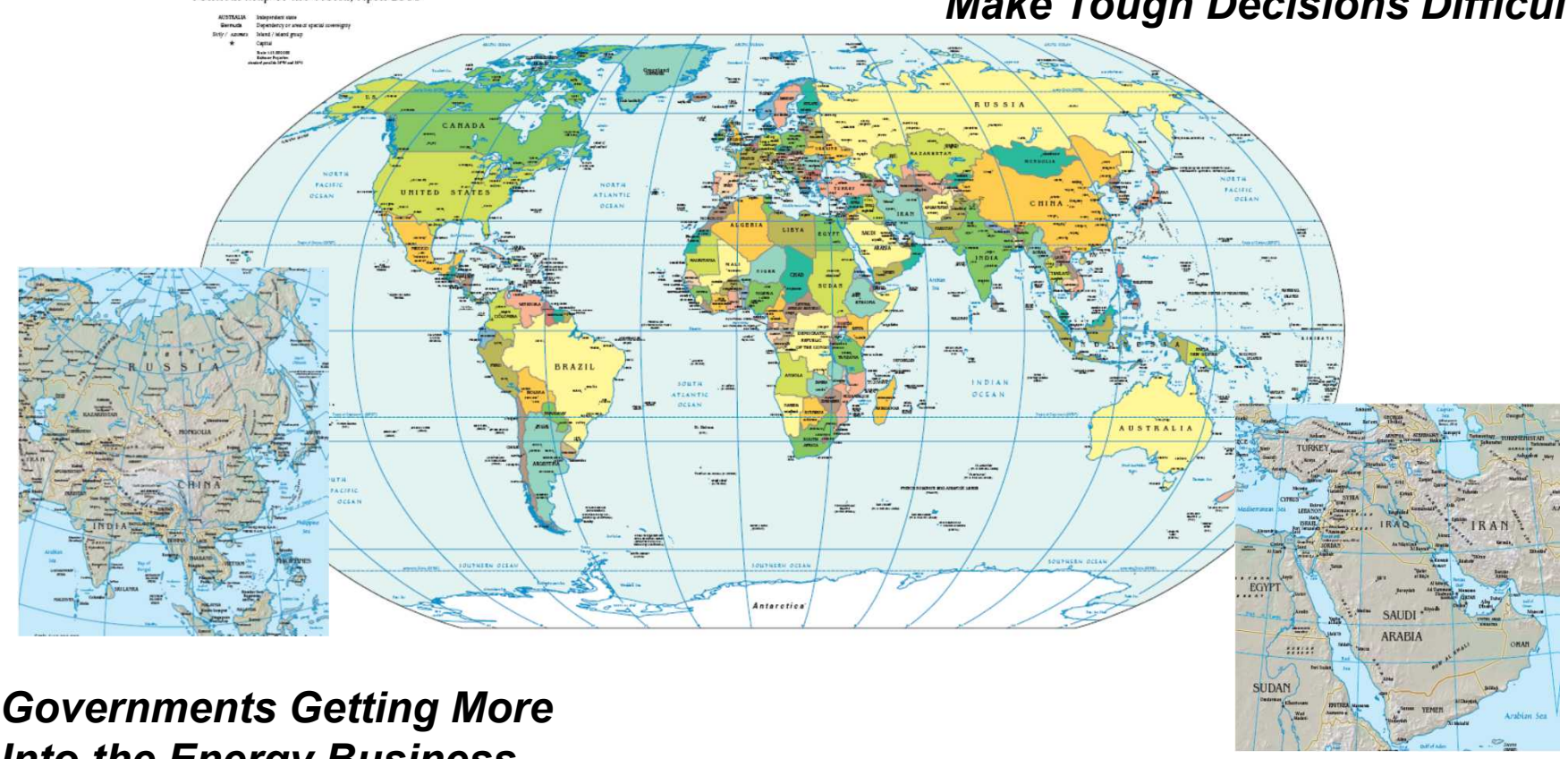
At 25%, 8.9

Source: Sandia GenSim Model and DOE/EIA AEO 2007

National and Geopolitics Make Solving the Energy Security & Climate Change Issues Problematic

U.S. Needs Coalitions

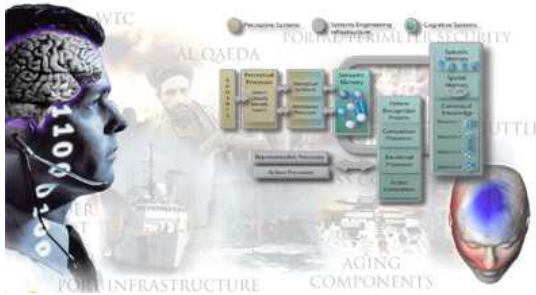
Close Democratic Elections Make Tough Decisions Difficult



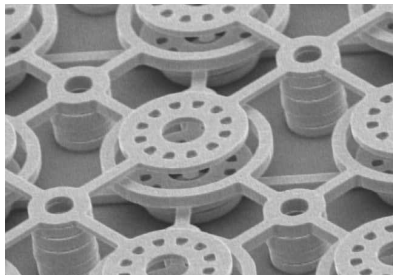
Governments Getting More Into the Energy Business

Middle East Critical to U.S. Security

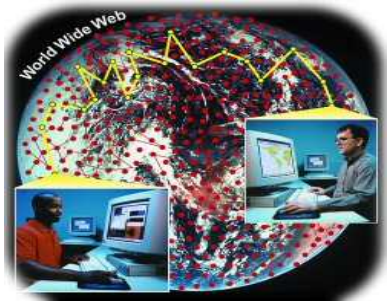
Fortunately, Science and Technology Will Accelerate And Over Several Decades Could "Disrupt" the Current System



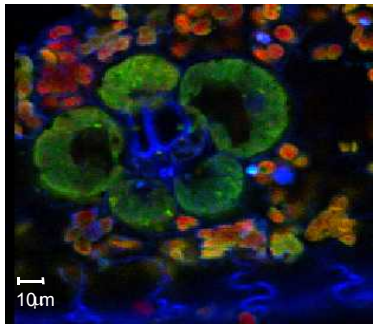
Cognitive Science-
Cogno



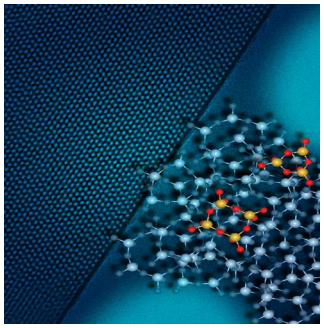
Microsystems -
Micro



Information Operations –
Info



Bioscience
Bio



Nanotechnolgoy
Nano

They will transcend high tech national borders, but will not solve our energy/environmental problems any time soon

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

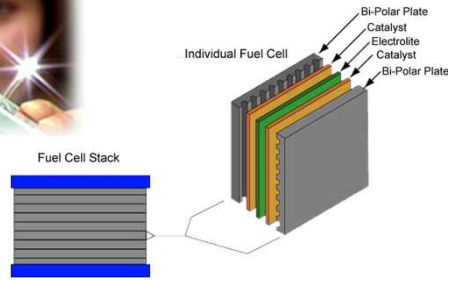
Many hurdles to overcome:

- 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

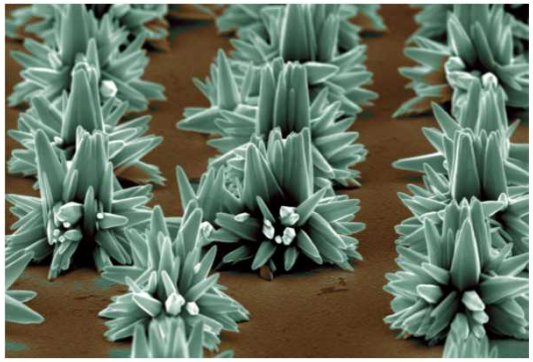
Nano Could Be Very High On The List of Energy Market Disrupters

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



Hybrid organic-inorganic solar cells using nano-composite materials

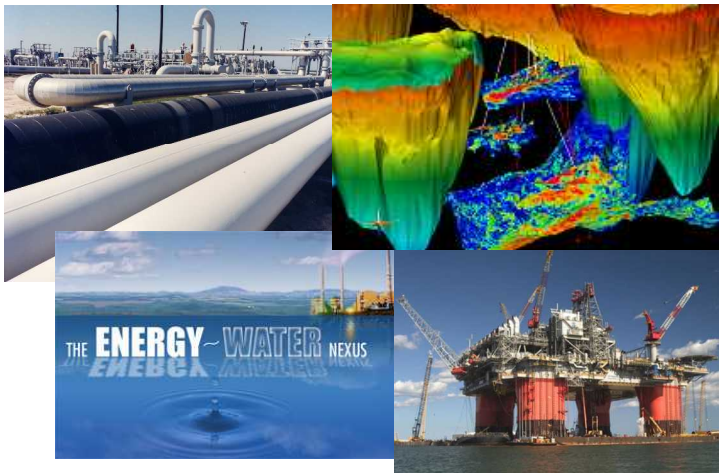


ZnO nanostructures - a critical component in low-cost hybrid solar cells

Center for Integrated Nanotechnologies (CINT)

Energy Resources and Nonproliferation Strategic Management Unit

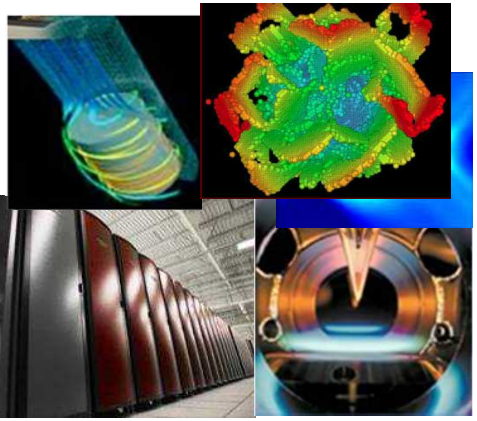
Safe, Secure, Reliable Energy and Water Supply Infrastructure



Energy Supply, Energy Efficiency, and Environmental Stewardship

"Science Underpins and Enables Technology for Our Energy Missions"

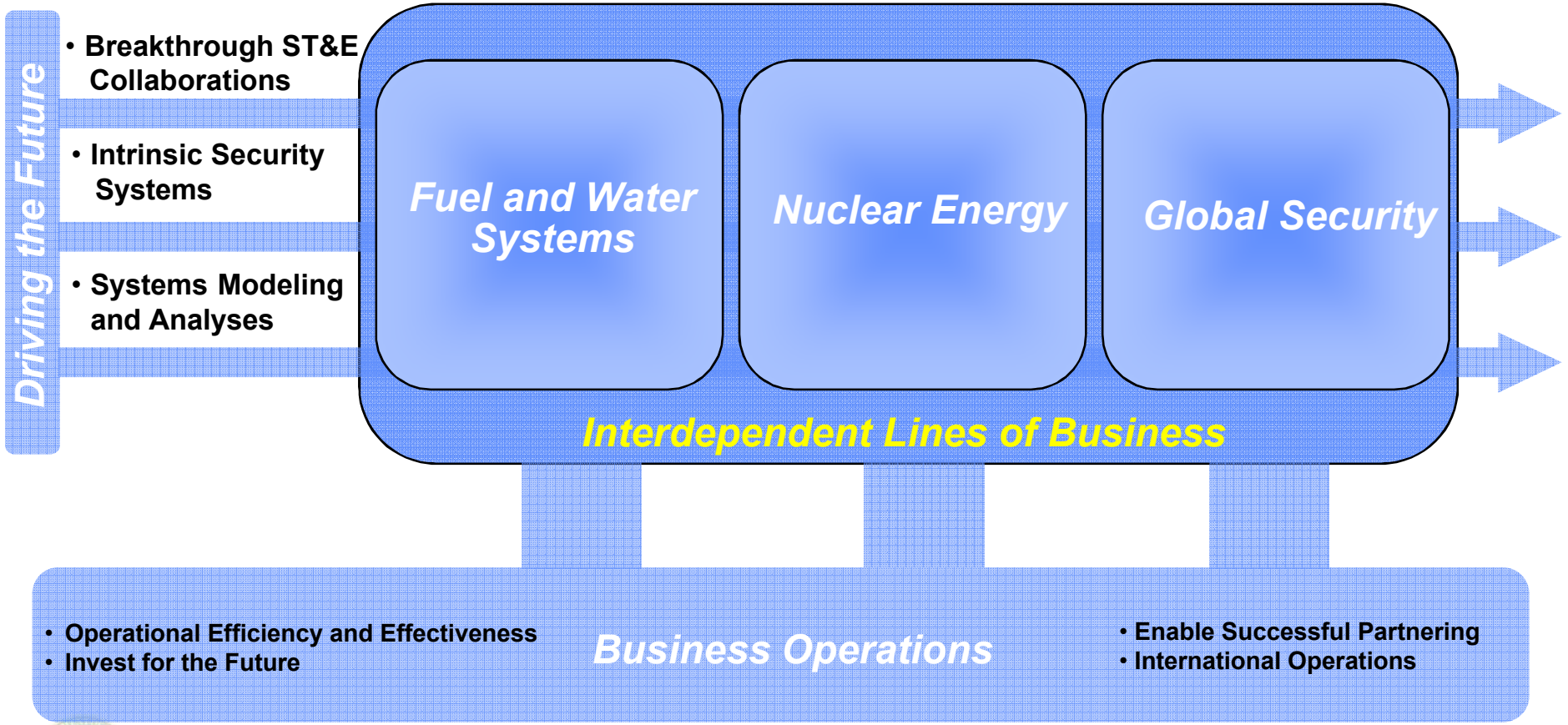
Science and Technology



Technology Solutions through International Cooperation

Energy, Resources, and Nonproliferation

"Lines of Business"

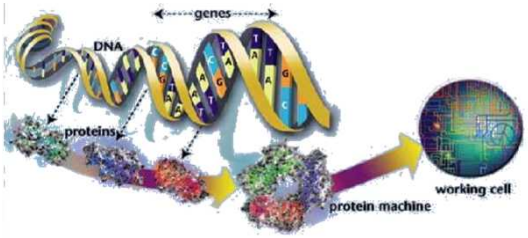


Fuel and Water Systems

Line of Business

Sandia National Laboratories

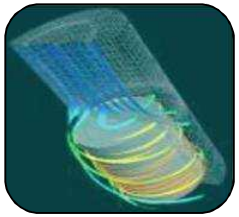
"Provide systems perspective and critical technological solutions for fuel and water that assure secure and sustainable supply, safe and resilient delivery infrastructure, and clean and efficient use of resources"

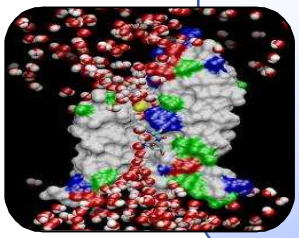


Fuels for the 21st Century

Launch Joint Bioscience Energy Initiative (JBEI)

Pursue Synthetic Fuels





Clean and Abundant Water

Create "New" Water

Water Resource Allocation

Infrastructure Security and Resilience

Secure Oil/Gas Infrastructure

Improve Military Base Energy Surety

NNSA National Nuclear Security Administration

LOCKHEED MARTIN

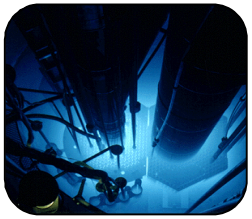
Nuclear Energy
Line of Business

Sandia National Laboratories

"Renew U.S. leadership in "Nuclear Energy" through an international closed nuclear fuel cycle, using our strengths in repository science, nonproliferation, safety and security, transportation, modeling, and system demonstrations."

National Technical and Policy Leadership

YMP License Application
Safety and Security
Destigmatize Transportation
WIPP Beyond TRU



Key System Demonstrations

Nuclear-Solar Hydrogen

Small Reactor Development

International Fuel Return Demonstration

Demonstrate Transparency Technology

Nuclear Fuel Cycle Science

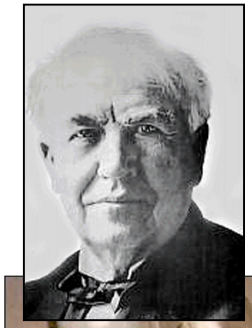
Advanced Waste Forms for GNEP

Advanced Modeling and Simulation

NNSA National Nuclear Security Administration

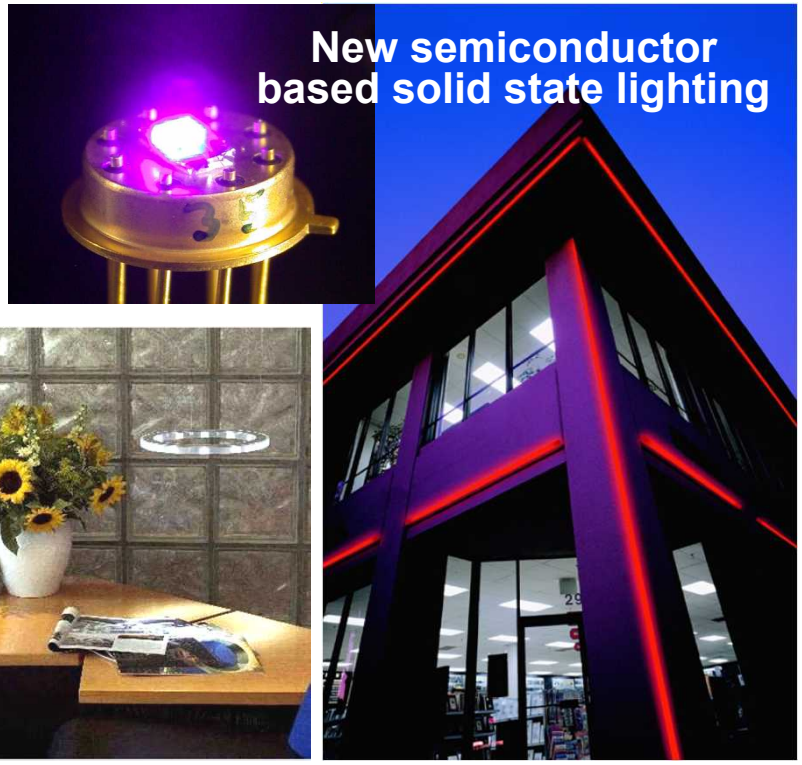
LOCKHEED MARTIN

Conventional Lighting Is the Last Technology That Still Uses Vacuum Tubes



Thomas Edison

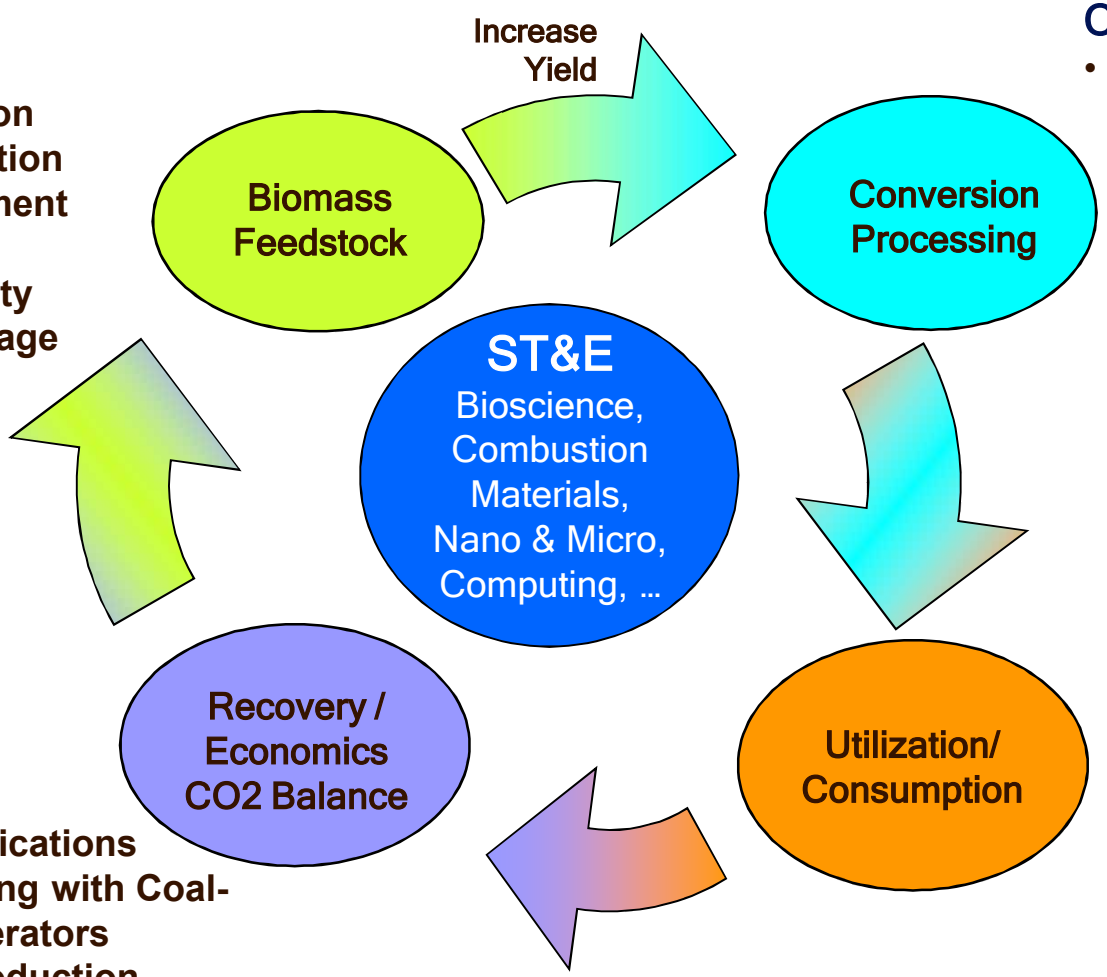
Old vacuum-tube based lighting



Sandia has been designated the lead lab for the National Center for Solid State Lighting

Sandia's Biofuels Strategy
A Systems Approach

Sandia National Laboratories



Challenges
- Biomass
  - Production
  - Optimization
  - Pretreatment
  - Scale-up
- Sustainability
  - Water usage

Challenges
- Biomass processing
  - Catalysis
  - Thermochemical
  - Biochemical
  - Scale-up
  - Microbial communities

Challenges
- Engine design
- Fuel Distribution
- Fuel Storage
- Materials Compatibility
- US Infrastructure Implications (Systems)

Challenges
- Carbon Implications
  e.g. Co-siting with Coal-fired generators
- Biomass production
  e.g. Transportation costs & Water availability

NNSA National Nuclear Security Administration

LOCKHEED MARTIN

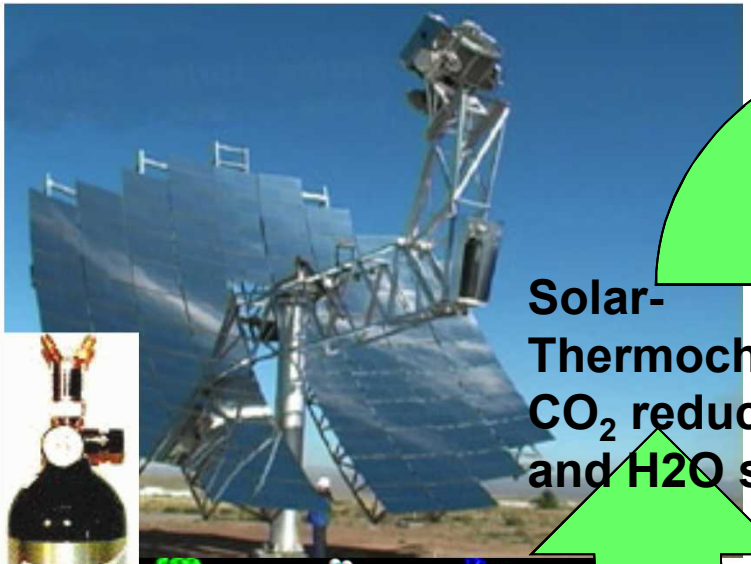
Sandia Carbon Capture, Reuse and Sequestration

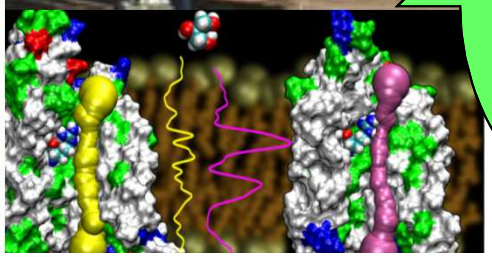
- Capture
  - Direct from Atmosphere
    - » Oceans: genome-to-life (GTL) of cyanobacteria
    - » Engineered system to mimic geosystem uptake of CO2
    - » Membrane System for CO2 Point Sources
  - Synfuels using CO2 and H2O as feedstocks enabled by renewable energy
  - Sequestration
    - » System Analysis and Risk Assessment
    - » Monitoring and Validation
    - » Geological Characterization

"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**.





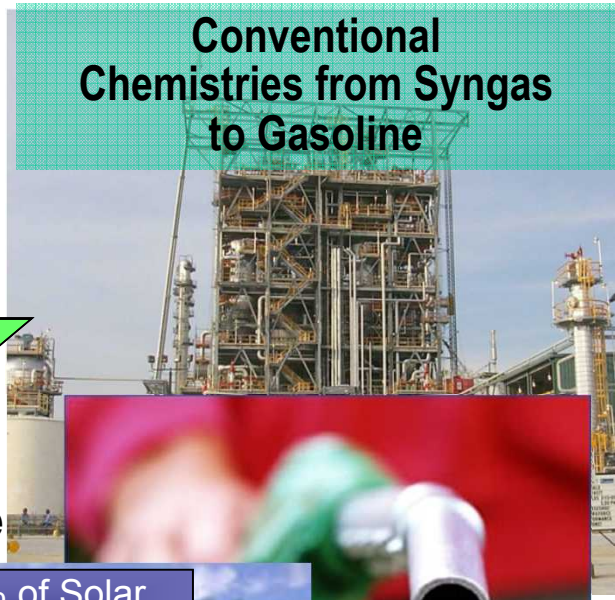
Solar-Thermochemical CO_2 reduction and H2O splitting

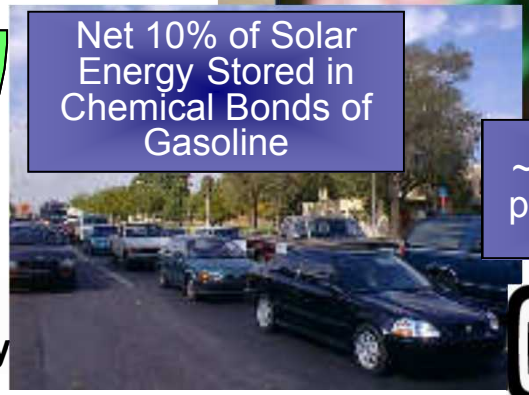
CO, H_2

$CO2, H2O$

Conventional infrastructure

Conventional Chemistries from Syngas to Gasoline





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

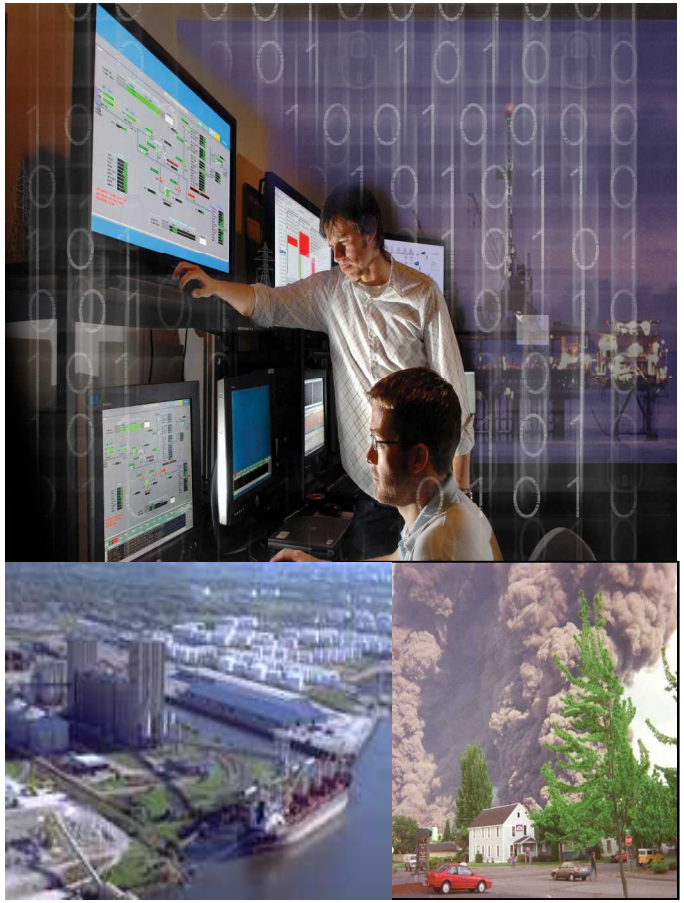
~$3.00/gallon to produce at scale

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

Sandia National Laboratories

Cyber Security

- Information infrastructure vital to energy sector and economy
  - Widespread automation of critical processes
  - Dependence on end-to-end information flows
- Growing efforts to manage cyber risk exposure
  - Vulnerabilities from increasing connectivity and reliance on COTS technologies
  - Sandia well engaged in critical information systems protection
    - » E.g., DOE National SCADA Test Bed, etc.



Problems and Prospects

- **Problem A—Global Economic Integration:** Growing global economic, financial and monetary interdependency, reduced long term U.S. relative global economic role & responsibilities, with political resistance to be overcome

  - **Prospects:** A bumpy ride, with the positive forces of competitiveness, economics, and technology improving global prosperity and quality of life, and overcoming politics, culture and ideology. With appropriate U.S. public policies, U.S. descent will be gradual and relatively orderly (glass half full)
    - » **Related Prospects:** Defense and military complexity will grow, as will requirements for sound, timely intelligence and need for cost-effectiveness

Problem B—Energy Security: Concentrated fossil energy resource ownership with oil & natural gas supply manipulation, supply interruptions and price swings

  - **Prospects:** A bumpier ride, but advanced, cost competitive, more secure energy technologies and systems will emerge

Problems and Prospects (Continued)

- **Problem C—Global Climate Change: Uncertainty of global climate change (how much, how fast and where), requiring global collective action beyond current (and most likely future) geopolitical capabilities**
  - **Prospects: A number of ruts in the road, with some political/public policy misfires, but advanced, cost competitive, cleaner energy technologies will emerge, along with improved adaptation capacity, though climate will continue to change**

Successfully learning our ABCs will require greater international political economic openness, competition and collaboration