



*Idaho National Engineering and Environmental Laboratory*

# ***Hydrogen Production from Nuclear Energy***

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***Dr. John M. Ryskamp  
INEEL***

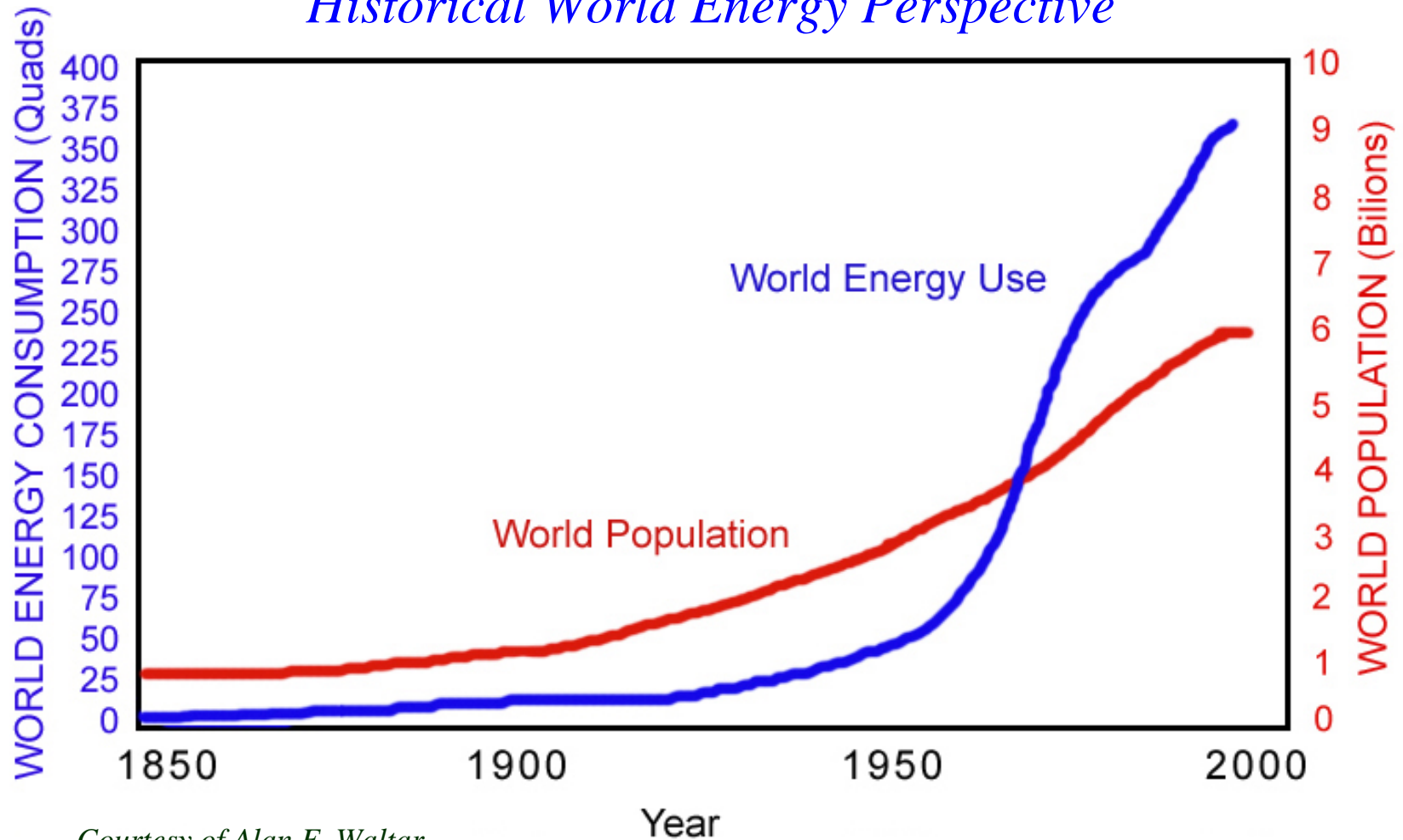
***IEEE Power Engineering Society Meeting***

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*April 28, 2003*

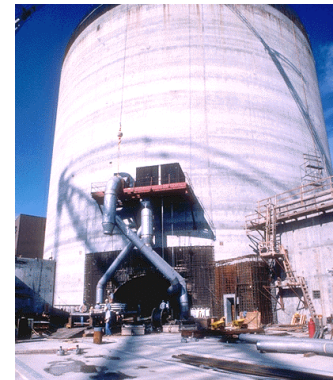
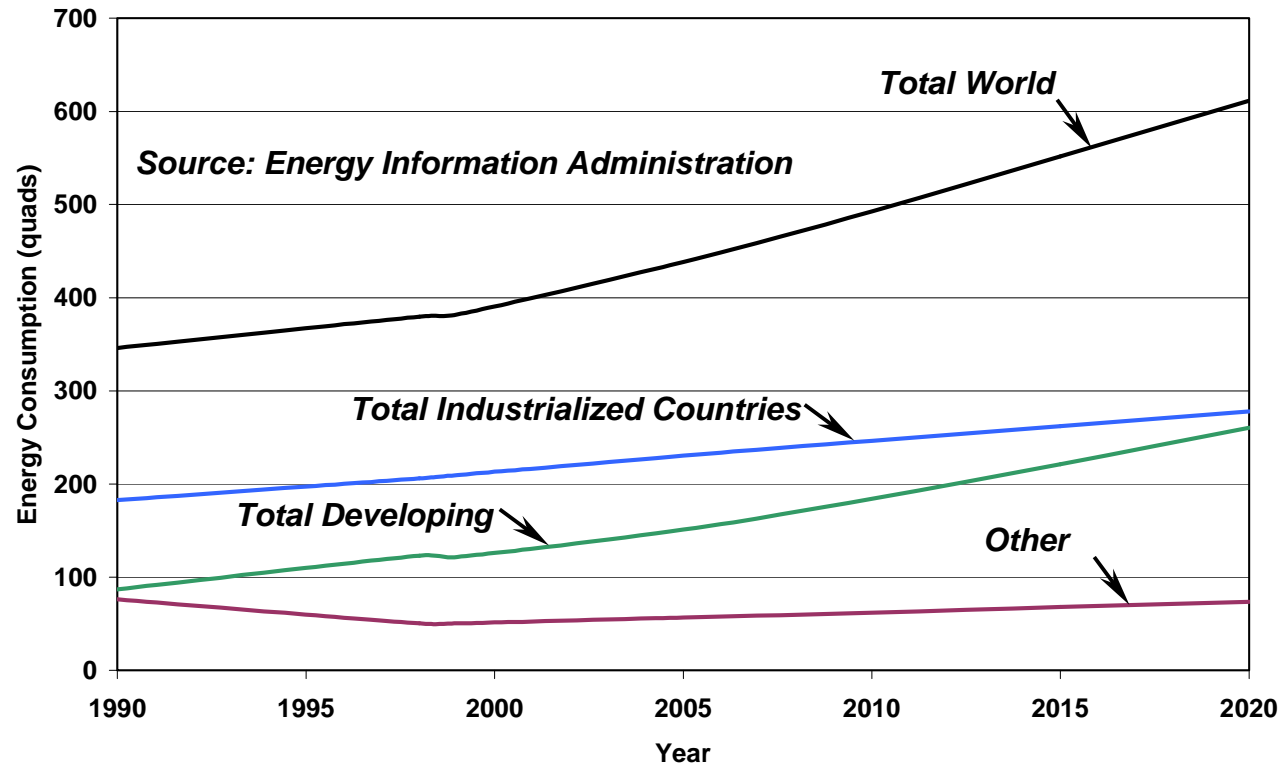
# Energy Needs for Sustainable Development

## Historical World Energy Perspective



Courtesy of Alan E. Waltar

# World Energy Demand



# World Energy Perspective

*Projected growth over the next half century  
(International Nuclear Societies Council)*

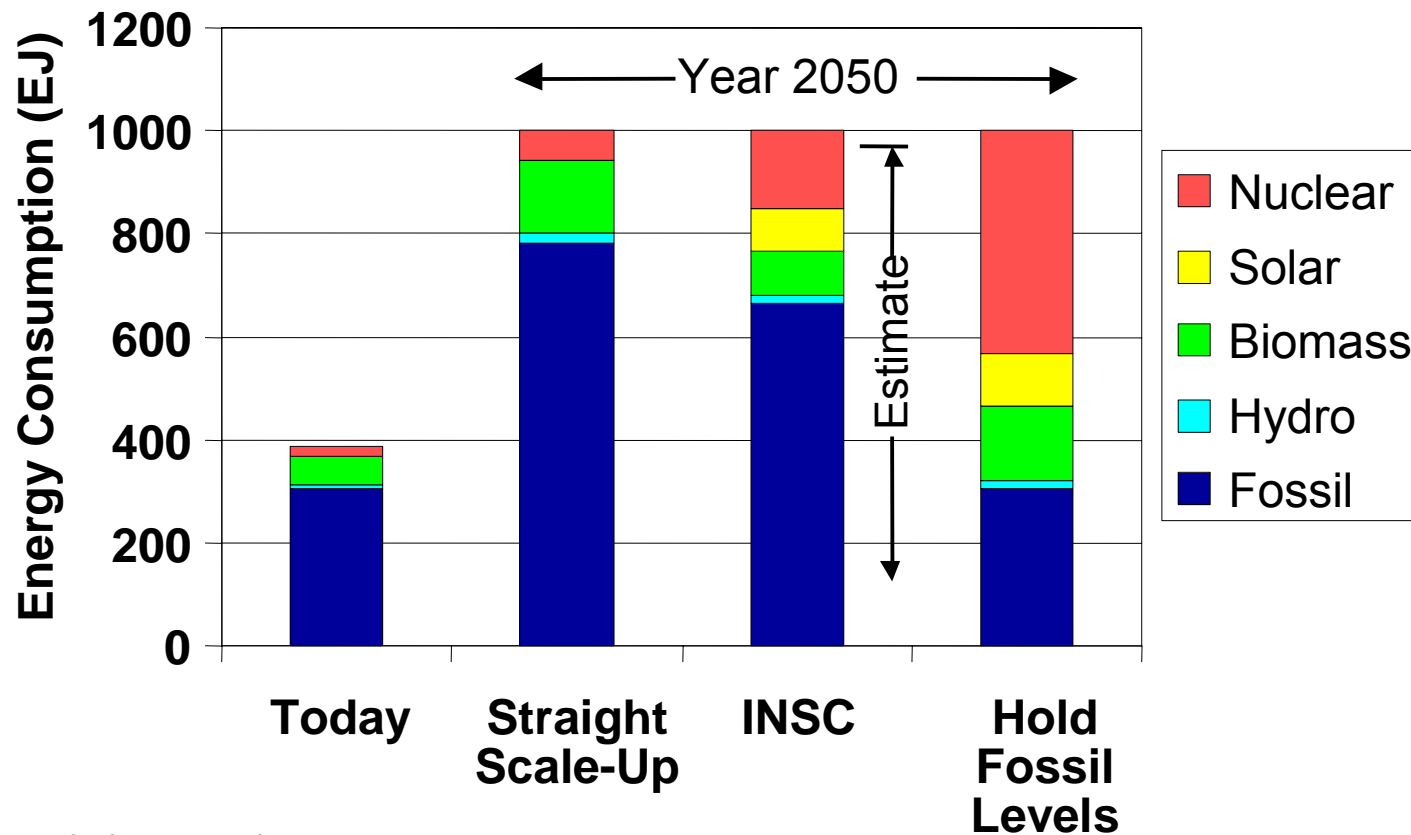
<b>Year</b>	<b>Population (Billions)</b>	<b>GJ/Person</b>	<b>Total Energy (EJ)</b>
2000	6	67	400
2050	10	100*	1000

\* NOTE: U.S. Today ~ 300 GJ/Person  
100 GJ/Person represents 5 times increase for poor nations

*Courtesy of Alan E. Waltar*

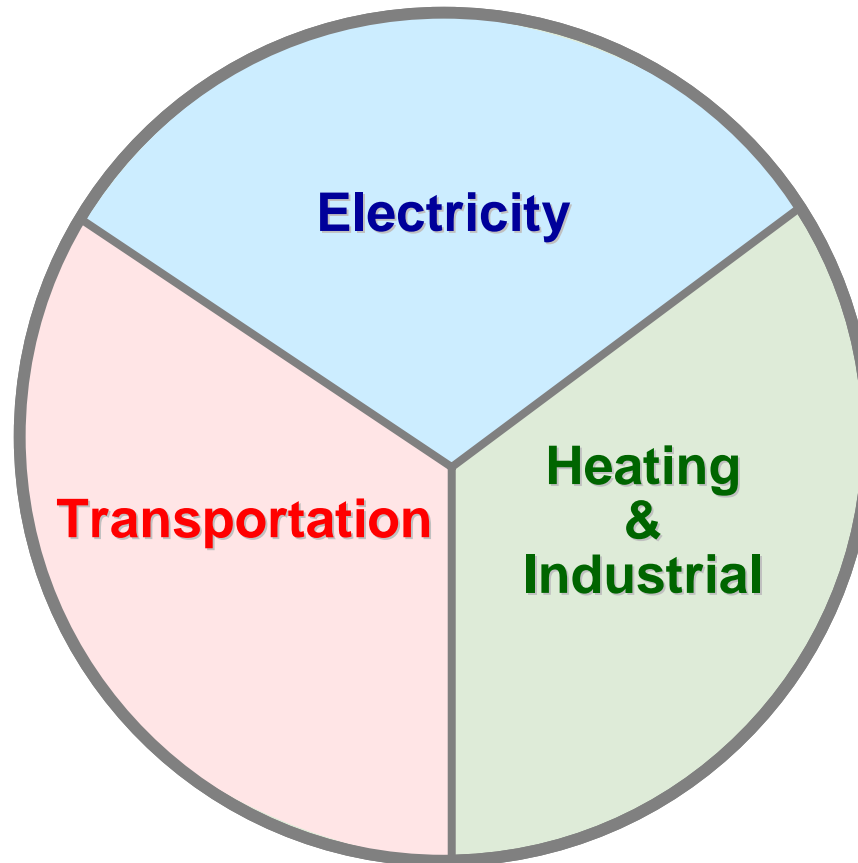
# Global Energy Mix

## *(Options for the Future)*



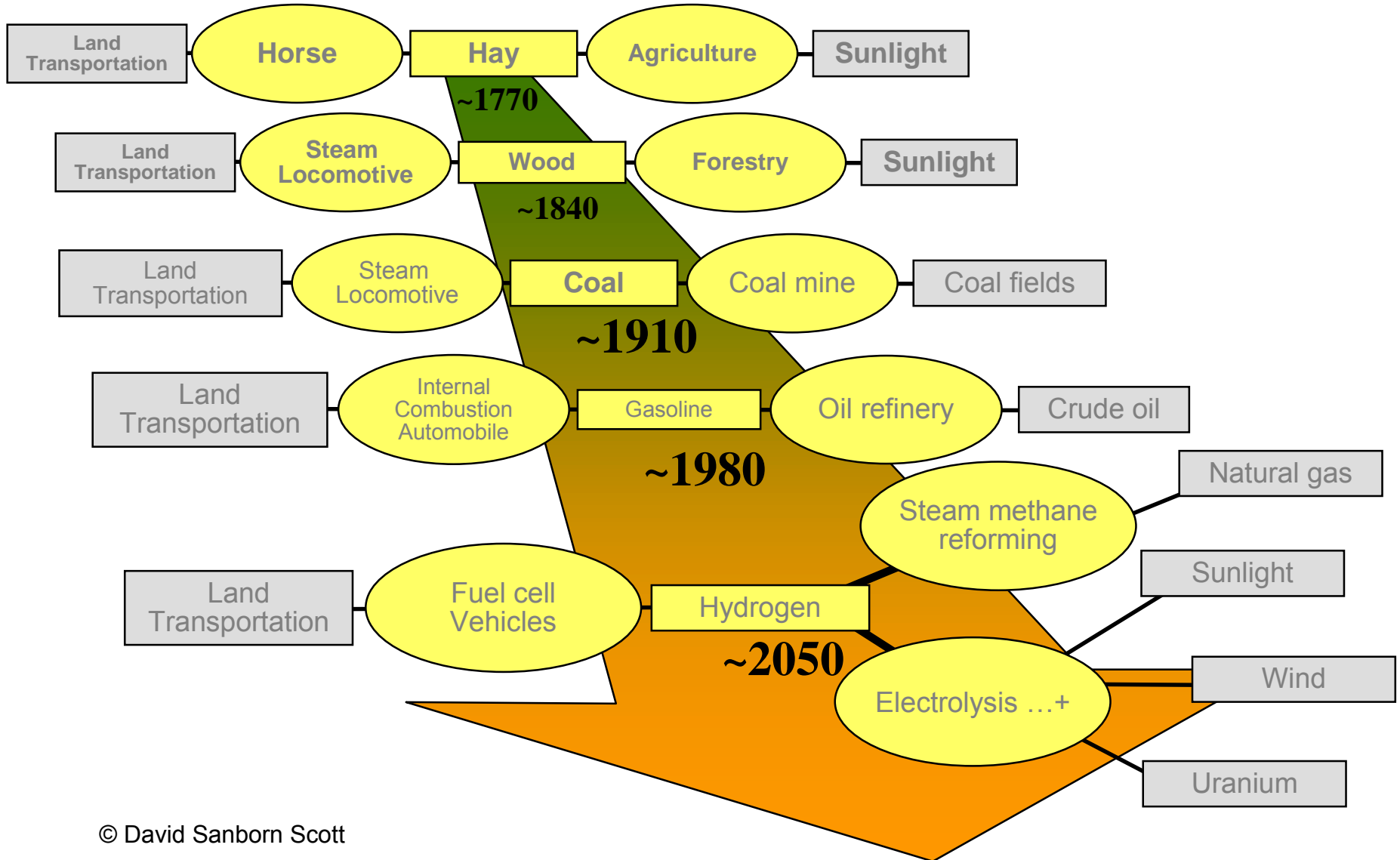
Courtesy of Alan E. Waltar

# Uses of Primary Energy



*Gen IV provides the opportunity for nuclear power to impact the other primary energy use sectors*

# Land Transport: $\Delta t \cong 70$ years



© David Sanborn Scott

# ***Present Hydrogen Consumption***

- ***Petroleum refining***
  - *Sulfur removal*
  - *Opening of benzene rings*
  - *Breaking of long-chain hydrocarbons*
- ***Anhydrous ammonia production***
- ***Chemical industry***
- ***Annual consumption***
  - *U.S.: 12 million t H<sub>2</sub>/yr (47 GWth if burned)*
  - *World: 50 million t H<sub>2</sub>/yr (200 GWth if burned)*

*(50 million t H<sub>2</sub>/yr would require 390 GWth input to a thermochemical process)*



# ***The Emerging Needs for Hydrogen***

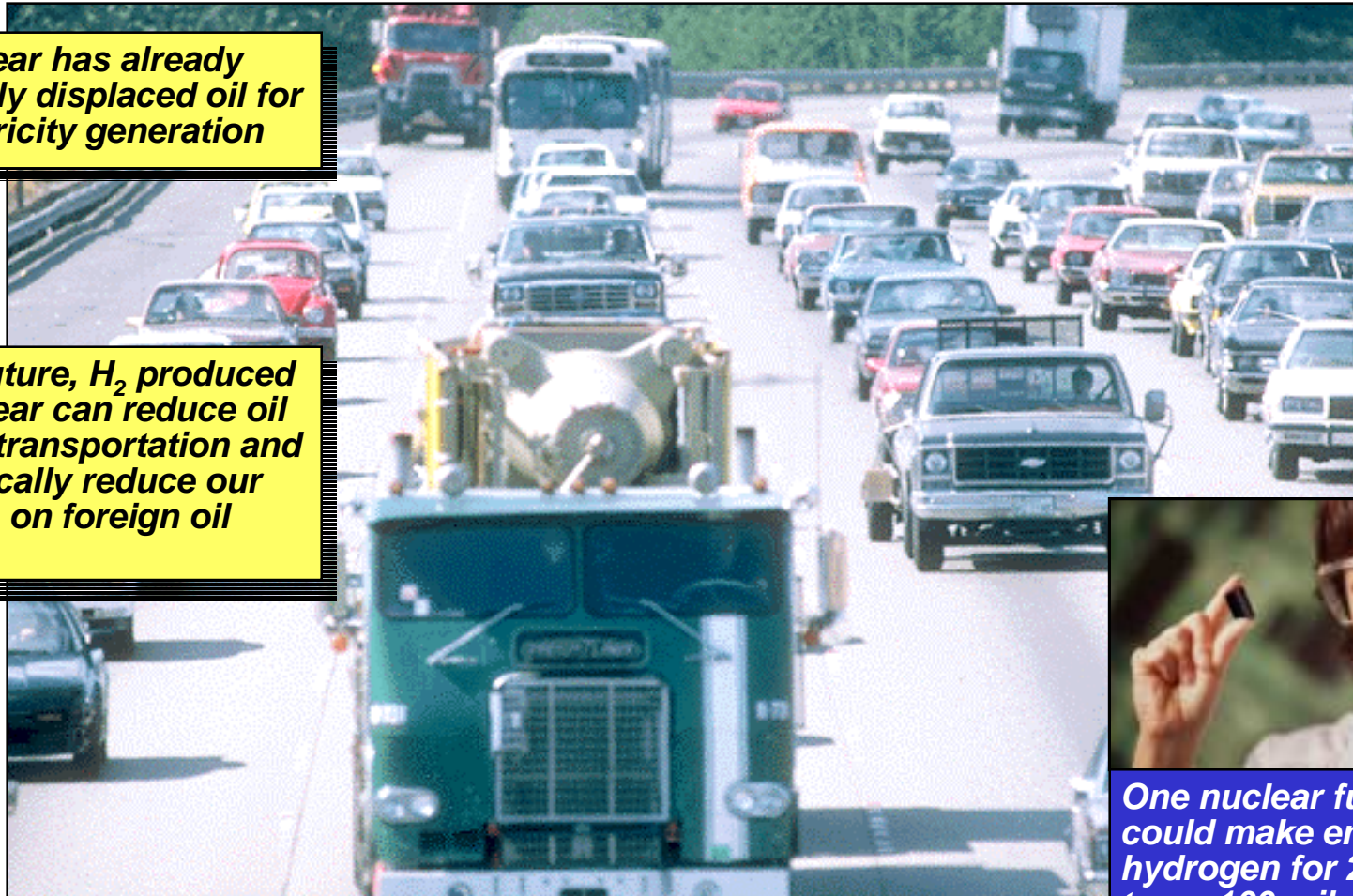
## ***“The Hydrogen Economy”***

- ***The “transportation fuel of the future”***
  - *28% of US energy used for transportation*
  - *Essential for overall CO<sub>2</sub> reduction*
- ***Distributed power – neighborhood fuel cells***
- ***Rapid hydrogen-demand growth to produce clean fuels from lower-grade crude oils***
- ***Within 10 to 20 years, the energy to produce hydrogen in the U.S. may exceed current energy production from nuclear power***

# ***Nuclear Can Do More: Hydrogen for Transportation***

***Nuclear has already largely displaced oil for electricity generation***

***In the future, H<sub>2</sub> produced by nuclear can reduce oil use for transportation and dramatically reduce our reliance on foreign oil imports***



***One nuclear fuel pellet could make enough hydrogen for 220 cars to go 100 miles***

## ***Methods for hydrogen production using nuclear energy***

- ***Steam methane reforming using nuclear energy for the endothermic heat of reaction***
- ***Conventional electrolysis using nuclear-generated electricity***
- ***Thermochemical cycles for water splitting***
- ***Hybrid cycles combining thermochemical and electrolytic steps***
- ***High temperature electrolysis using nuclear electricity and heat***

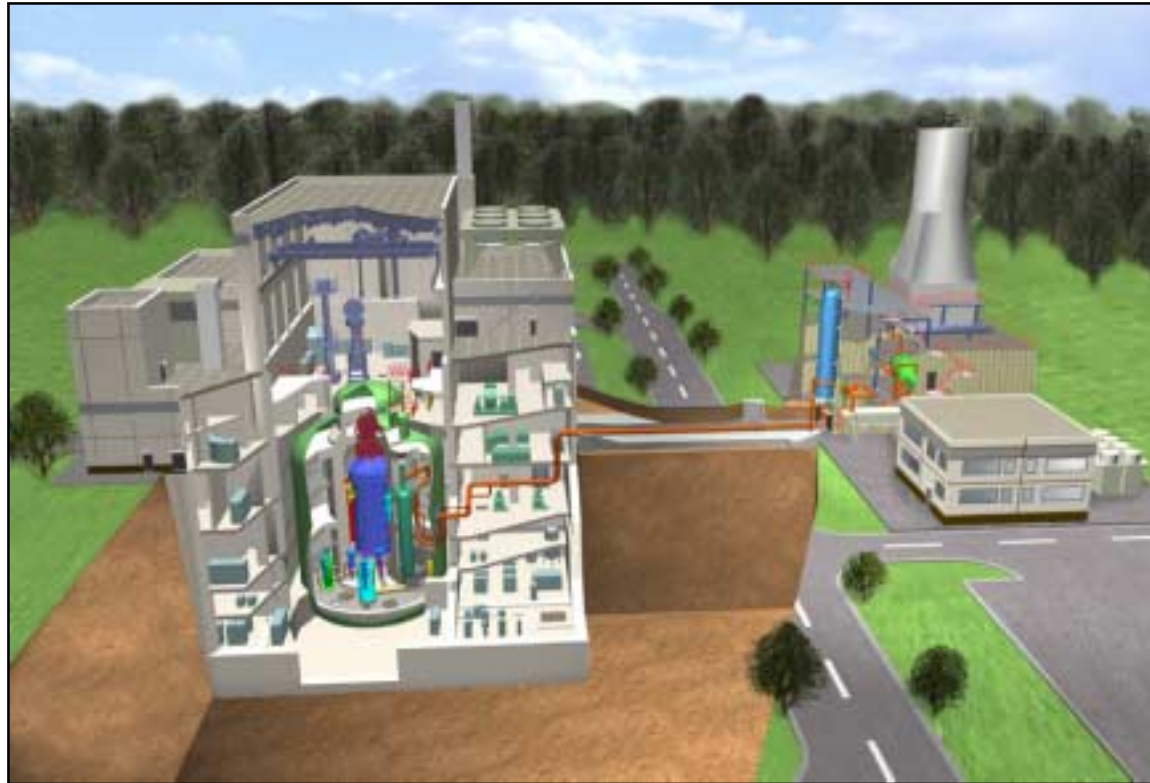
## **Steam methane reforming using nuclear energy for the endothermic heat of reaction**



(80% of CH<sub>4</sub> converted at 800° C)

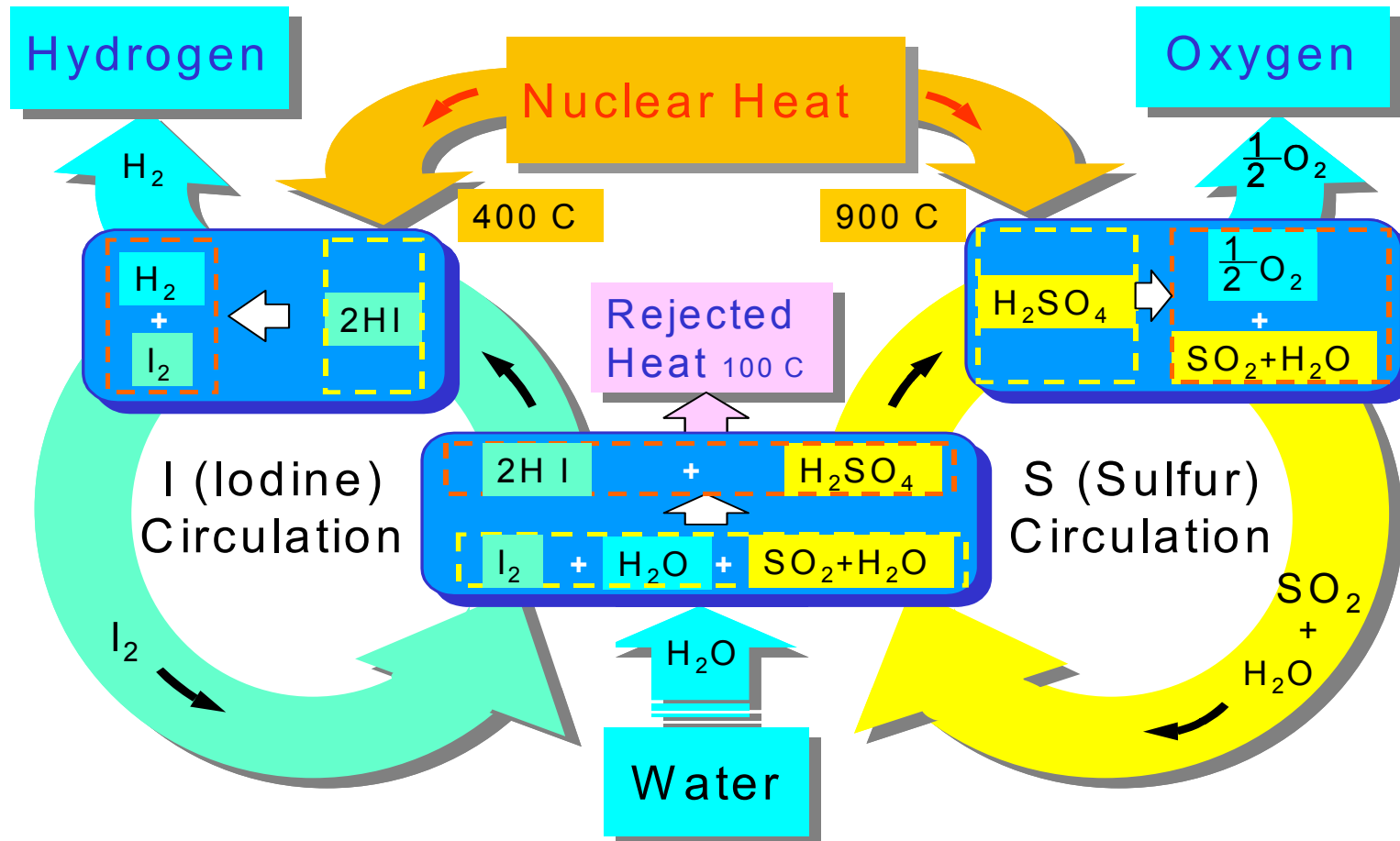
- *Advantages*
  - *Existing technology*
  - *Avoids methane use to produce steam*
  - *Easier to sequester CO<sub>2</sub> (than CO<sub>2</sub> from burning methane)*
- *Disadvantages*
  - *Still uses large quantities of methane (natural gas)*
  - *Releases large amounts of CO<sub>2</sub>*

# ***High Temperature Test Reactor***



***Using HTTR for NPH demonstration***

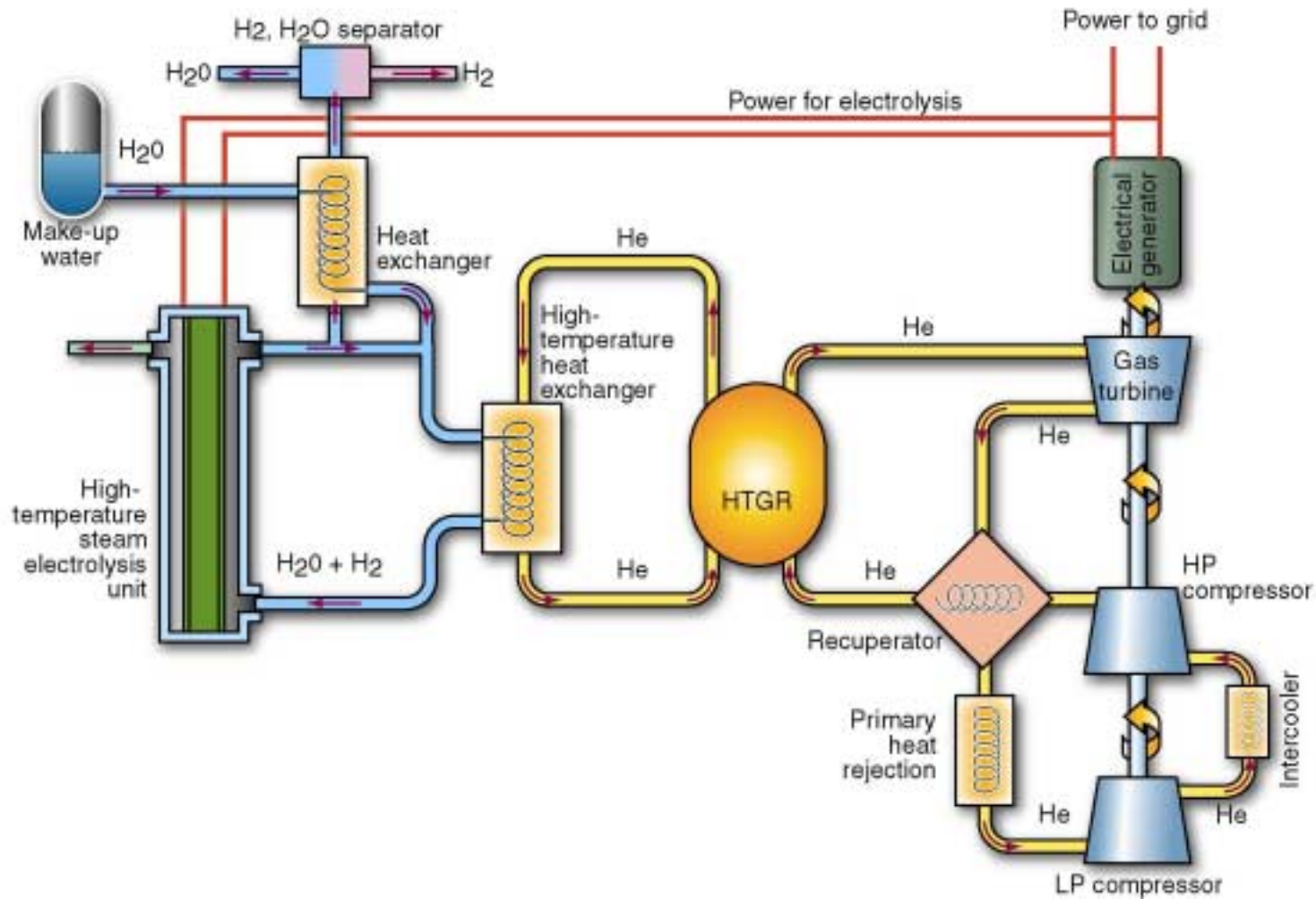
# Thermochemical Water Splitting



# ***High temperature electrolysis using nuclear electricity and heat***

- *Advantages*
  - *Builds on existing Solid Oxide Fuel Cell technology*
  - *Lower operating temperatures than thermochemical cycles*
  - *Less corrosive operating conditions*
- *Disadvantages*
  - *Will have lower efficiencies than thermochemical cycles*

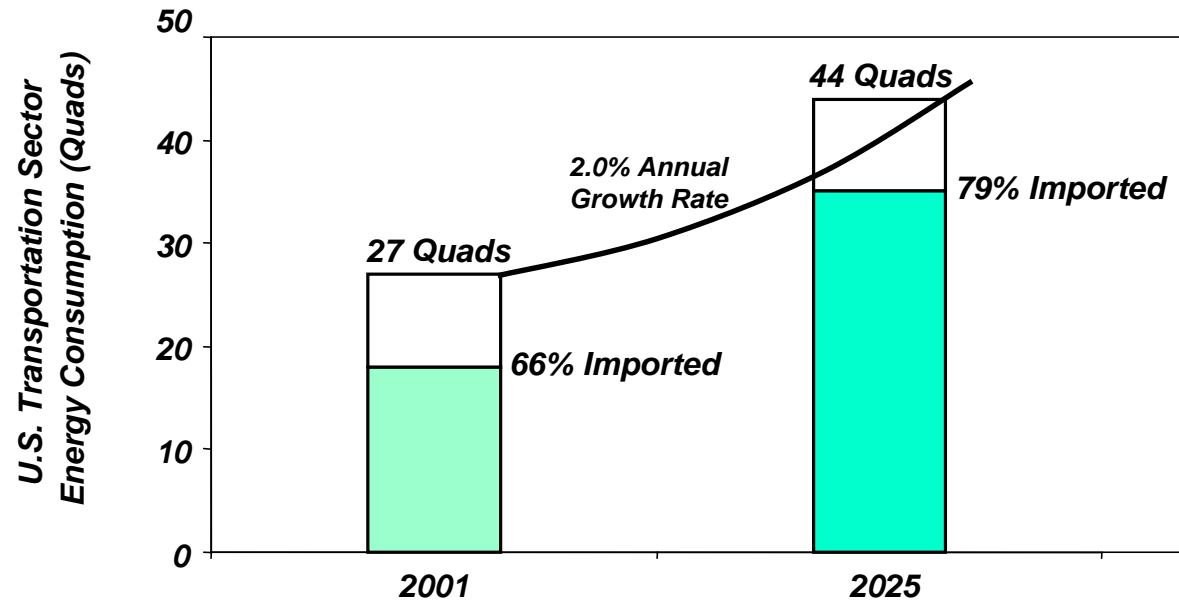
## High Temperature Electrolysis using a Nuclear Reactor Heat Source





# Potential for Nuclear in Transportation

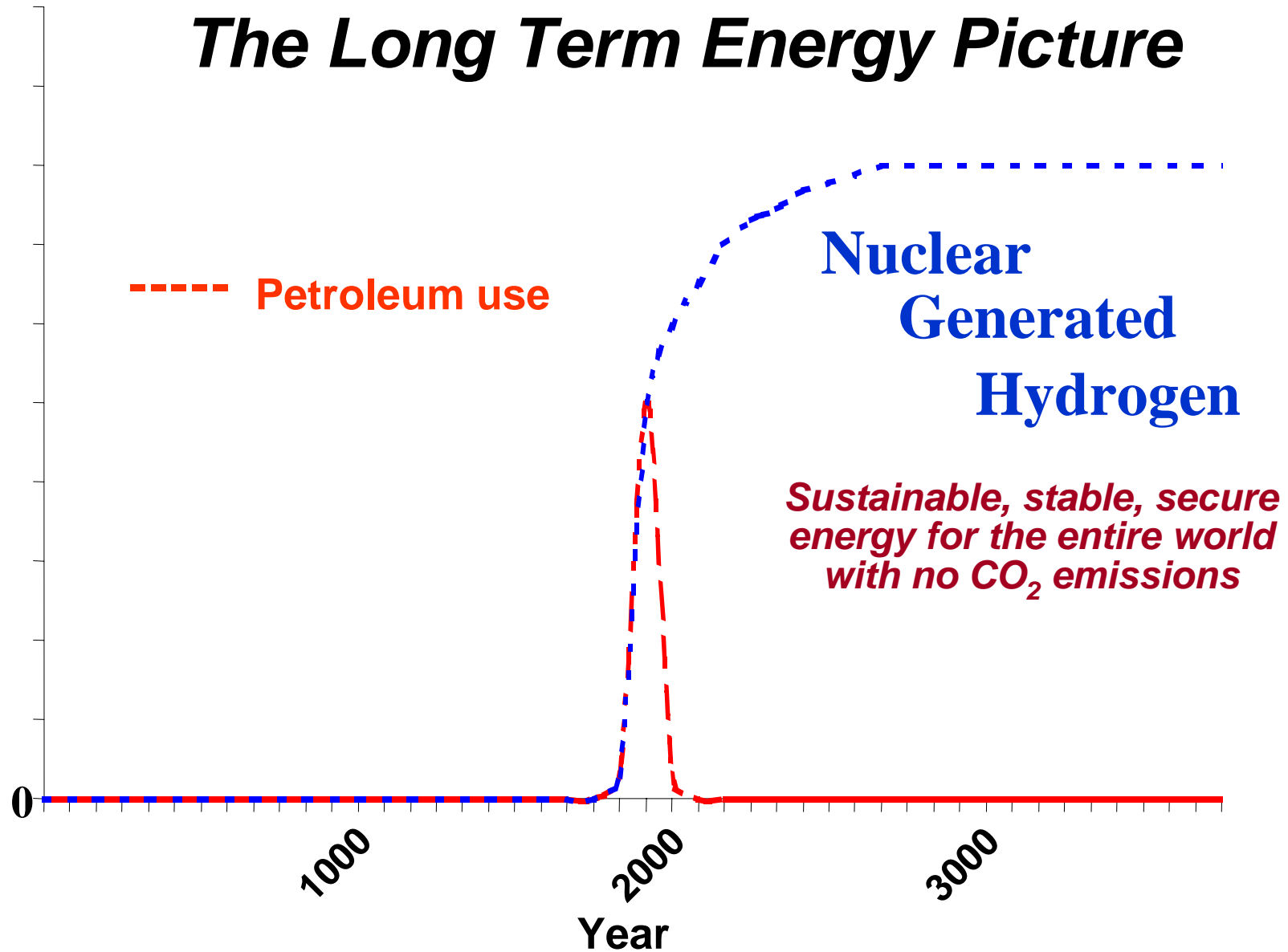
**Growing U. S. Transportation Sector Energy Demand and Imports**



Source: 2003 Annual Energy Outlook

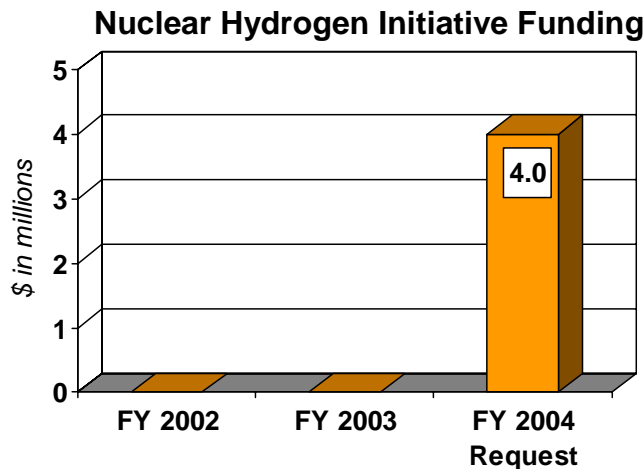
- **Transportation sector growth leads electricity & heating**
- **Outlook is for a disproportionate increase in imports**
- **Increasing dependence on imports clouds the outlook for energy security and stability**
- **Hydrogen can contribute if production-distribution-end use issues can be successfully addressed**

# The Long Term Energy Picture



# ***Nuclear Hydrogen Initiative: Developing Nuclear Energy Systems for Clean and Abundant Hydrogen Production***

- ◆ Nuclear energy systems offer opportunity for economical, clean, and abundant source of hydrogen



## Planned Accomplishments in FY 2004

- ◆ Complete a Nuclear Hydrogen Technology Roadmap
  - Built on National Hydrogen Energy Roadmap and inter-office cooperation
  - Define R&D required to develop an integrated nuclear hydrogen production plant
- ◆ Develop concept for an integrated nuclear hydrogen production system
- ◆ Initiate R&D on high temperature and corrosion resistant materials for thermo-chemical process

# ***The Nuclear Hydrogen Outlook***

- ***Demand for hydrogen is large today and growing 4-10%/yr***
- ***President Bush has announced a FreedomFUEL program***
- ***Long-term, a 30 million t/yr U.S. hydrogen supply would be able to serve one-quarter of our gasoline use***
- ***Nuclear energy required for this would be 225 GWth***
- ***Thermochemical cycles have highest efficiency but most daunting operating conditions***
- ***Electrolysis is promising, particularly in the near term***