Hydrogen Production from Nuclear Energy

By

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Hydrogen…..The Vision

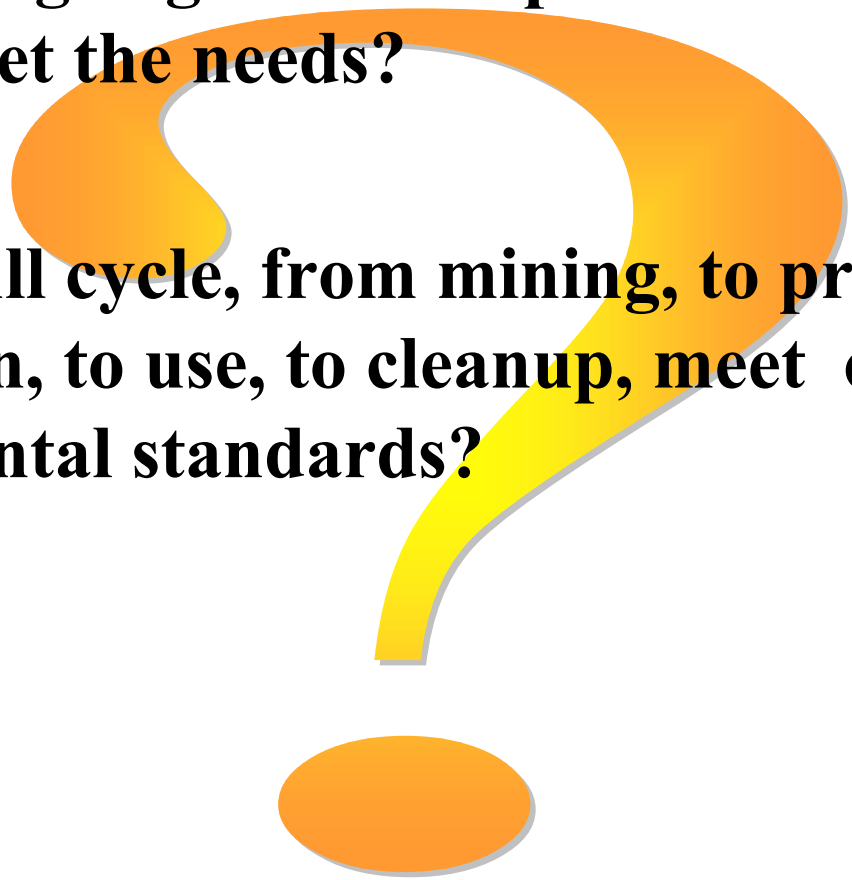
- **Energy Security**

- **Environmental Compatibility**

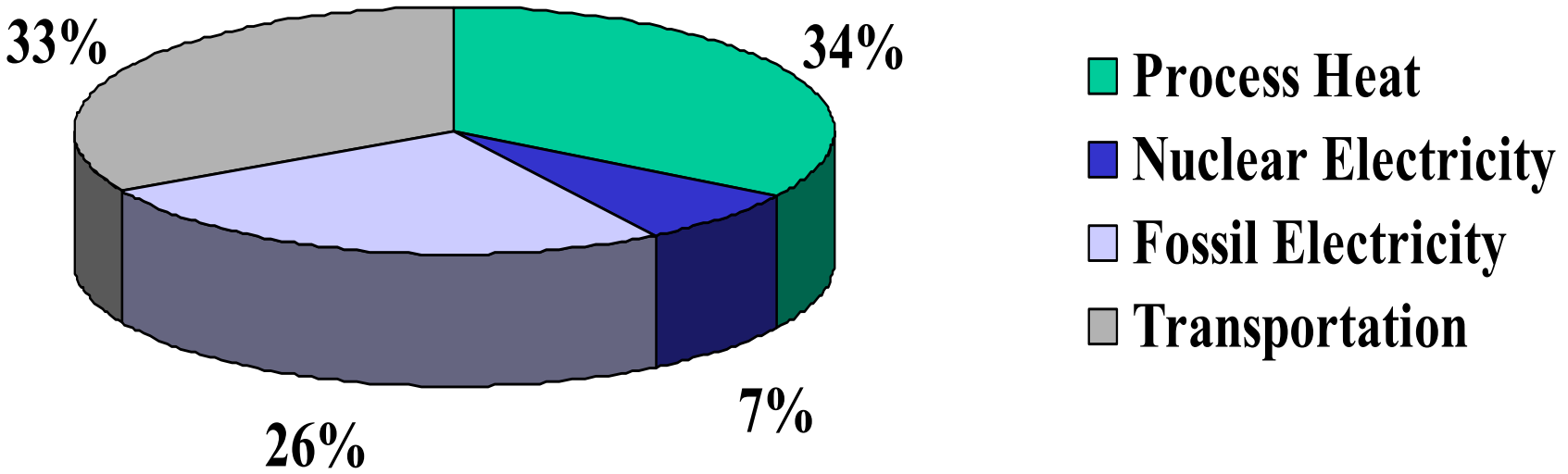
if…

Two Questions are Addressed

- **Is the hydrogen generation process of sufficient scale to meet the needs?**
- **Does the full cycle, from mining, to production, to distribution, to use, to cleanup, meet our environmental standards?**



Energy Utilization



Hydrogen Technologies

- **Steam Reforming**
- **Advanced Steam Reforming**
- **Electrolysis**
- **Thermo Chemical Processes**

Hydrogen Generation

- **Steam reforming of methane accounts for nearly all the 50 million tons of hydrogen used world-wide for ammonia based fertilizers and oil product enhancement.**

- **Electrolysis also is a mature technology and is used primarily for the production of high purity oxygen and hydrogen.**

- **Hydrogen produced by high temperature thermo-chemical processes has not been demonstrated on a commercial scale but promises high efficiency production in the future.**

Relative Costs

- **H2 produced by electrolysis — $3.00/kg @ $0.06/kwh**
- **H2 produced by methane reforming — $0.80/kg**
- **H2 expectations for nuclear & thermo chemical — $1.30/kg**

Cost of Hydrogen by Electrolysis

- 3 kg H2 to drive 250 miles
- 12.5 gal gasoline to drive 250 miles at 20 miles /gal
- 152 kwh to generate 3 kg H2
- 152 kwh @ $0.06/kwh = $9.00 + service and equipment
- 12.5 gal of gasoline @ $1.50/gal = $18.75
- Conclusion: Electrolysis H2 is competitive
- BP executive: "At the refinery gate, hydrogen's cost-mile driven is actually substantially less than conventional fuel because of the outstanding efficiency of the fuel-cell engine. Hydrogen's current high cost can be attributed to the expense of transporting and dispersing it."

Transportation: Annual Hydrogen/Energy Requirement

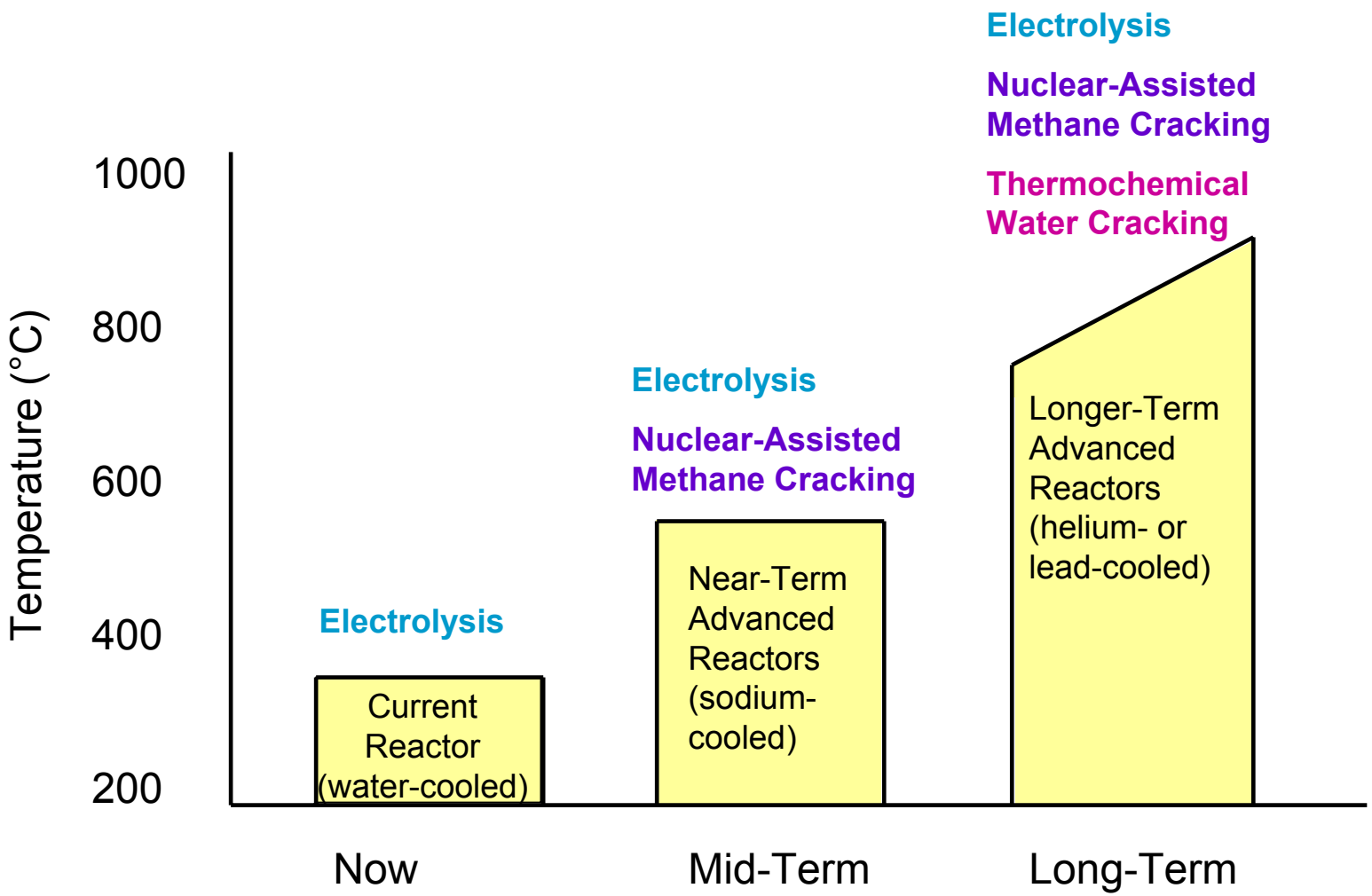
Fuel used	0.013 kg H_2/mile
From electrolysis	0.66 kWh/mile
Miles driven in U.S. in 1997	2.6×10^{12} miles
Requirements	3.4×10^{7} T H_2 and 241 GWe

- **To provide the needed electricity:**
- **241 1,000 MWe electrical generating plants**
  OR
- **640,000 — 1.5MW windmills — 71,000 square miles**

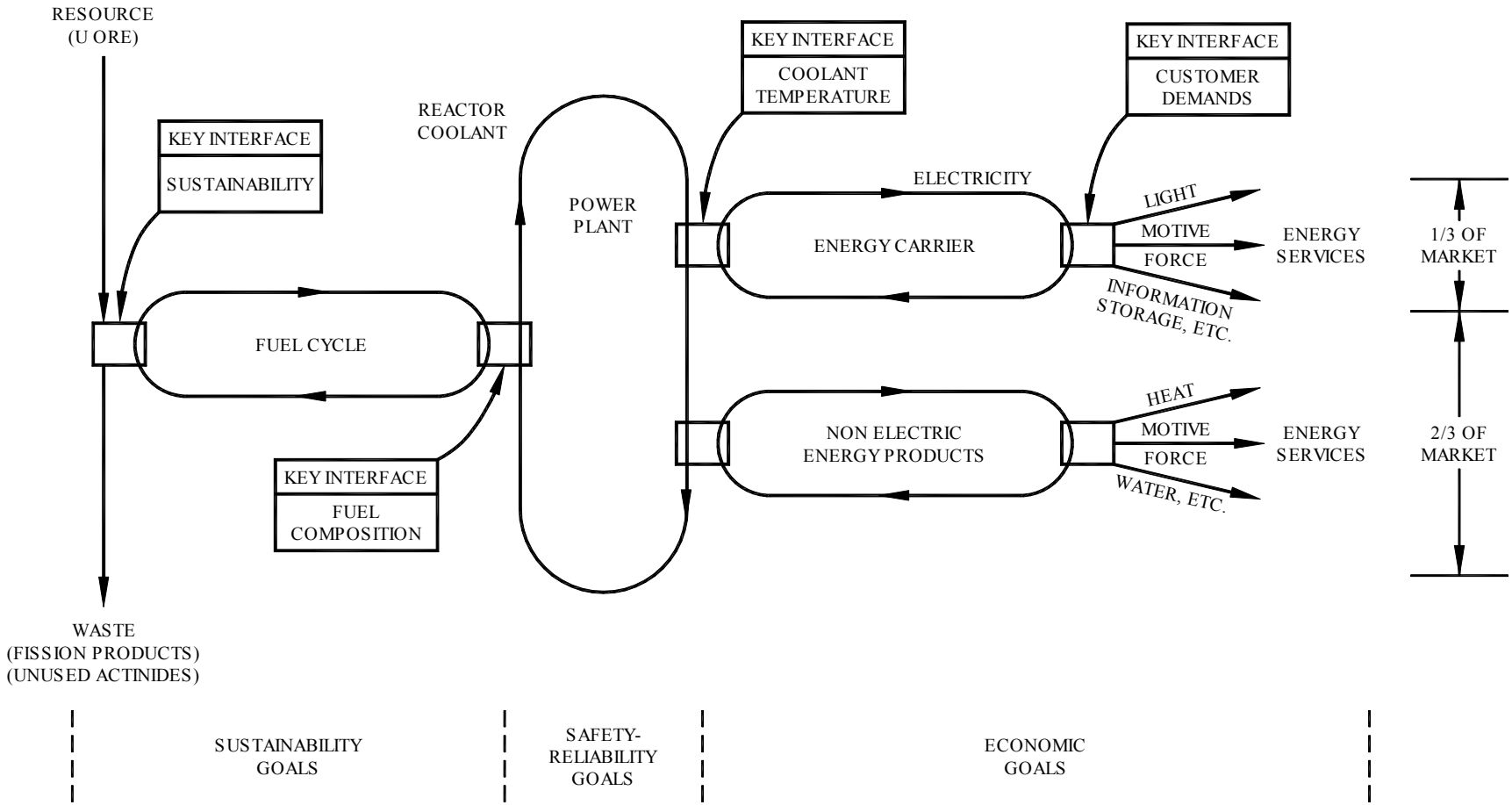
EXTERN-E External Costs

	¢/kWh
• Coal	3-10
• Gas	1-4
• Nuclear	0.2-0.5

Deployment of Nuclear-Generated Hydrogen



Nuclear as a Link in the Energy Supply Chain



GENERATION 4 GOALS FOR NUCLEAR ENERGY SUPPLY

Hydrogen Distribution

- **Extraction of hydrogen from fossil fuels by stationary or on board reformers is a near-term option for transportation or stationary uses.**

- **Distribution of hydrogen with personal and large central electrolyzers is a near term option.**

- **Use of existing methane pipelines to concurrently distribute hydrogen, with large centrally located generation plants is a longer-range option.**

Transition to Nuclear/Hydrogen Now

- **Off-peak nuclear power**
- **Distributed Electrolyzers**
- **Ubiquitous distribution - the electrical grid**

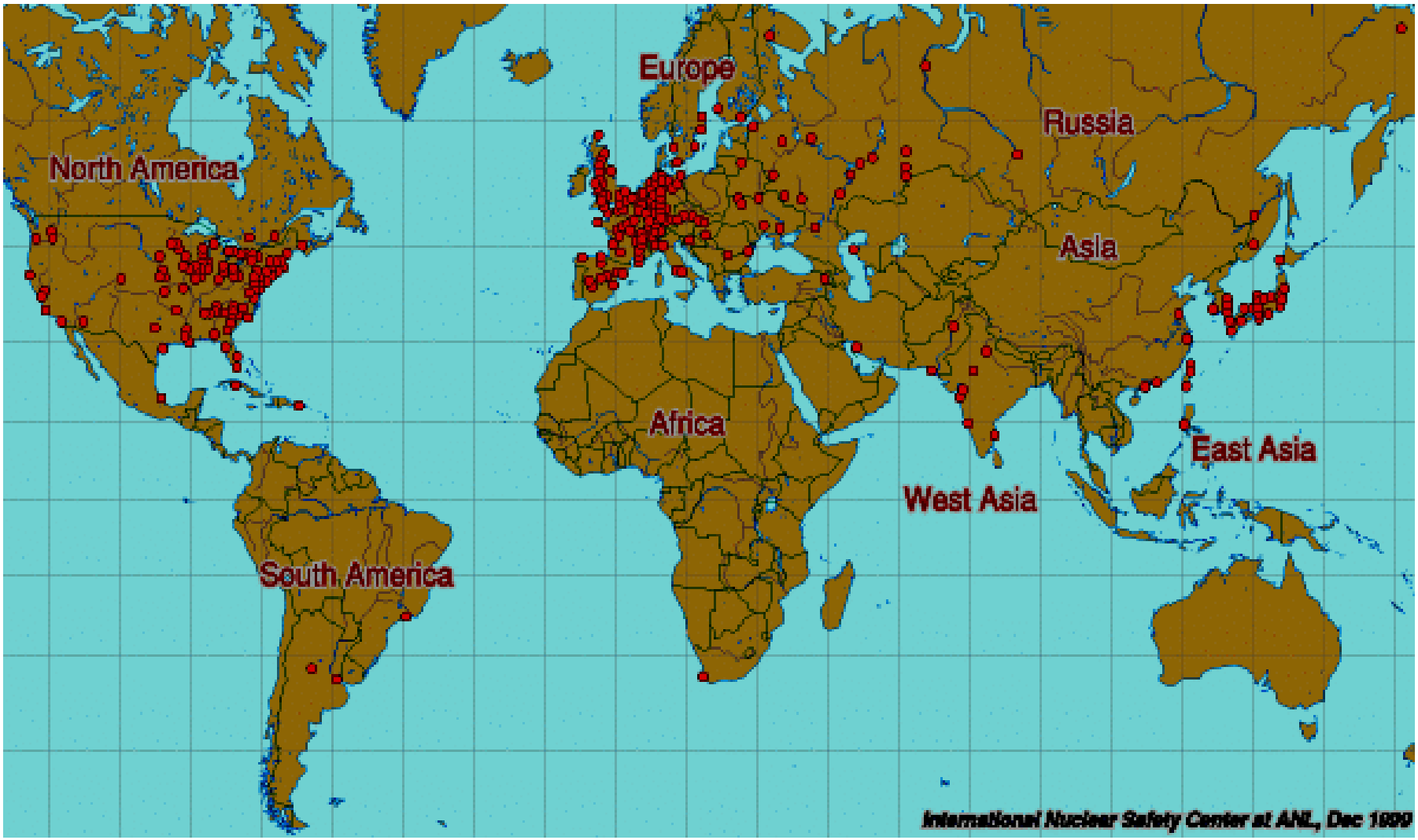
Chicken and Egg Problem

- **Large numbers of fuel-cell vehicles, without adequate fuel availability, are not possible. However, the required infrastructure will not be created unless there are significant numbers of fuel-cell vehicles.**

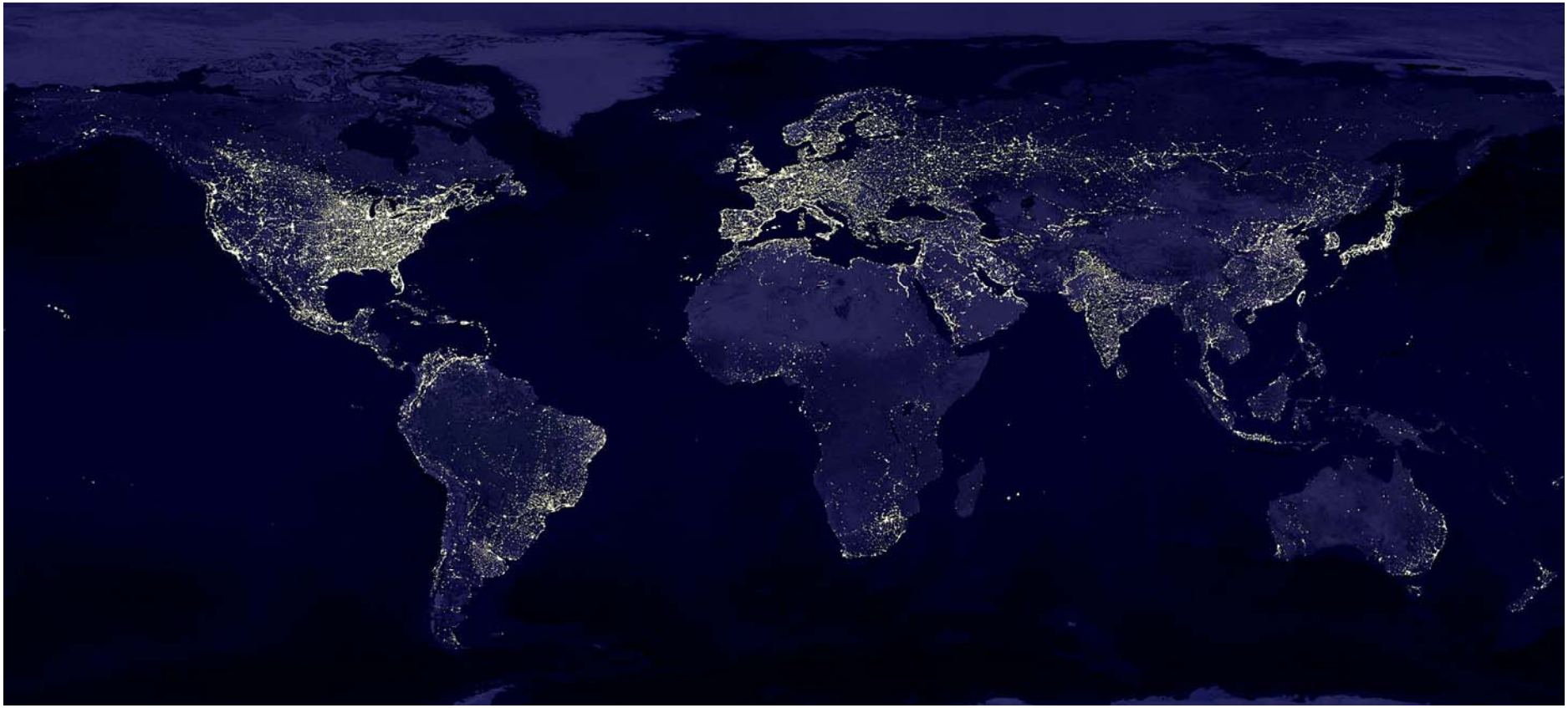
- **Stuart—The first path-distributed electrolytic hydrogen at fleet sites or at the vehicle by "Hydrogen Fuel Appliances". These use the existing electrical grid to transmit energy.**

- **Key issues that must be addressed include subsidy funding, incentives for developing refueling stations, creation of uniform standards, and general education about the topic.**

Nuclear Reactors of the World



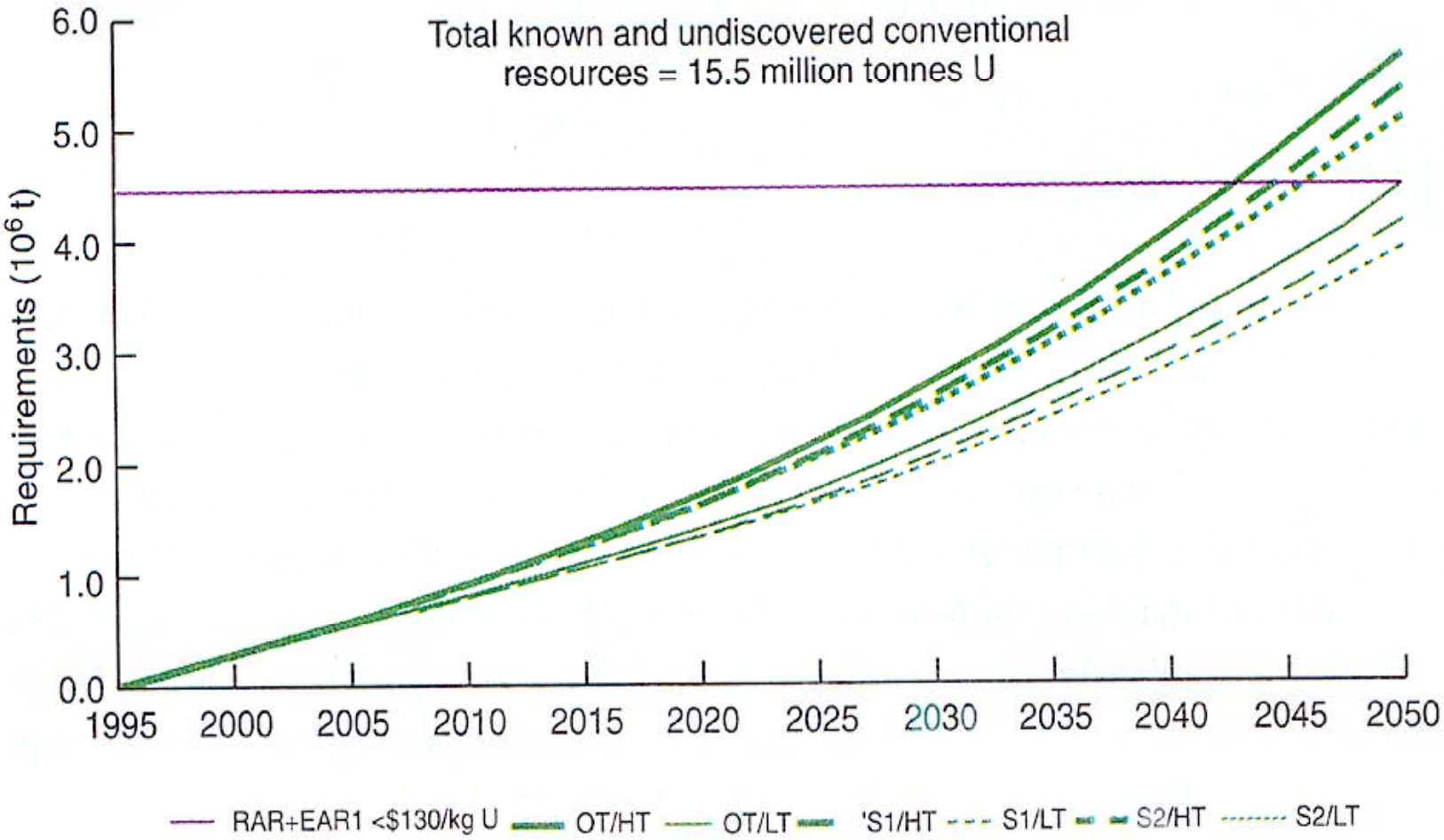
Energy for Tomorrow



Sustainability

- **Optimistic growth rate for nuclear power without hydrogen generation is 2.5% per year**
- **The growth rate could double or triple should the market for hydrogen production from nuclear energy materialize**
- **The sustainability of the nuclear/hydrogen option would be questioned**
- **Fast breeder reactors would receive renewed attention**

Global Energy Outlook



Conclusions

- **Hydrogen, when produced from fossil fuels, is no solution for energy independence or environmental compatibilty**
- **Wind, solar, and geothermal do not possess the energy density to generate sufficient hydrogen**
- **The transition to a nuclear/hydrogen economy can begin today with electrolysis**
- **Should the nuclear/hydrogen vision materialize then uranium resource depletion becomes important**