# America's Energy Security
## *a Global Context*

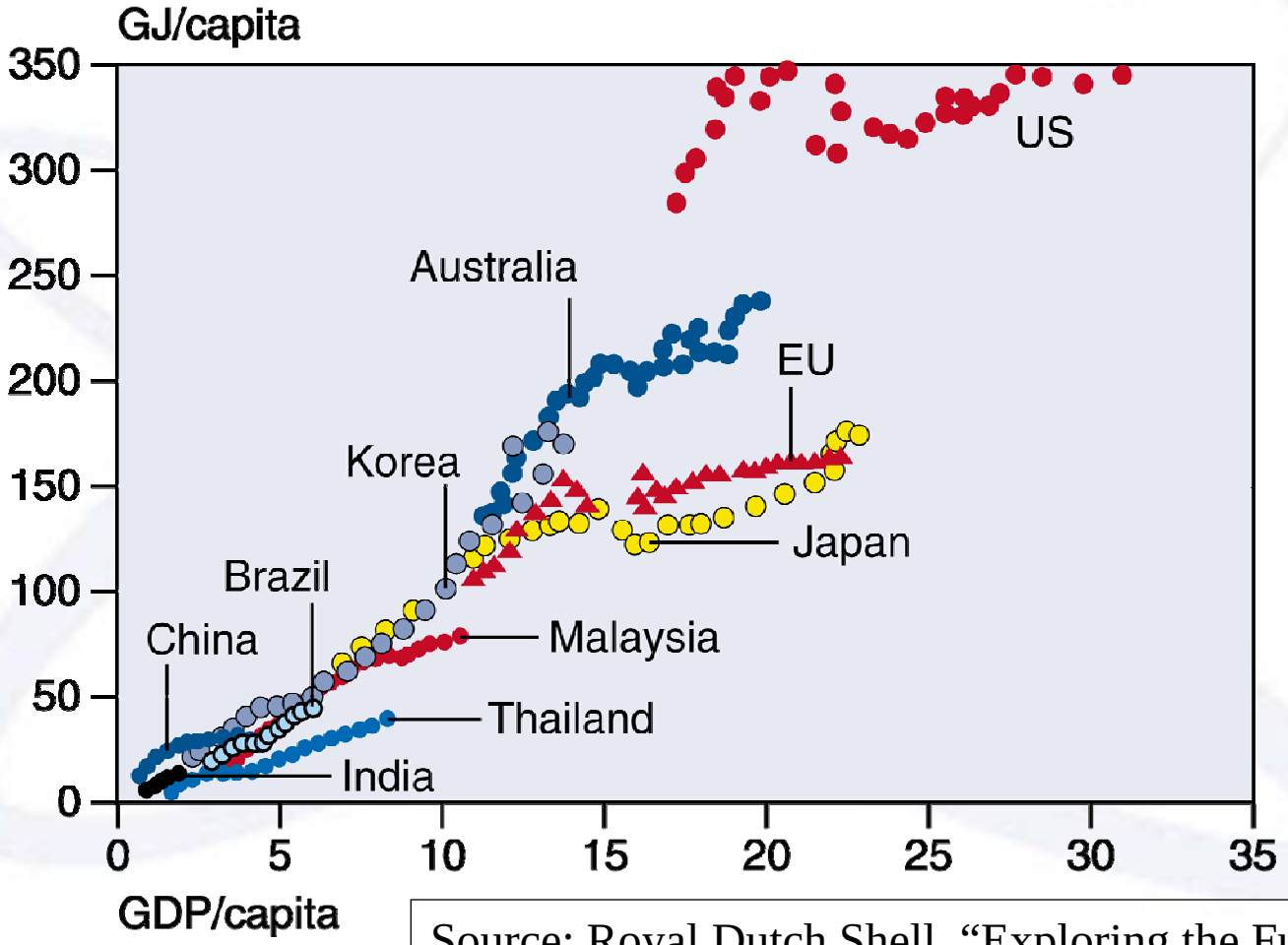
***Up and Atom Breakfast***

7 February 2006

Harold McFarlane

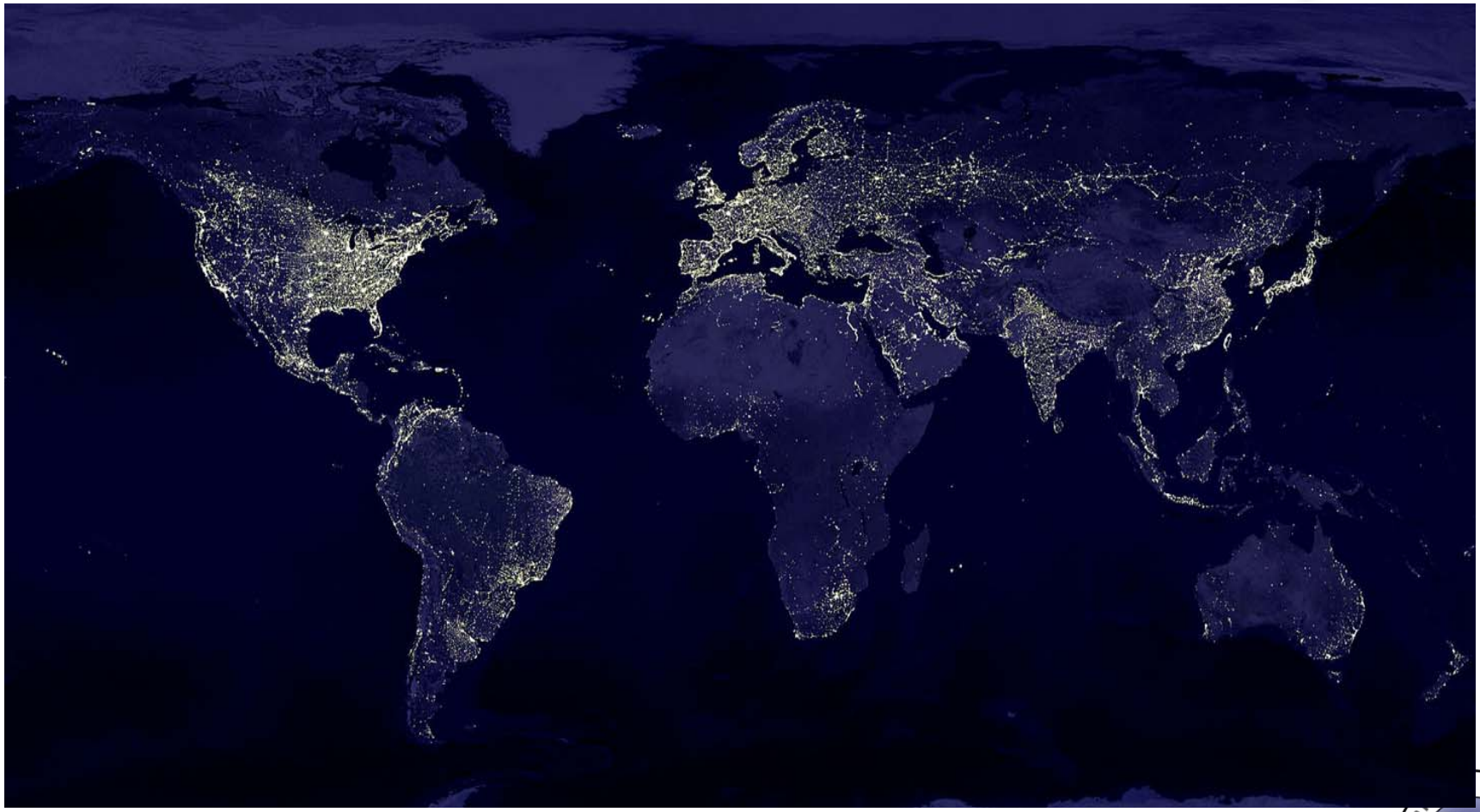
ANS Vice-President/President Elect

# Energy is the fuel of national prosperity

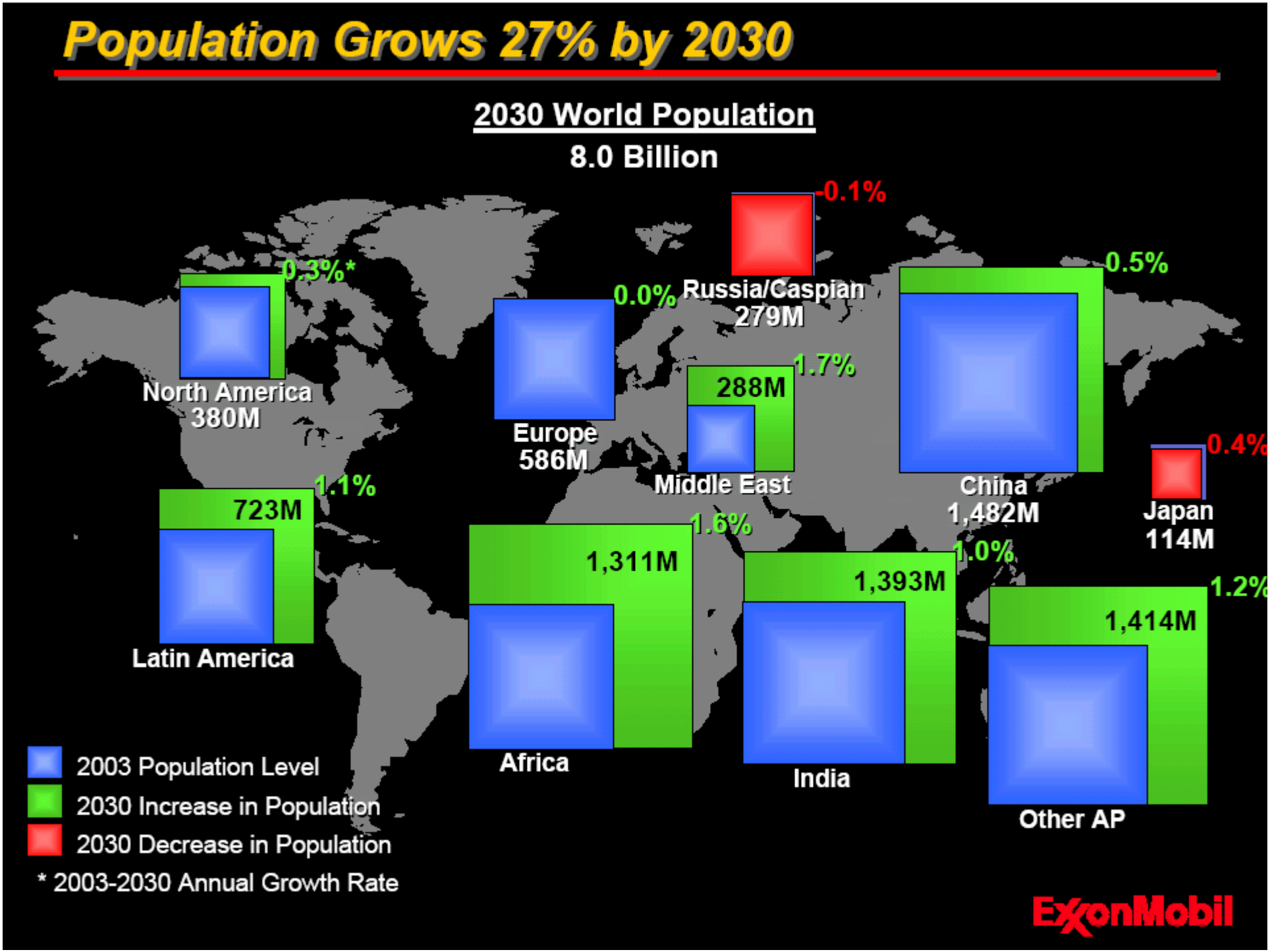



Source: Royal Dutch Shell, "Exploring the Future - Energy Needs, Choices and Possibilities

# Nuclear R&D: a global imperative?

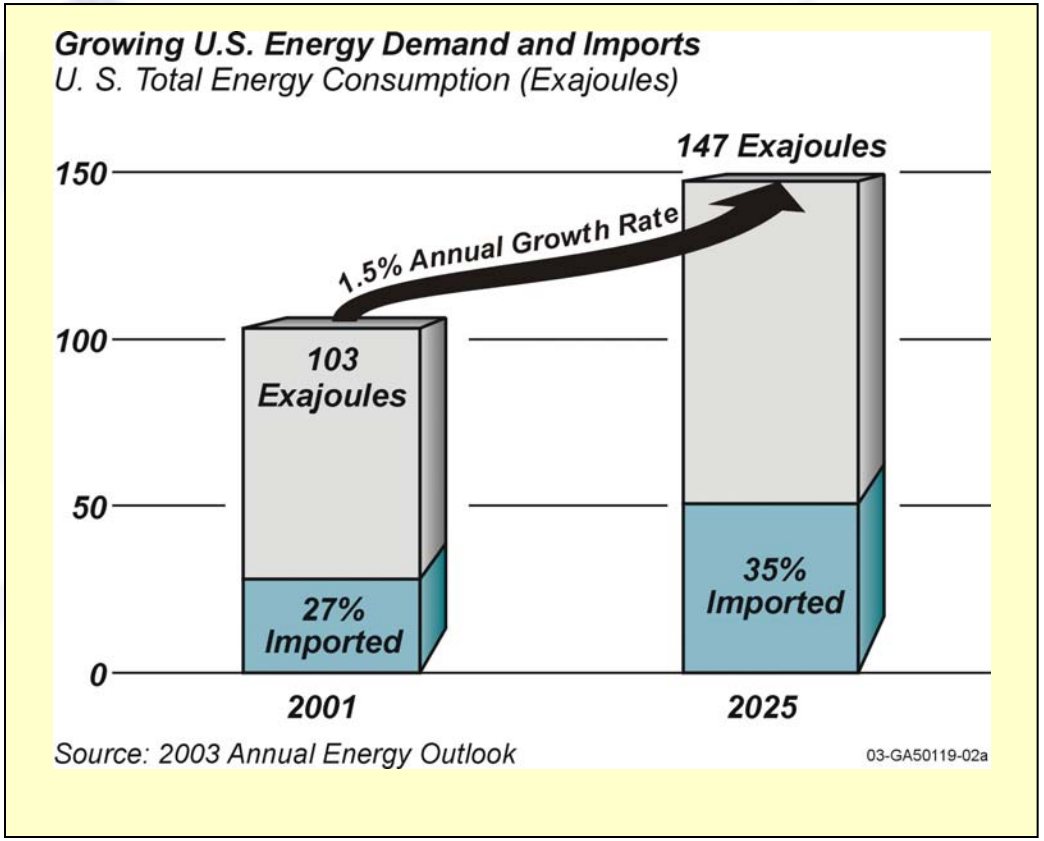


# Population Grows 27% by 2030



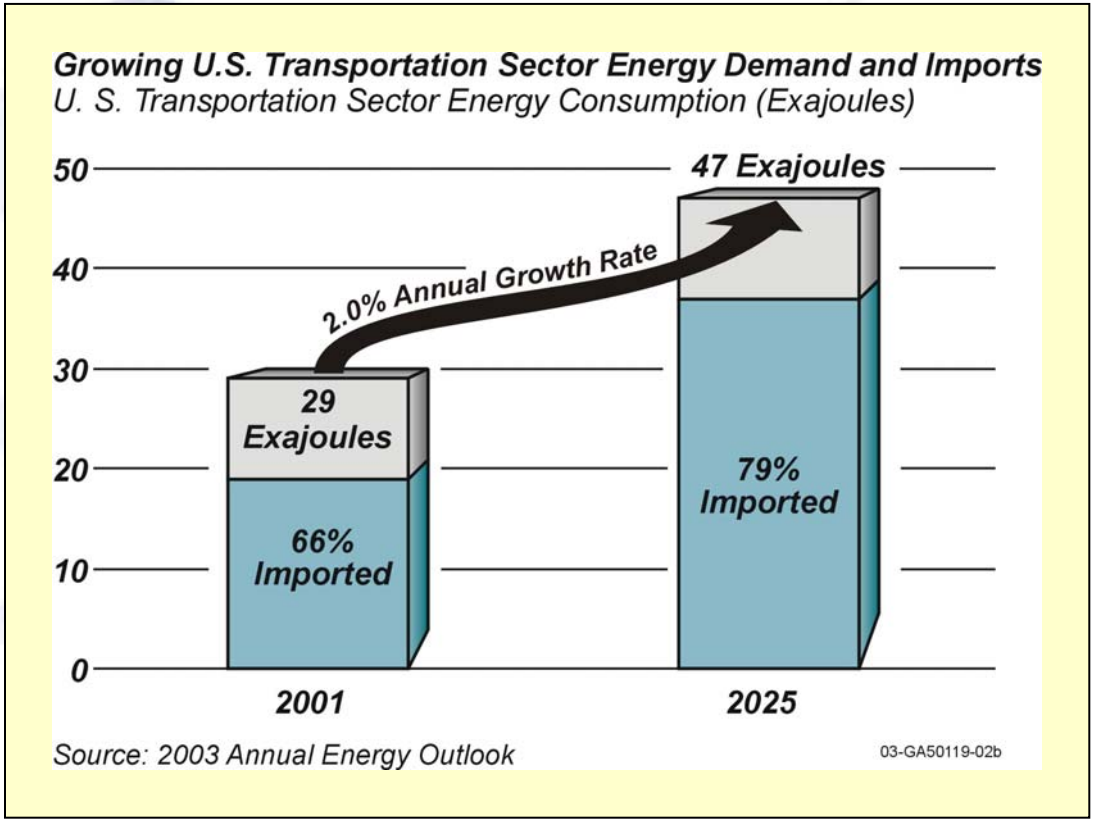
# Forecast for energy growth in the U.S.

- Annual outlook is 1.5% growth in U.S. energy to 2025
- Most growth is in natural gas and coal
- Imports will increase



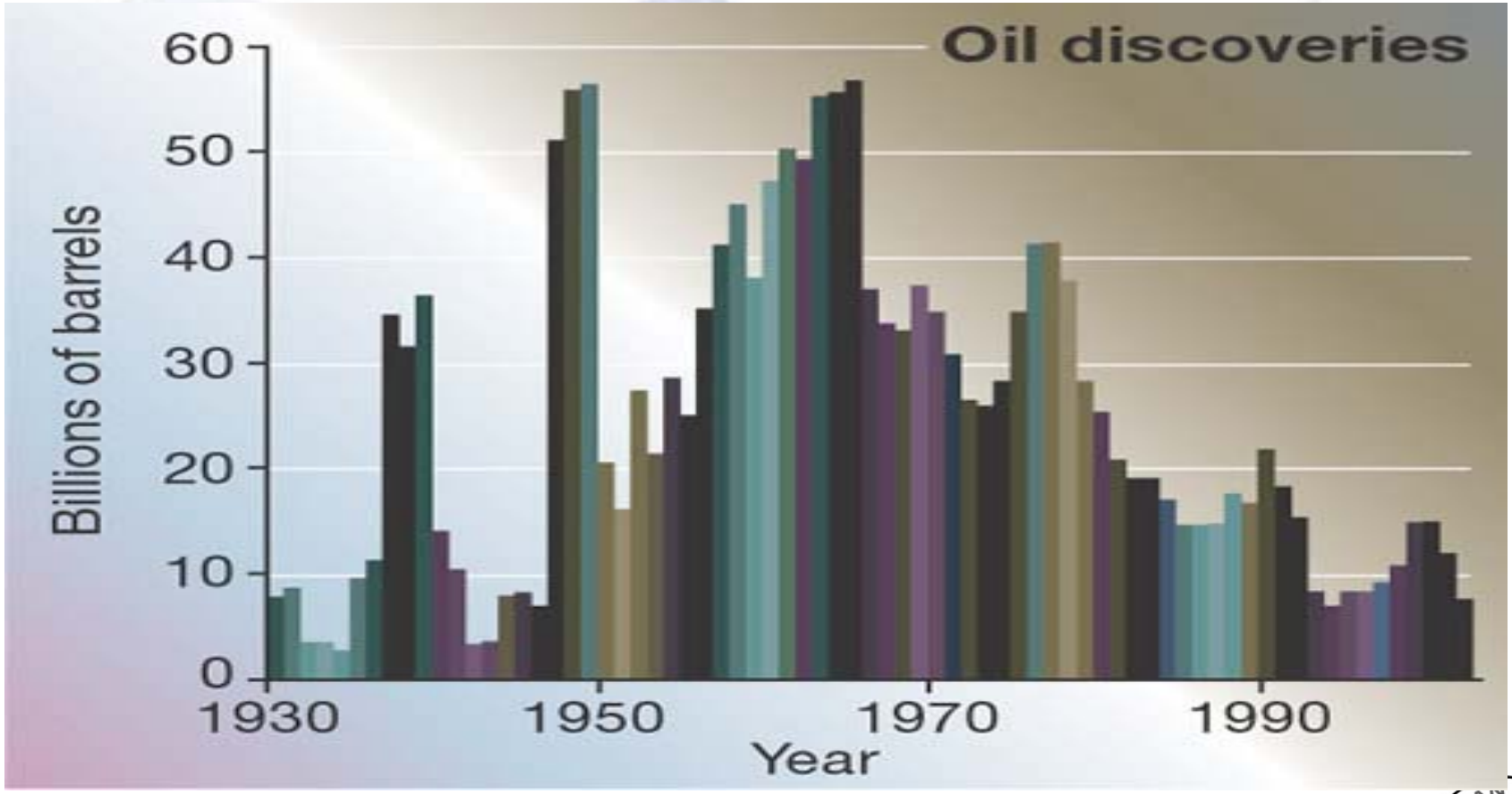
# Growth in the demand for transportation energy is even greater

- Transportation sector growth leads electricity and heating
- Outlook is for a disproportionate increase in imports
- Increasing dependence on imports clouds the outlook for energy security and stability



# New oil discoveries are smaller, deplete quickly, more costly

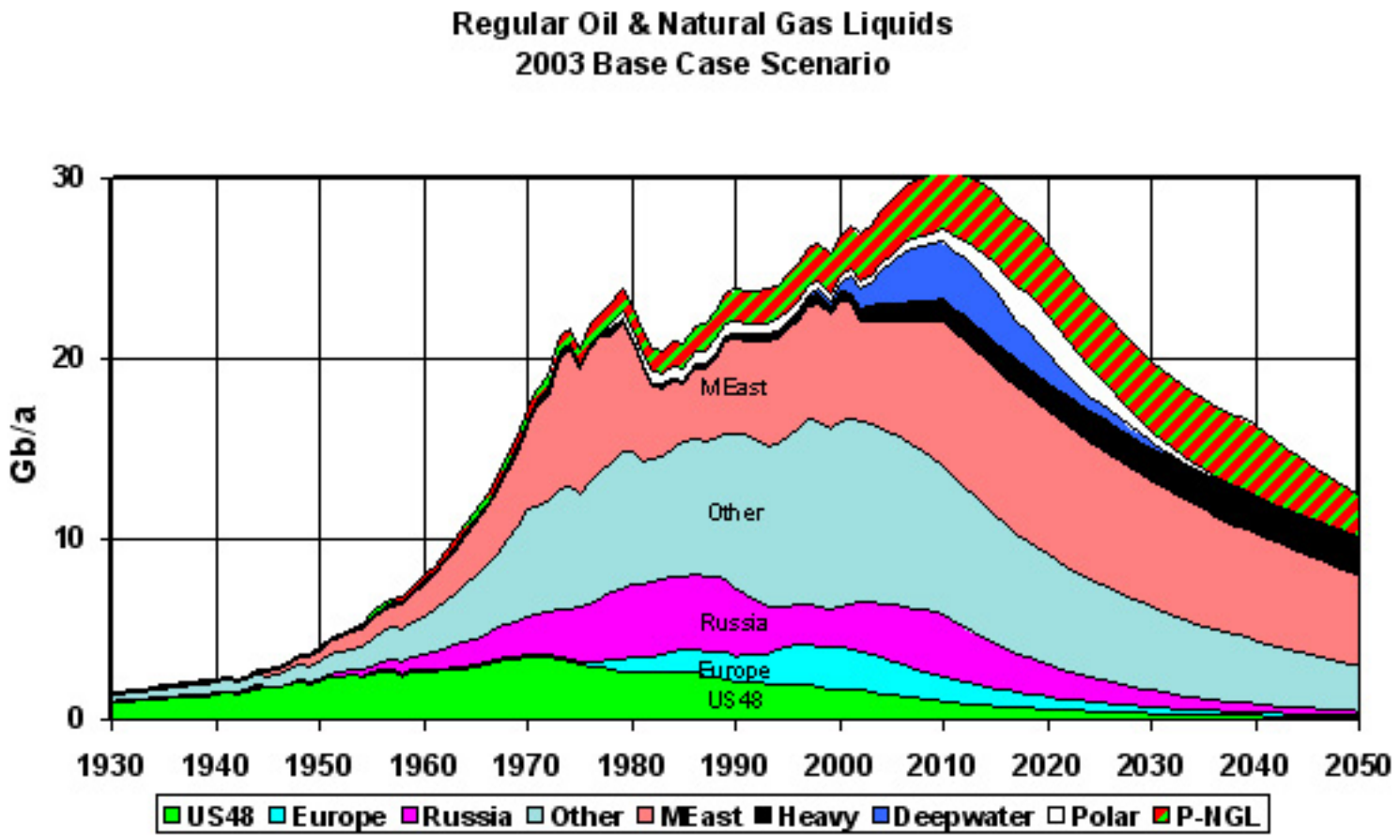
**(source: nature 17 June 2004, p.694)**



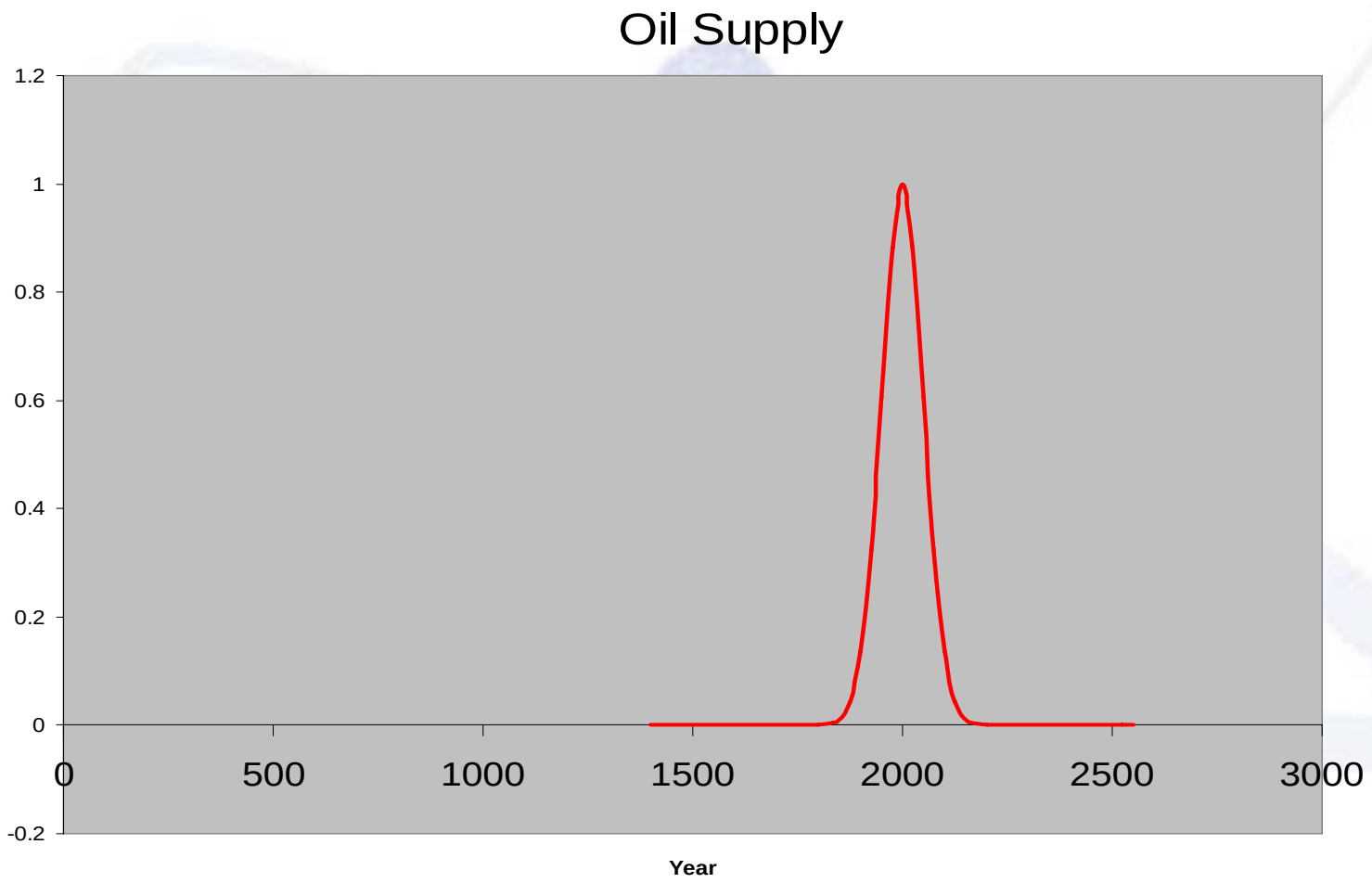
# Most oil production in the “Golden Triangle” in the Middle East


From Simmons & Company, International

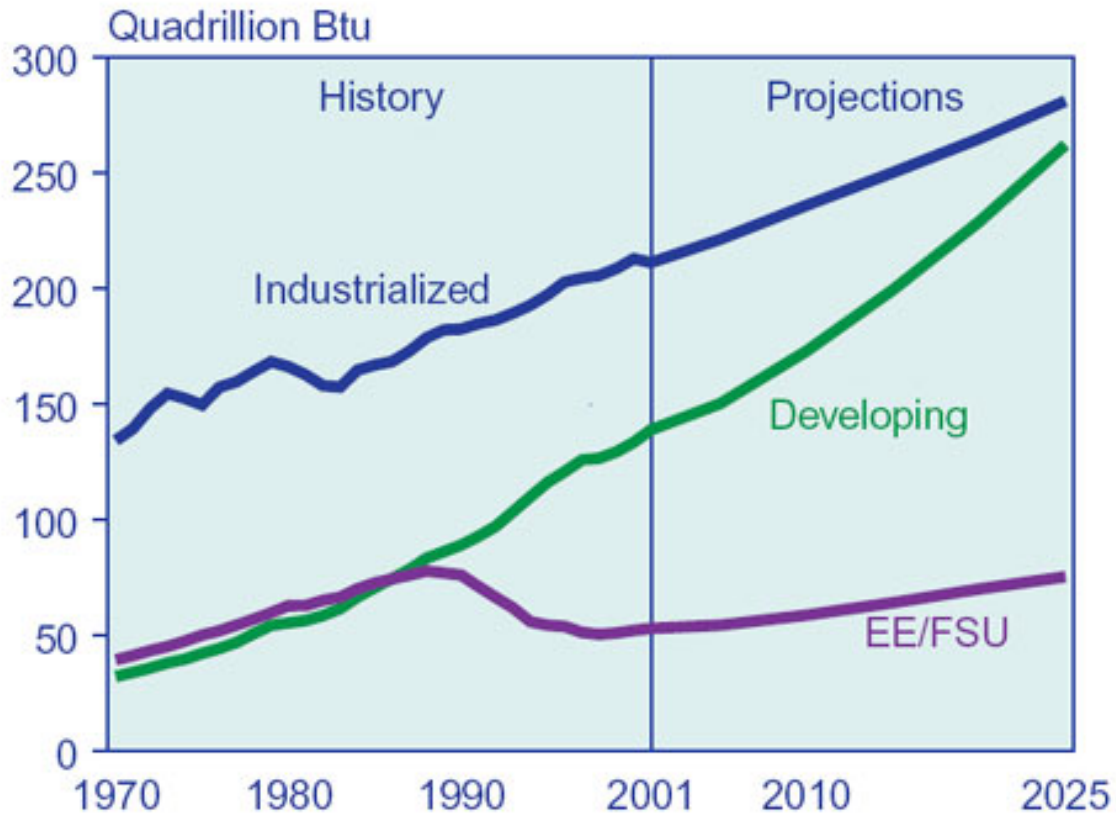
# Ultimately the geologists have it right



# Oil in perspective



# World energy demand increasing

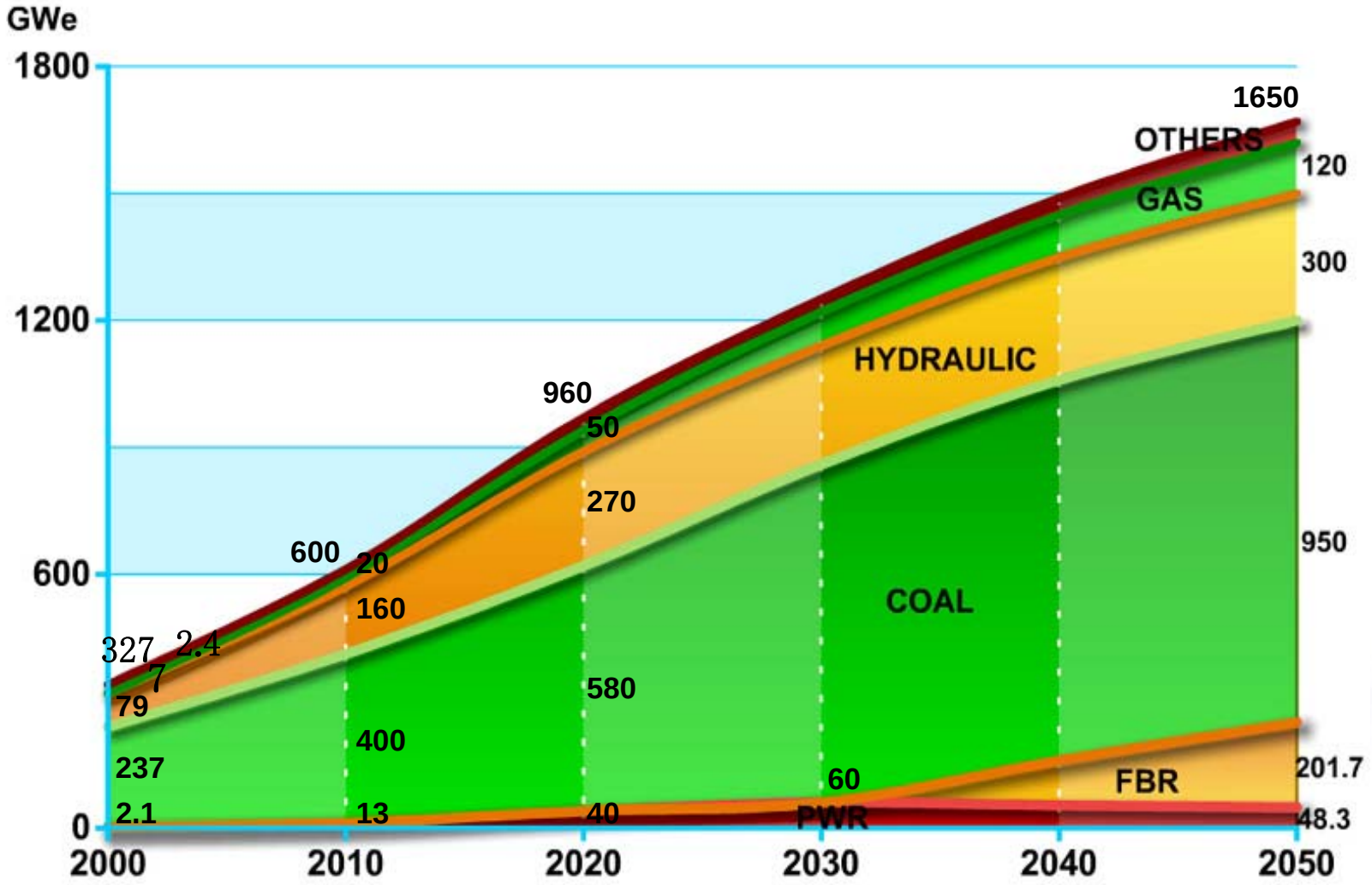



*Source: EIA IEO 2004*

**The increase is projected to be about 55 quads in industrialized countries alone over the next 25 years**

**1 quad is a mile-long coal train (11,000 tons) every 2 hours 24-7 for a year**

XU MI, Oct. 2005
CHINA INSTITUTE OF ATOMIC ENERGY




Electric Capacity Development Envisaged In China

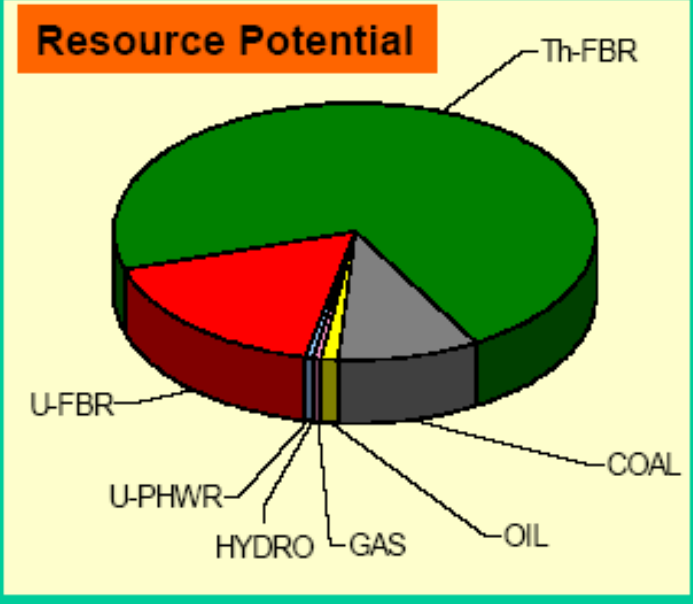
| | 1991 Envisaged | | | 2005Envisaged | |
|---|---|---|---|---|---|
| Energy | Exploitable In 2050 | Standard Coal Equivalent (billion tsce) | Total Requirement (billion tsce) | Standard Coal Equivalent (billion tsce) | Total Requirement (billion tsce) |
| Oil | 0.1×$10^9$t | 0.45 | | 0.5 | |
| Gas | 1500×$10^9$$m^3$ | | | 0.3 | |
| Hydraulic | 260～370GWe | 0.65 | | 0.6 | |
| Coal | 3.4×$10^9$t | 2.50 | | 2.5 | |
| Nuclear | 240GWe | 0.60 | | 0.6 | |
| Others | | 0.30 | | 0.5 | |
| Total | | 4.5 | 4.5 | 5.0 | 5.0 |

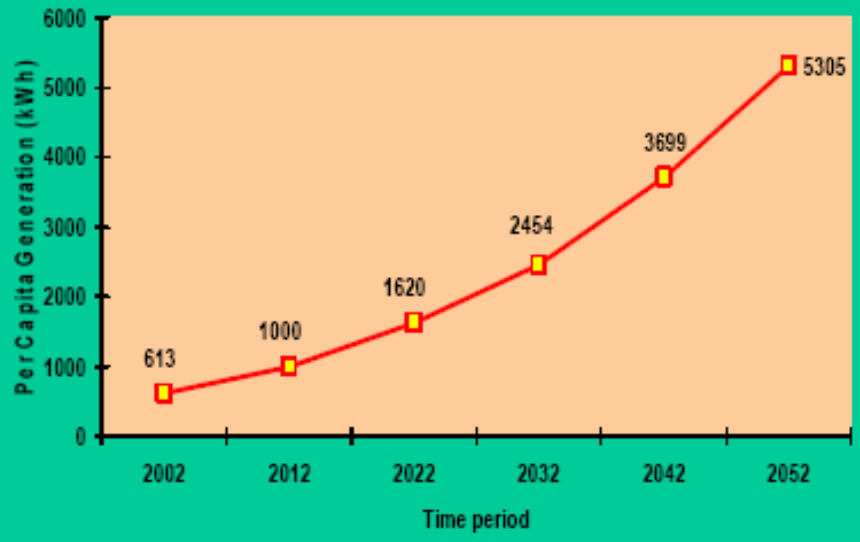
# Indian Energy Growth Scenario

| | 2003-04 | 2052 |
|---|---|---|
| ➢ Electricity Generation (GWe) | 112.0 | ~ 1344 |
| ➢ Nuclear Energy Share (GWe) | 2.72 | ~ 275 |
| ➢ PHWR (GWe) | 2.10 | ~ 0 |

➢ Faster Growth is needed to reach the target

➢ FBR with Closed Fuel Cycle is inevitable

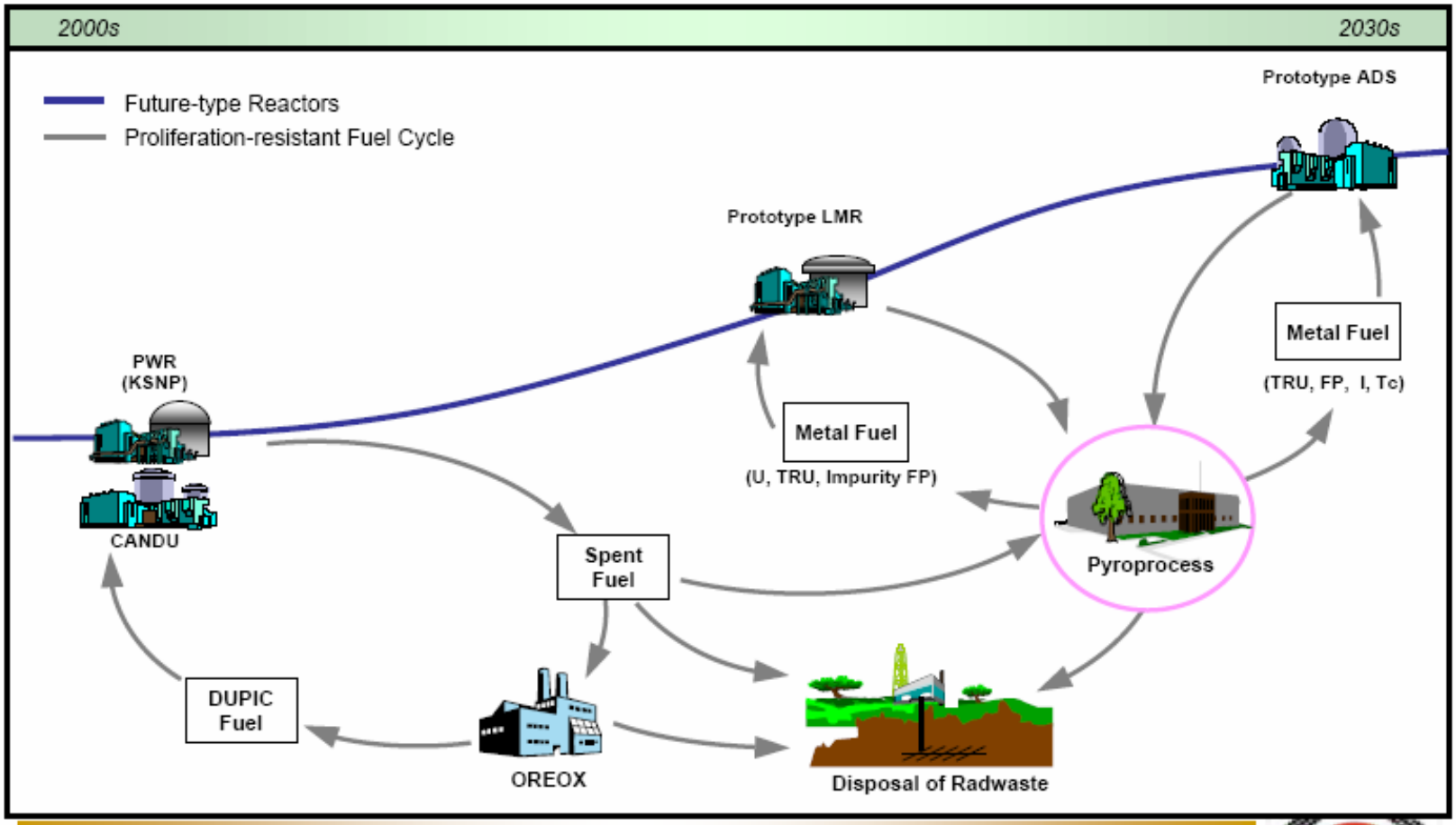



Baldev Raj, GLOBAL 2005, October 2005

# Prospect of Advanced Nuclear Fuel Cycle : KIEP-21

"K : *Korea*, I : *Innovative*, E : *Environmentally friendly*, P : *Proliferation resistant*"




Prof. Jun Kai Lee, October 2005
(Ph.D. Princeton 19XX)

# U.S. Energy security needs diversity and domestic energy sources

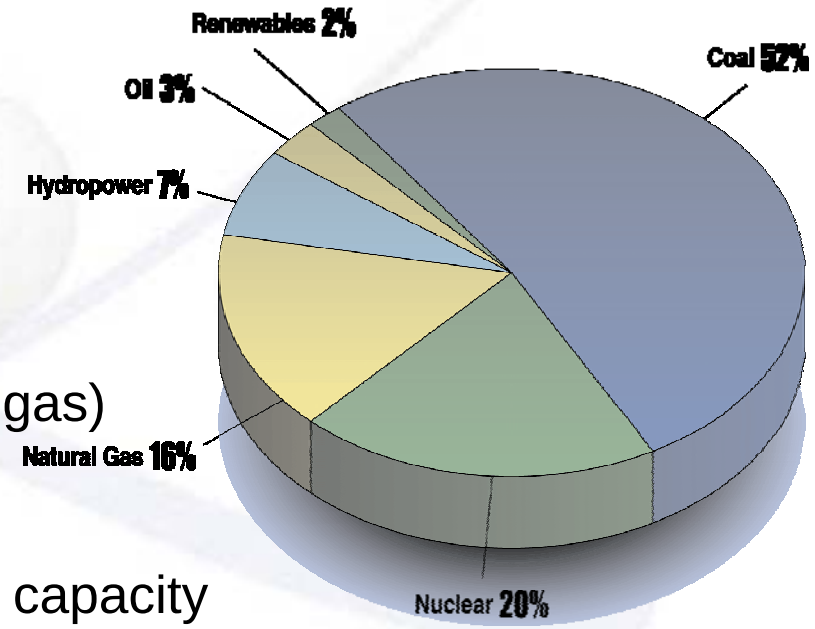
Petroleum, a key energy source

- 97% of transportation
- 35% of industrial input
- 13% of residential
- 8% of commercial

Hydrocarbons (petroleum,coal, natural gas) provide ~85% of United States energy

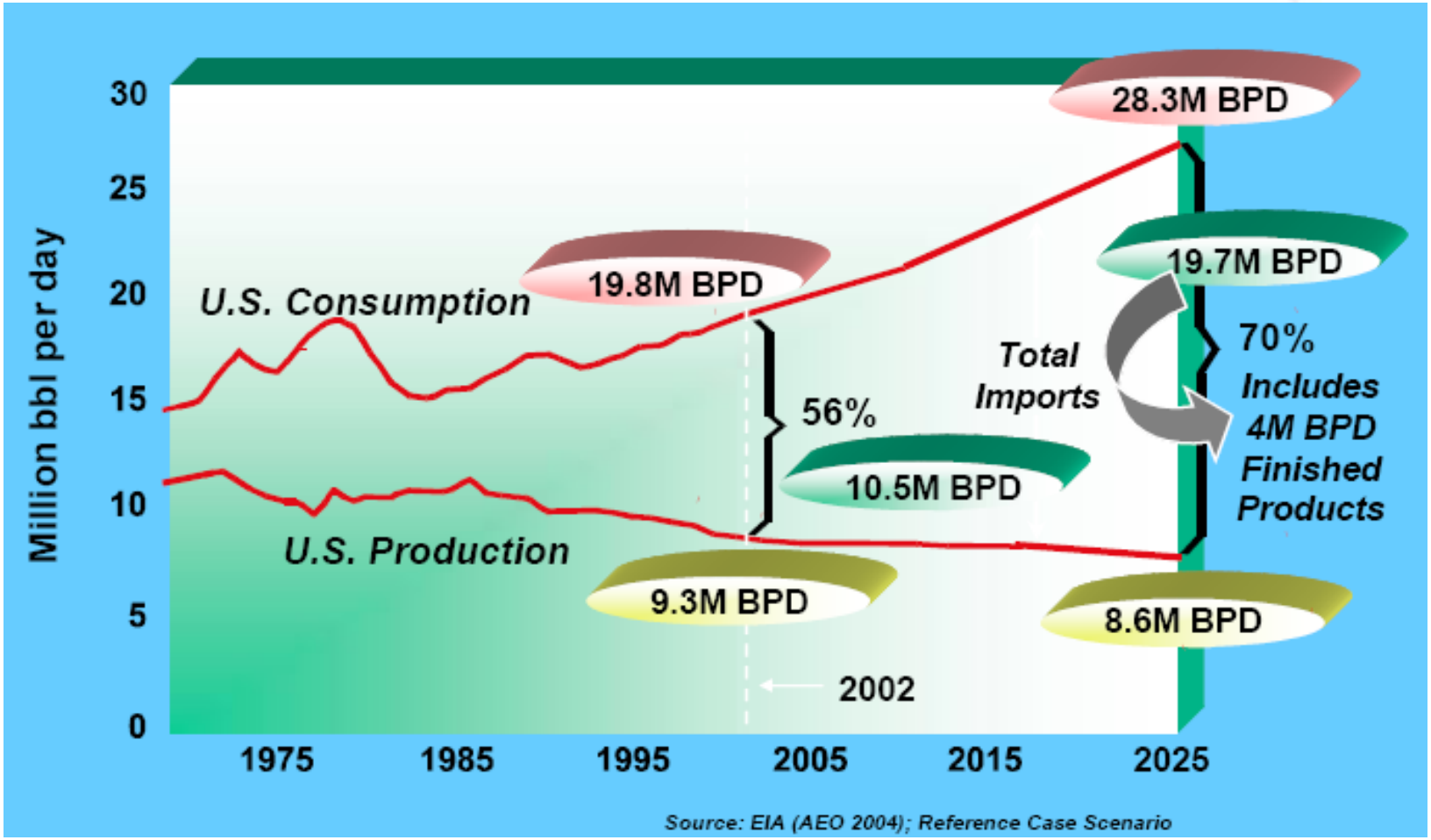
Hydrocarbons provide ~70% of electric capacity

Electric Generation

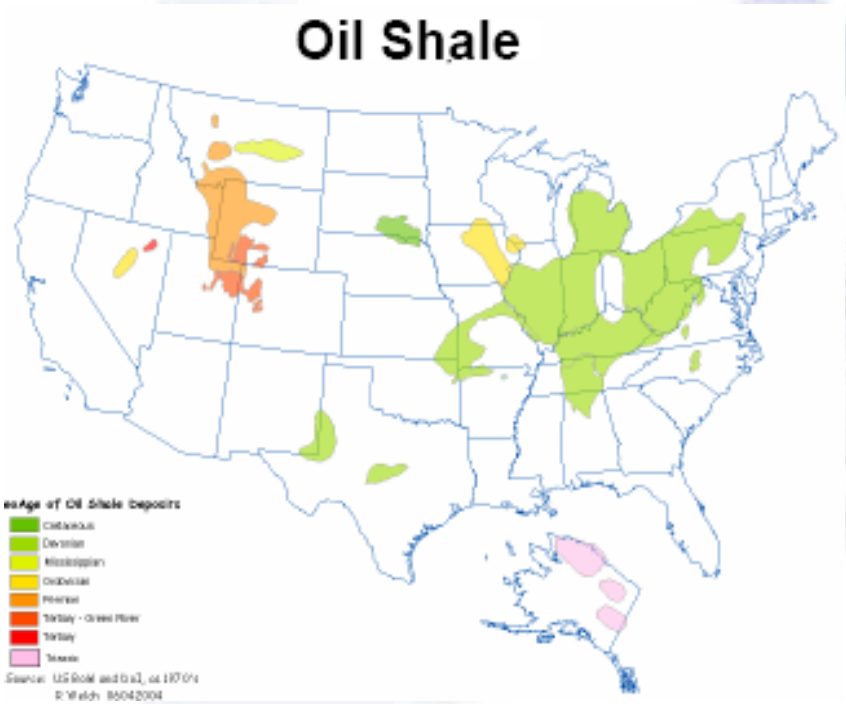



Source: U.S. Department of Energy, Energy Information Administration, 2001

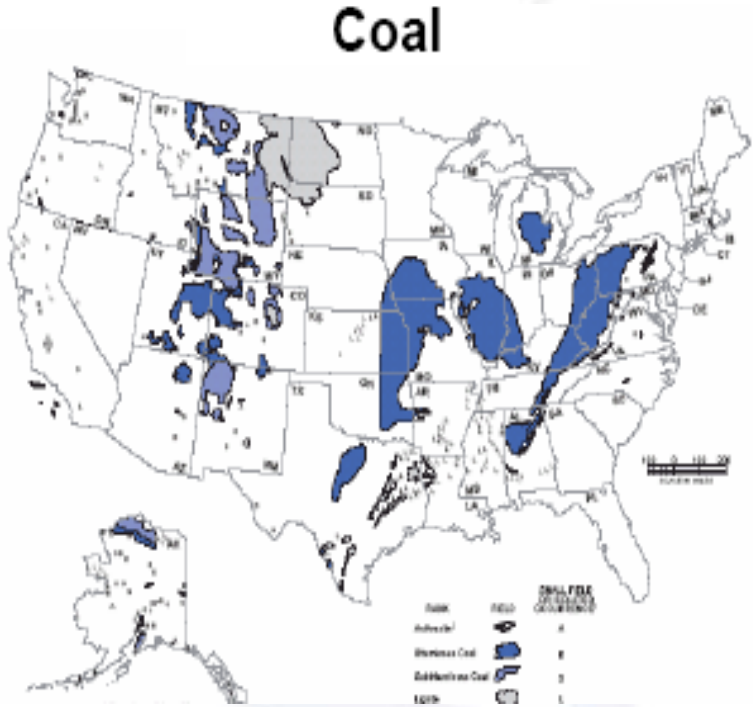
# United States dependence on foreign oil



# Resources in United States




~2 Trillion BOE



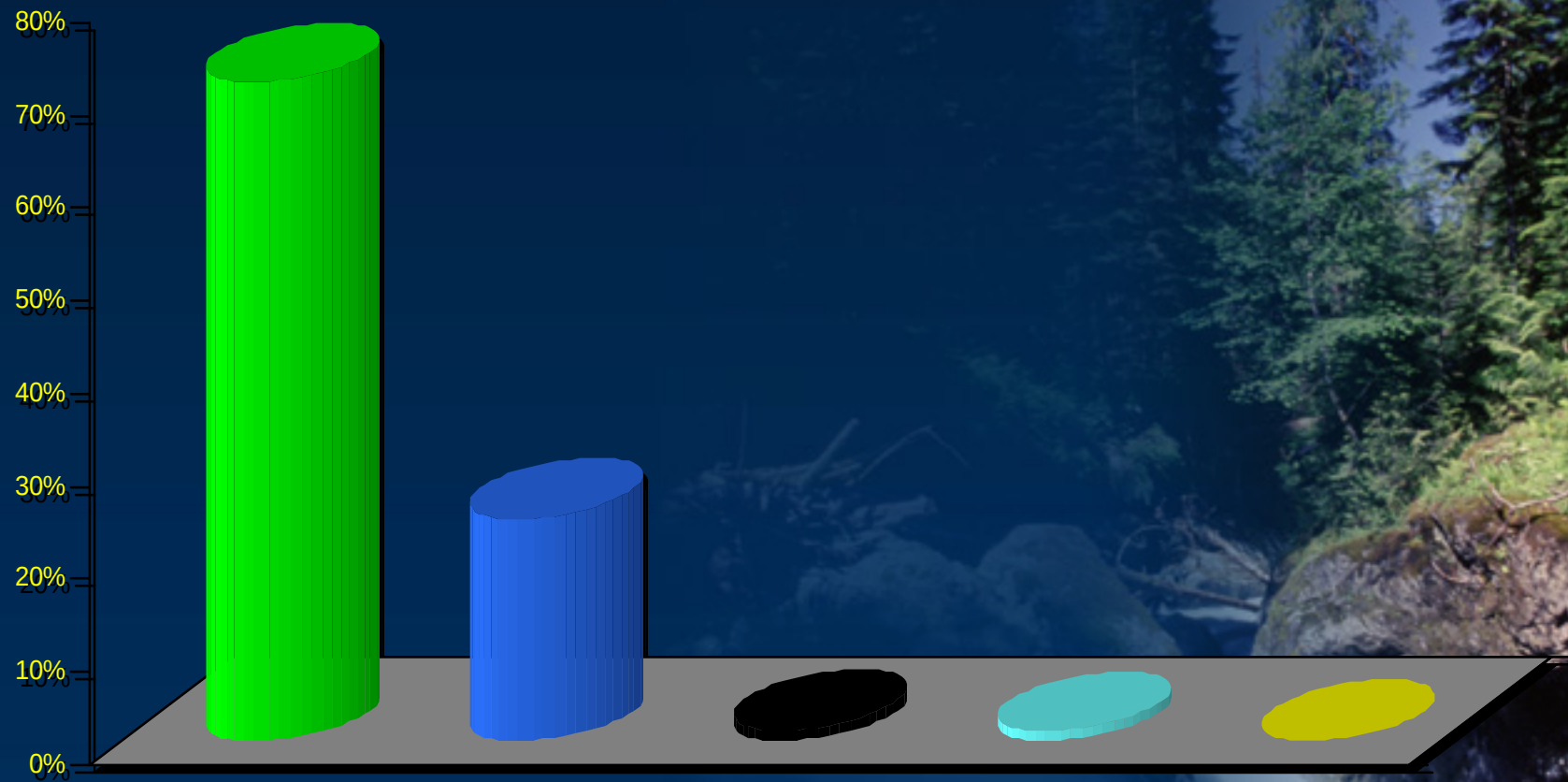

~800 Billion BOE

**BOE** – Barrels of Oil Equivalent

**Source: EIA, 2005**

# U.S. Emission-Free Electricity

(2003)




*Source: U.S. Energy Information Administration*

Idaho National Laboratory

NEI

# Options for use of coal resources

- Conventional pulverized coal system
  - Advantages: developed technology, economical, relatively efficient (35%+)
  - Disadvantages: $SO_X$, $NO_X$, $CO_2$, wastes (ash, sludge, et al)
- Gasification
  - Advantages: reduced emissions, potentially higher efficiency
  - Disadvantages: Water usage, $CO_2$, byproducts
- Coal to liquid hydrocarbons

# Synthetic Hydrocarbon Fuel Requirements

## Hydrogen

**Near term**
- natural gas
- electrolysis
- coal
- biomass

**Long term**
- water splitting
- gas hydrates
- oil shale

## Carbon

**Near term**
- natural gas
- coal
- biomass

**Long term**
- coal
- shale
- gas hydrates
- recycled carbon ($CO_2$)

## Energy

**Near term**
- coal
- natural gas
- nuclear

**Long term**
- coal
- shale
- nuclear
- gas hydrates

# Replacement liquid fuels will first be from heavy oils and tar sands

***Syncrude Canada Ltd.***
***Tar Sands Operations***

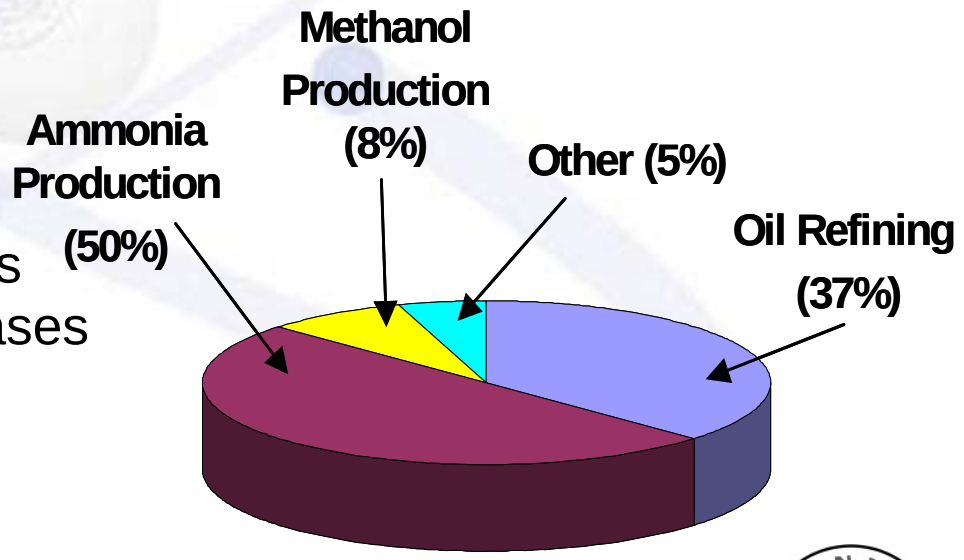

- Large quantities of tar sands and heavy oils are located in the western hemisphere (Canada, Mexico, Venezuela, and the United States)
- But we currently do not have cheap hydrogen to make gasoline, and diesel and jet fuels

# Current hydrogen use is significant

- Although hydrogen is the most abundant element in the universe, it does not naturally exist in its elemental form in large quantities or high concentrations on earth.
- The World consumption in 2002 was 50 million tons $H_2$/yr, produced primarily by steam reforming of methane

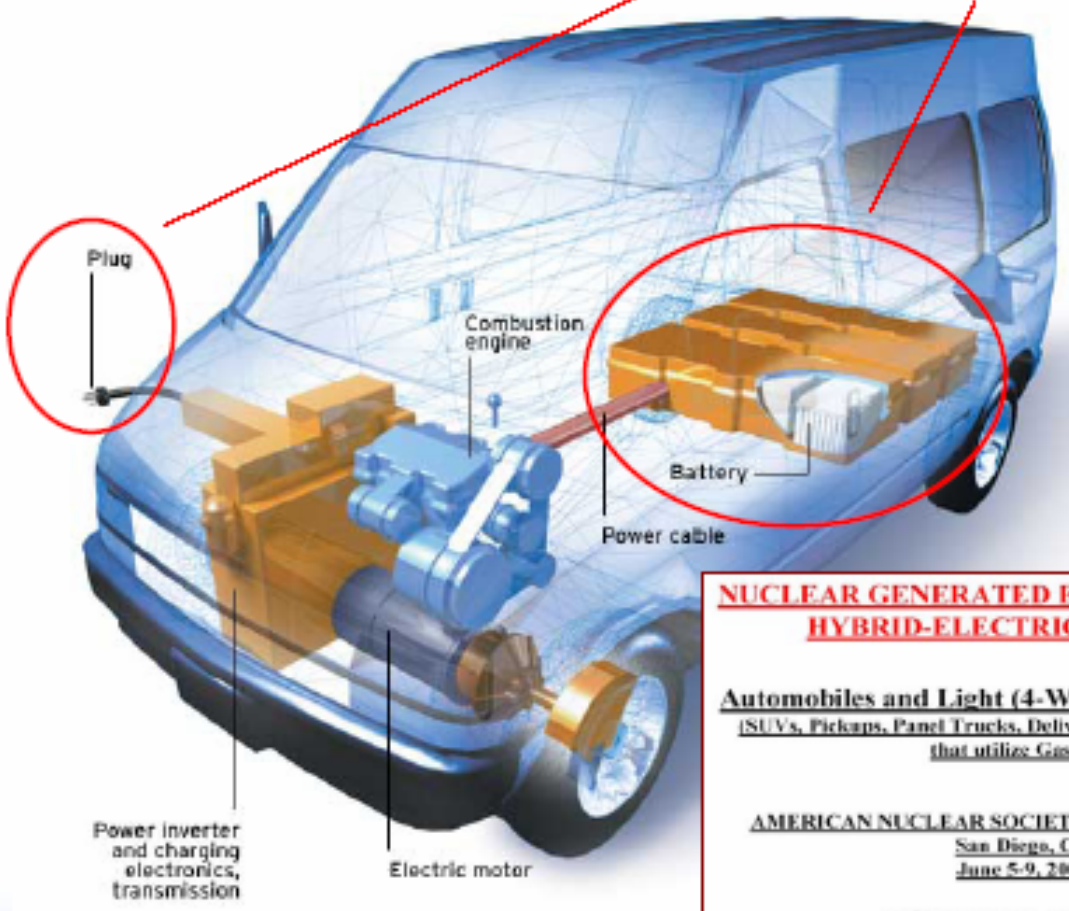
- We are now using more than 5% of North American natural gas for $H_2$ production which, with natural gas use for

  electricity production, is putting pressure on home heating costs
- The current $H_2$ production releases 320 million metric tons $CO_2$/yr



# Plug-In Hybrid Electric Vehicles

## PHEV = hybrid + plug + larger battery





Using Plug-in Hybrid Vehicles

**NUCLEAR GENERATED ELECTRICITY FOR HYBRID-ELECTRIC VEHICLES**

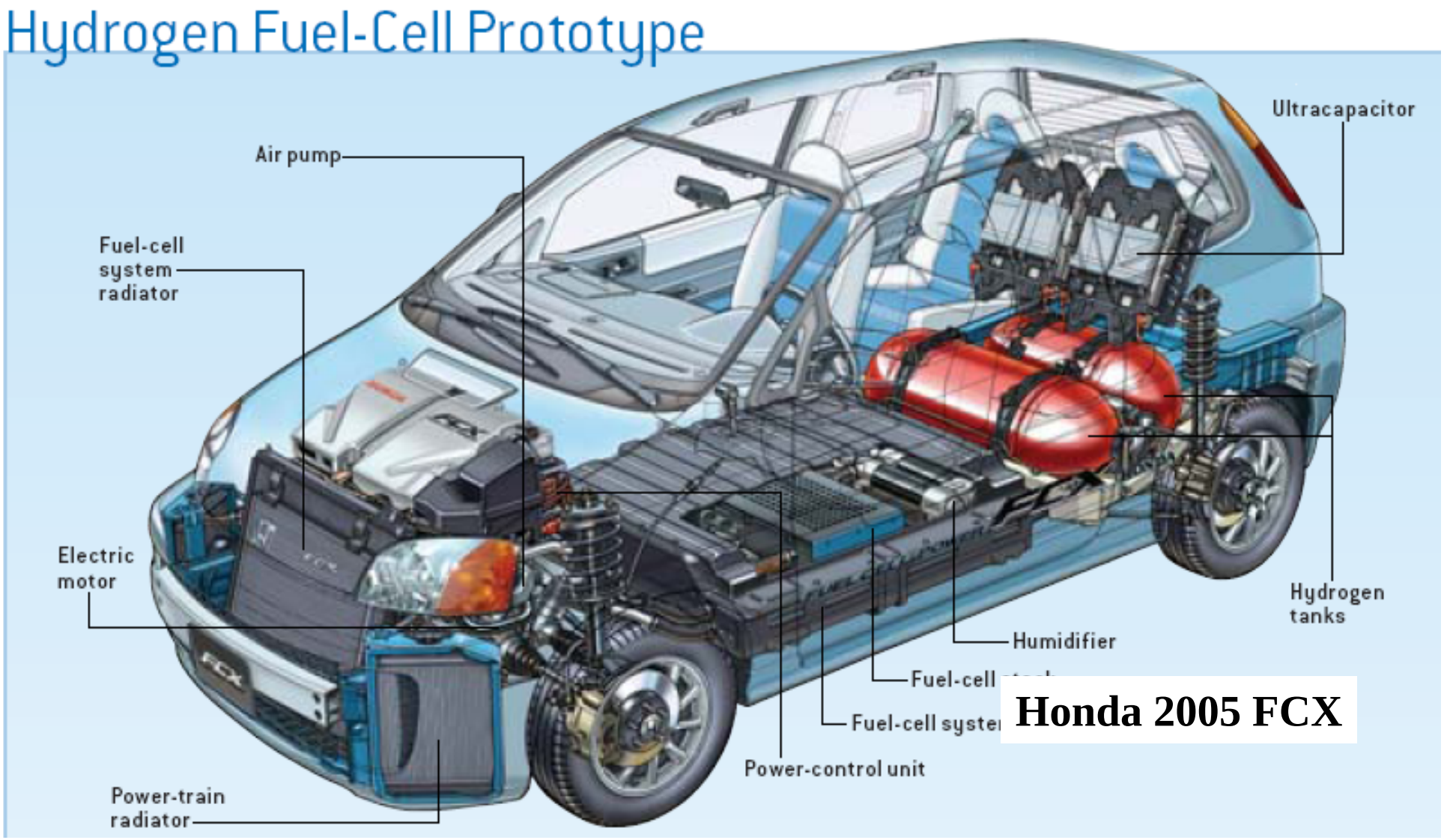
**Automobiles and Light (4-Wheel) Truck Vehicles**
(SUVs, Pickups, Panel Trucks, Delivery Vans, Minibuses, etc)
that utilize Gasoline

AMERICAN NUCLEAR SOCIETY ANNUAL MEETING
San Diego, CA
June 5-9, 2005

**ROBERT E. UHRIG**
Distinguished Professor Emeritus
Department of Nuclear Engineering
University of Tennessee, Knoxville

Idaho National Laboratory

# Eventually we will have viable fuel cells - hydrogen fuel & water out the tailpipes



# Fischer Tropsch to produce fuels

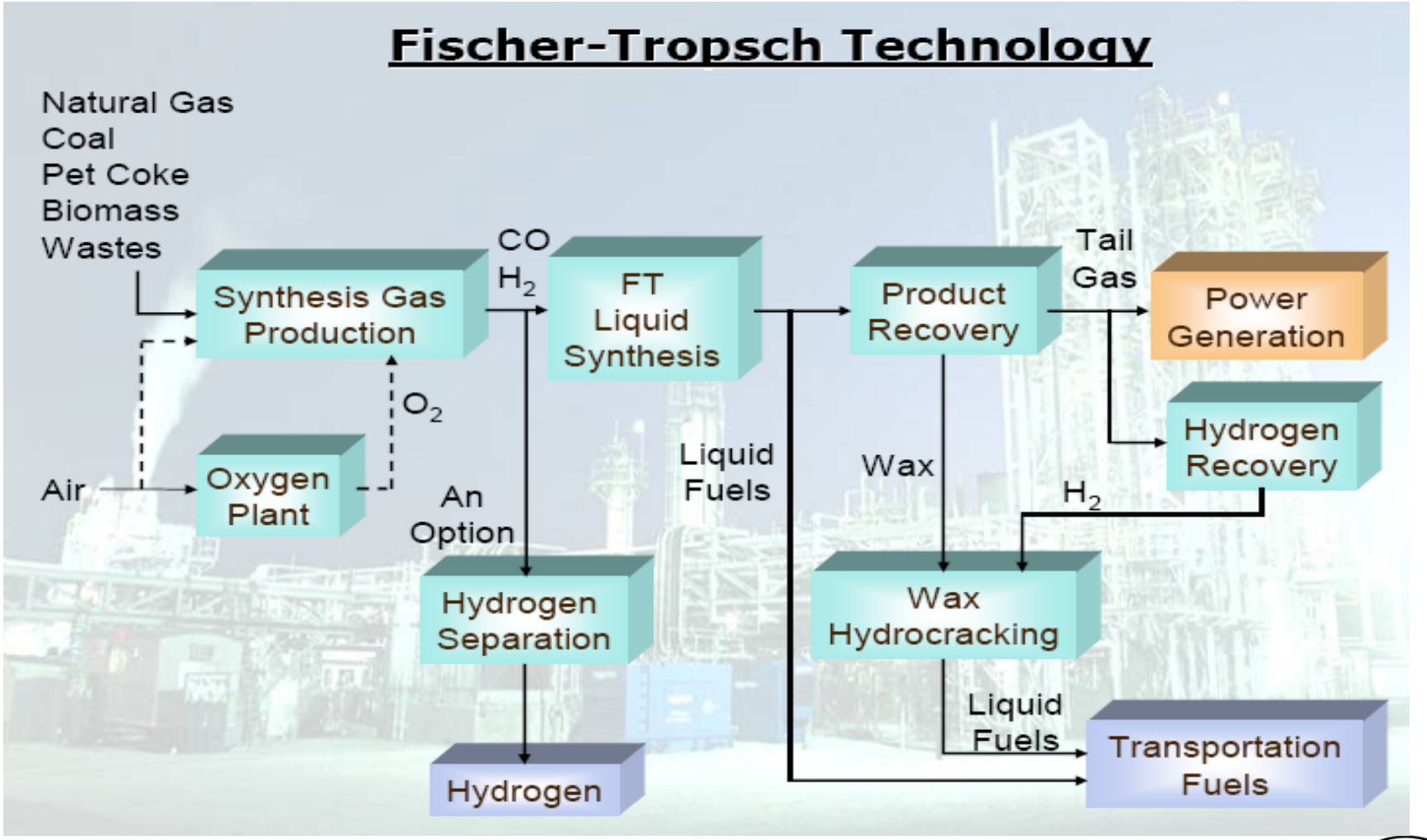



Diagram from presentation by Bill Harrison, ODUSD(AS&C)

# Hydrogen Initiatives

- Hydrogen production - nuclear energy
- Hydrogen production - fossil or renewables
- Hydrogen infrastructure - hydrogen storage, fueling infrastructure

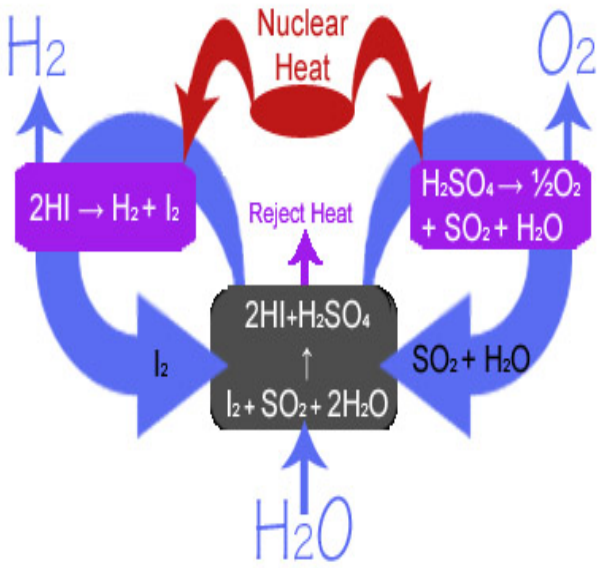
**Nuclear Hydrogen Plant**

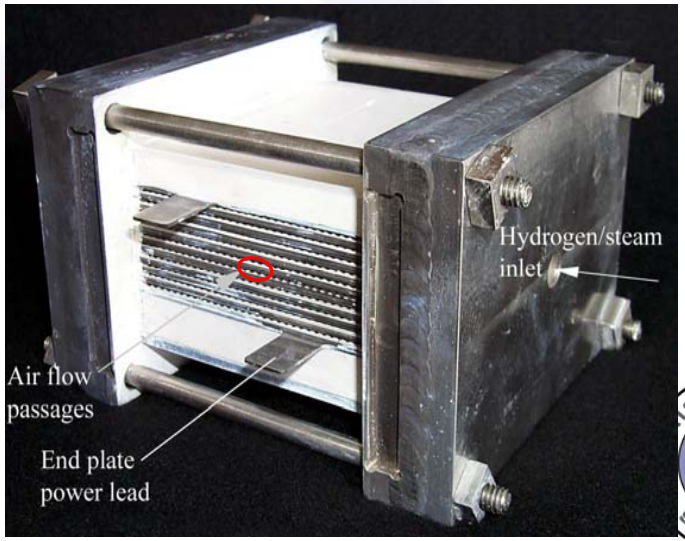
**Hydrogen from diesel**

**Phoenix Hydrogen Fueling**

# Hydrogen Production Technologies

- Two technologies will use the heat from the high-temperature helium coolant to produce hydrogen
- The first technology of interest is the thermo-chemical splitting of water into hydrogen and oxygen
- The second technology of interest is thermally assisted electrolysis of water
- The efficiency of this process can be improved by heating the water to high-temperature steam before applying electrolysis



# Science and engineering need acknowledged

- NAS, “Rising Above the Gathering Storm”
  - Last year, more than 600,000 engineers graduated from institutions of higher education in China, compared to 350,000 in India and 70,000 in the United States.
  - Recently, American 12th graders performed below the international average for 21 countries on general knowledge in math and science.
  - The cost of employing one chemist or engineer in the United States is equal to about five chemists in China and 11 engineers in India.
  - Chemical companies last year shut 70 facilities in the United States and marked 40 for closure. Of 120 large chemical plants under construction globally, one is in the United States and 50 are in China.
- Science, Technology, Engineering and Mathematics (STEM) Education Coalition
- State of the Union Address

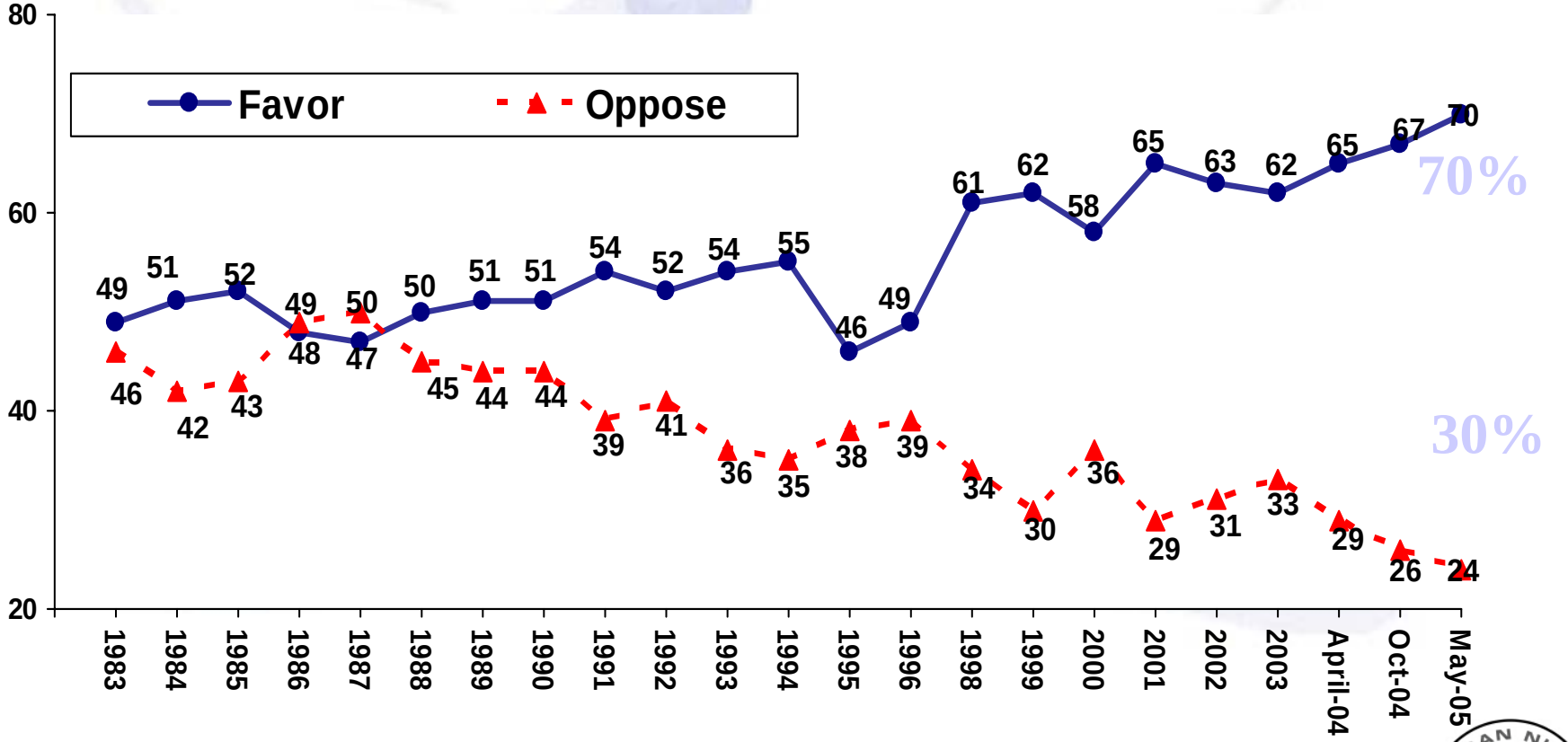
# World Nuclear University

77 fellows from 34 countries at first summer institute in Idaho

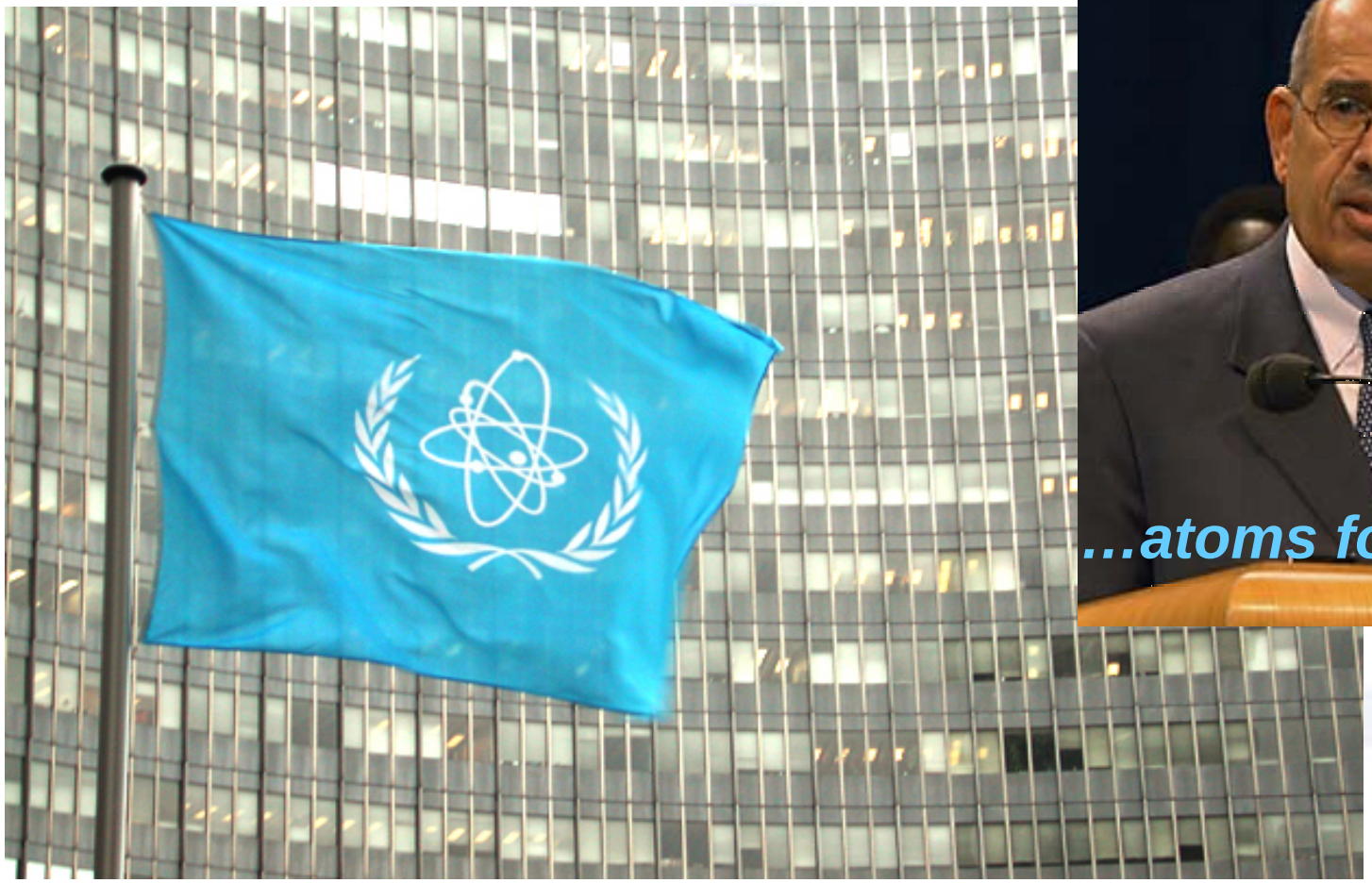
# Conditions for nuclear resurgence

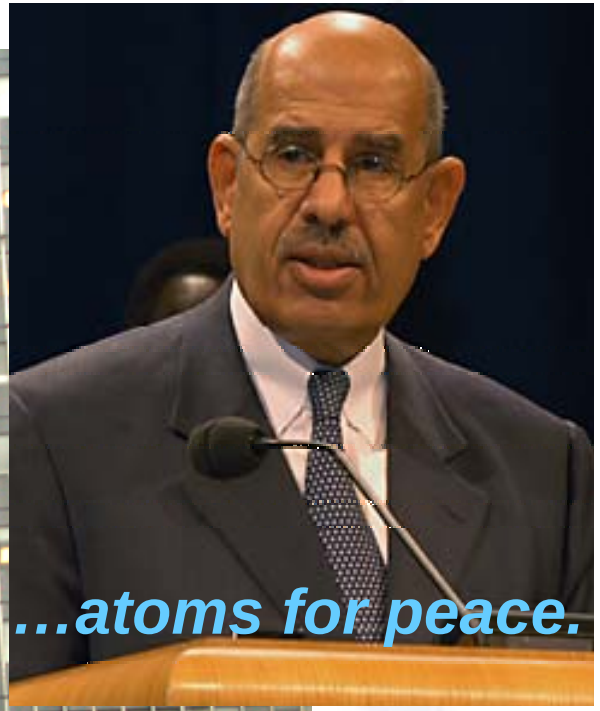
- Federal action on spent fuel issue
- Continued safe, efficient operation of current fleet
- Stable, predictable regulatory framework
- Acceptable nonproliferation regime
- Public acceptance
- New plant orders
- Infrastructure
  - Manufacturing
  - Skilled labor
- Sustainability—get greener

# USA is decidedly pro-nuclear today



# IAEA wins Nobel Peace Prize 2005






**1 of every 10 US light bulbs is powered by uranium from a former Soviet warhead.**

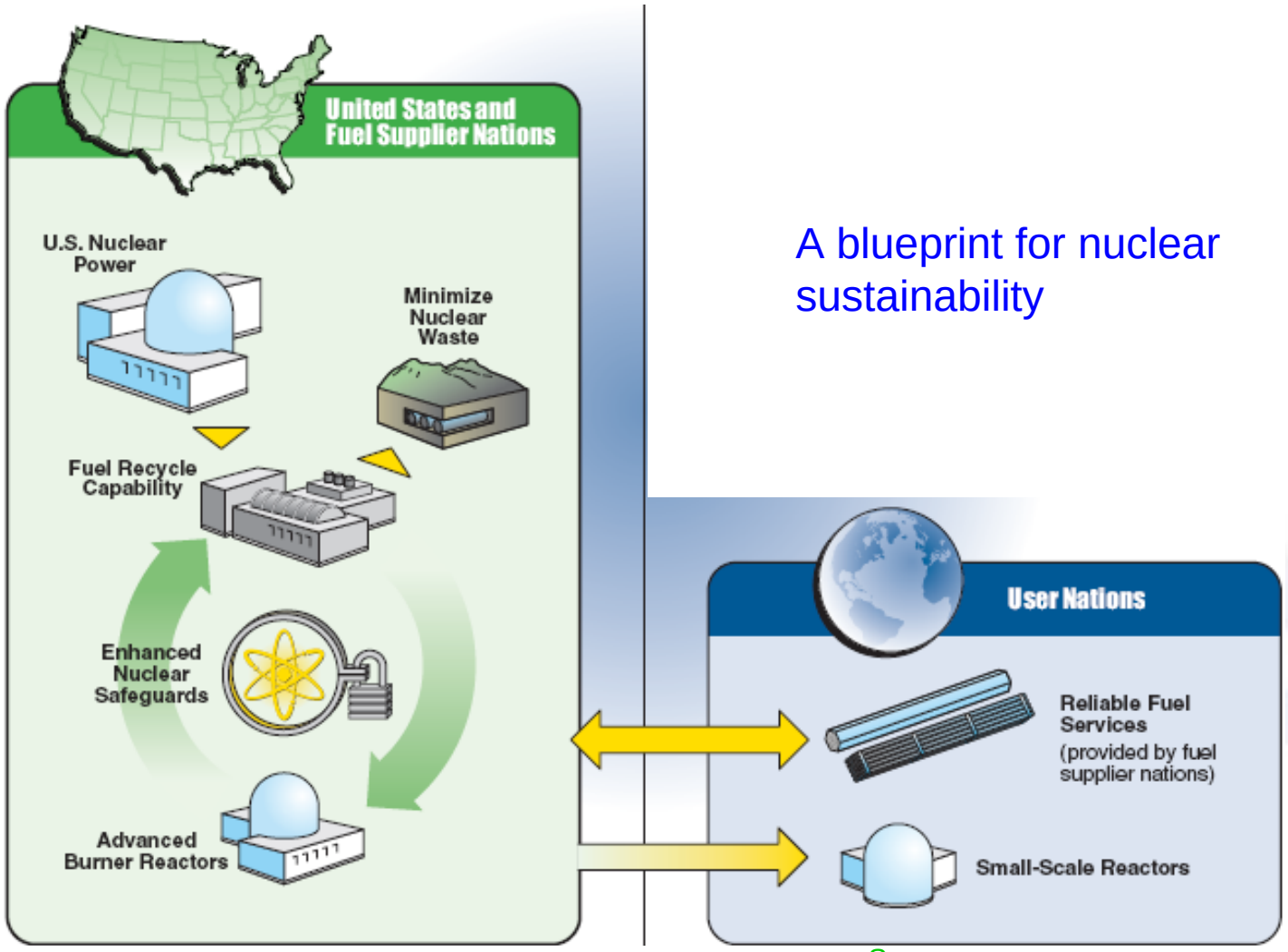
# New plant construction—the foundation of US nuclear growth

- New plant order expected within 2 years
- 10 companies or consortia are involved in early permitting process
  - Dominion and Dominion-led consortium
  - Duke Energy
  - Entergy Corp.
  - Exelon Nuclear
  - NuStart Energy Development LLC
  - Progress Energy
  - South Carolina Electric & Gas/Santee Cooper
  - Southern Nuclear Operating Company
  - TVA-led consortium
- 2-3 orders/year by 2020

# Getting green: closing the fuel cycle

- Nuclear is currently an extractive industry
- “Closing the fuel cycle is inevitable.” GLOBAL 2005
- It takes 50 years to fully implement a new energy technology
- No huge rush for US to implement, but…
  - Spent fuel assurance needed by utilities
  - Maybe last chance to influence international development
  - Serious R&D is needed now

# Global Nuclear Energy Partnership (GNEP)




A blueprint for nuclear sustainability

Source: www.gnep.energy.gov

# Key Elements of GNEP

- **Expand domestic use of nuclear power**
- **Demonstrate more proliferation-resistant recycling**
- **Minimize nuclear waste**
- **Develop advanced burner reactors**
- **Establish reliable fuel services**
- **Demonstrate small-scale reactors**
- **Develop enhanced nuclear safeguards**

Source: www.gnep.energy.gov