Hydrogen Production Using Nuclear Energy

SRNL™
SAVANNAH RIVER NATIONAL LABORATORY
We Put Science To Work

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Outline

- Brief SRNL Introduction
- U.S. and World Energy Picture
- Hydrogen Economy and Production Needs
- The Nuclear Hydrogen Option
- Summary

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Savannah River National Laboratory

Advanced Hydride Laboratory

Fuel Cell Vehicle with MH Storage

- Newest of the DOE National Laboratories
  - Part of the SRS Defense Complex (14,000 employees & 310 sq. miles)
  - Hydrogen (i.e. tritium) major mission for over 50 years
  - Designed, built and currently operate world's largest MH based processing facility
- Increasing focus on related national needs
  - Laboratory has 940employees (45% with advanced degrees)
  - Over 90 scientists/engineers dedicated to hydrogen technology (*largest hydrogen staff in country)*
  - Provides technical solutions from concept-RD&D-operation
  - Current major focus on hydrogen technology

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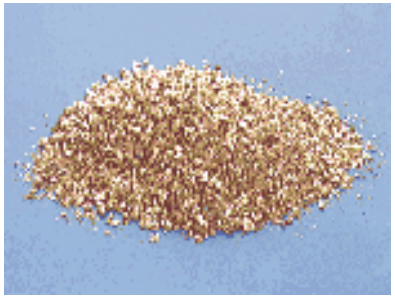
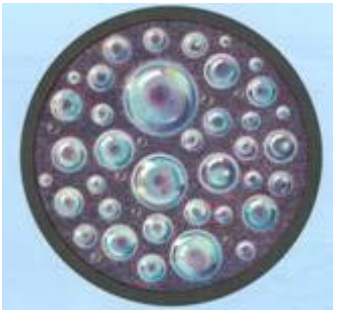
Hydrogen Research at SRNL

- 60,000 ft^2 hydrogen R&D lab in progress
  - Located at Savannah River Research Park
  - 30,000 ft^2 reserved for academic & industrial partners
- Operation scheduled for October 2005
- Focus on hydrogen R&D
  - Advanced storage
  - Separation, production, sensors, safety and hydrogen effects on materials



Intermetallic Hydrides

Doped Carbon Nanotube



Glass Microsphere

Complex Metal Hydrides

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About our Energy Future

- World energy needs are growing rapidly
- There is a finite supply of oil and gas
- Alternative energy supplies need to be developed soon
- Environmental concerns are increasing
- America needs energy security & diversity
  - Petroleum imports will exceed 75% by 2025

WE NEED A SUSTAINABLE ENERGY SYSTEM

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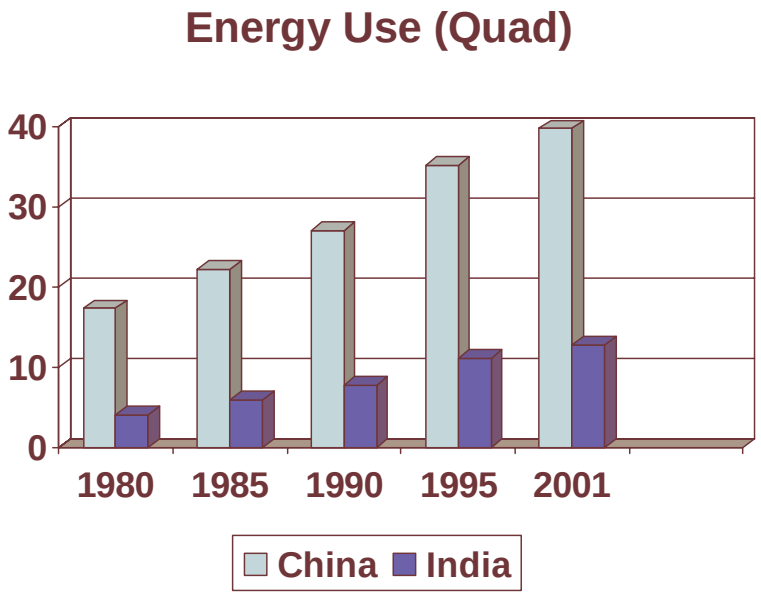
Growing World Energy Demand



Note: U.S. = 100 Quad

- Rapid Energy Growth in Developing Economies
- China now is No. 2 Oil Importer (passing Japan)
- Growth Rate in Energy Use since 1980:
  - U.S. = 1.2% per year
  - China = 4.0% per year
  - India = 5.5% per year

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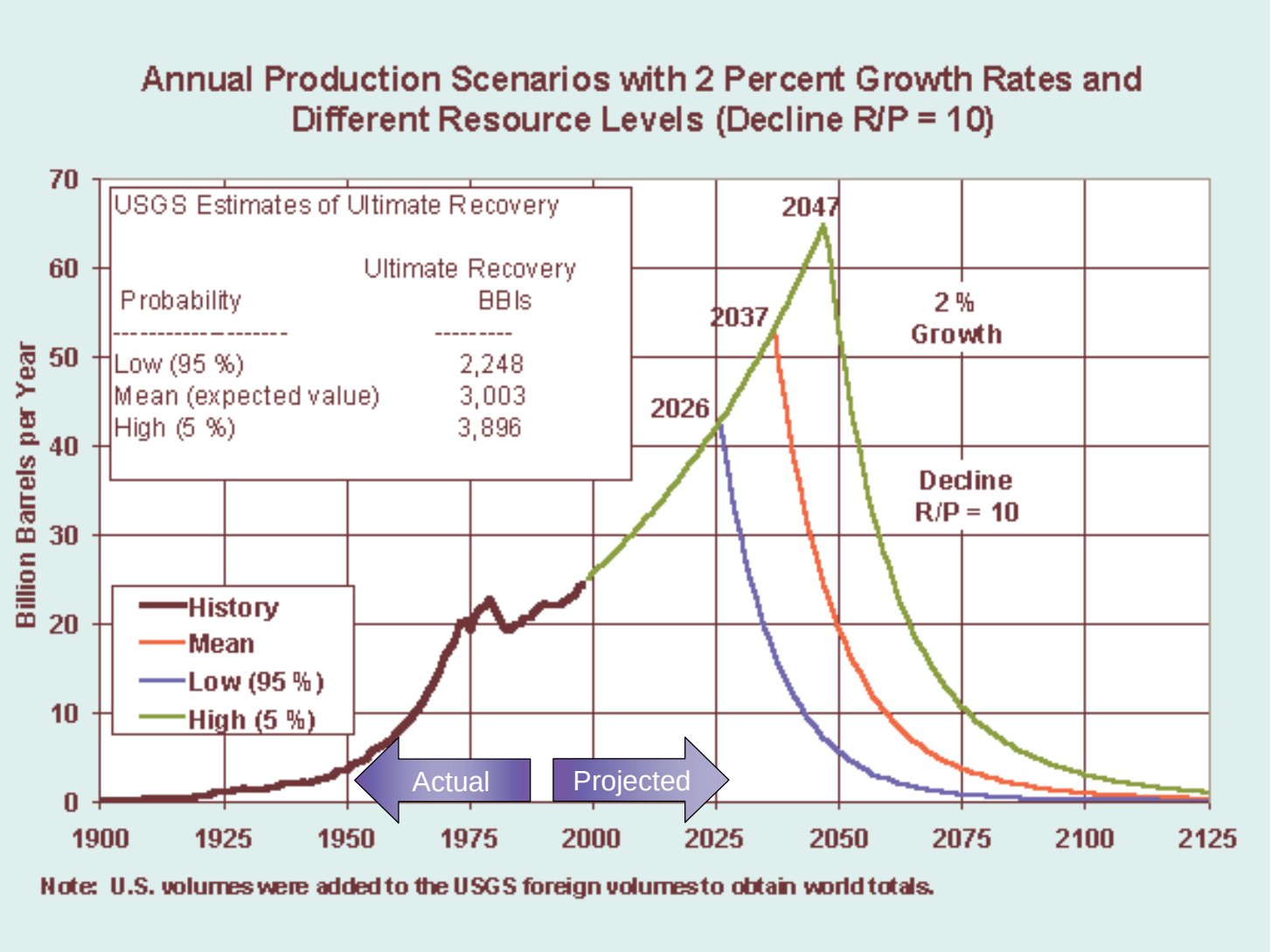
Oil Production Predicted to Peak Before Mid-Century



Source: DOE Energy Information Agency, 2000

Switching to Natural Gas is Not a Solution

Remaining Recoverable Fossil Energy Resources
(Quads)

	U.S.	World
Oil	**1108**	**15,242**
Natural Gas	**1082**	**14,028**
Coal	**35,693**	**143,000**
Unconventional (Tar sands, Oil shale, Heavy Oil, etc.)	**Large**	**Large**

Source: DOE Energy Information Agency

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Is Hydrogen the Answer ?

Biomass

Renewables

Hydro
Wind
Solar
Geothermal

Nuclear

Oil

Coal

Natural Gas

With Carbon Sequestration

HIGH EFFICIENCY & RELIABILITY

H_2

ZERO/NEAR ZERO EMISSIONS

Transportation

Distributed Generation

Source: DOE

Hydrogen Economy will require a lot of hydrogen

- Current industrial hydrogen use
  - 10 million tons per year = 40 GW(th)
  - >90% for oil refineries and ammonia plants
- Fuel for all light-duty vehicles in 2050
  - 110 million tons hydrogen per year = 450 GW(th)
  - 11-fold increase over current industrial use
  - Hydrogen for other needs could double this value
- Total energy for hydrogen could equal or exceed that for electrical power production

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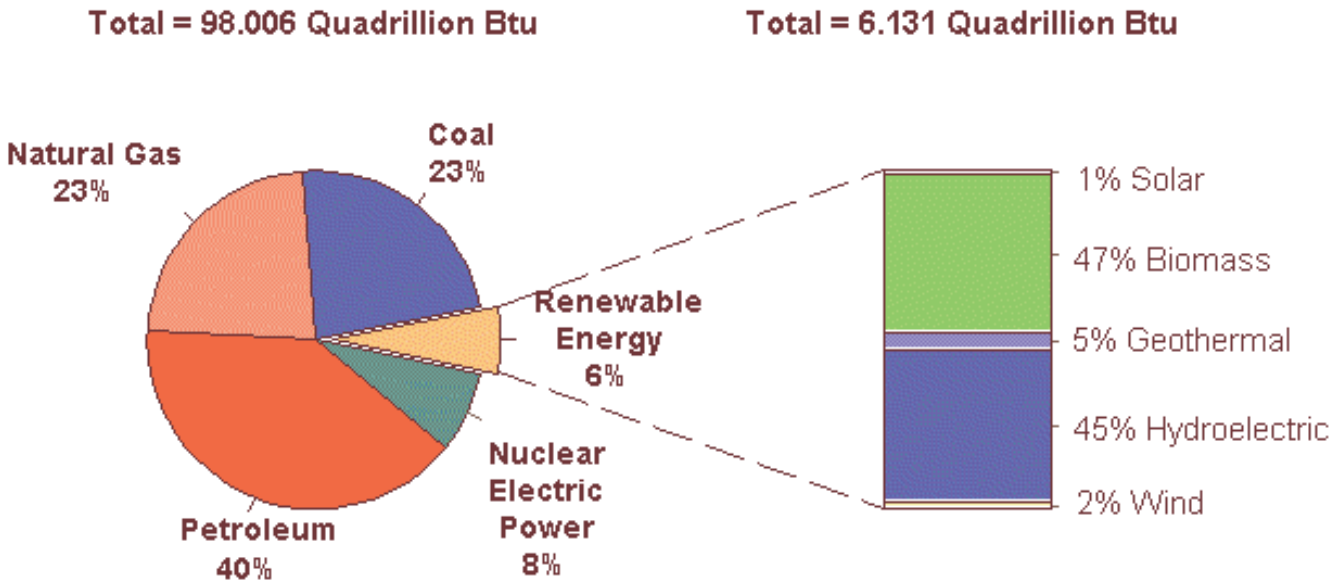
Is Renewable Energy the Answer?



Source: DOE/EIA Report: Renewable Energy Trends 2003, July 2004

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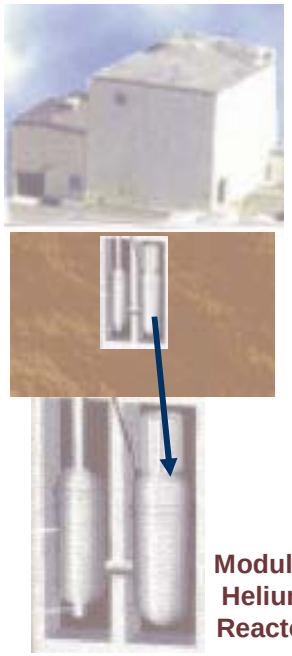
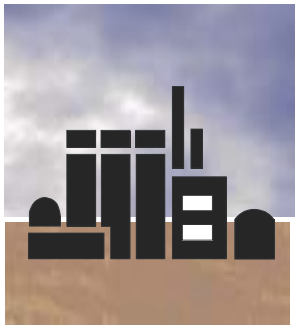
Nuclear Hydrogen Future

Centralized Nuclear Hydrogen Production Plant



Modular Helium Reactor

Heat



Thermochemical Process

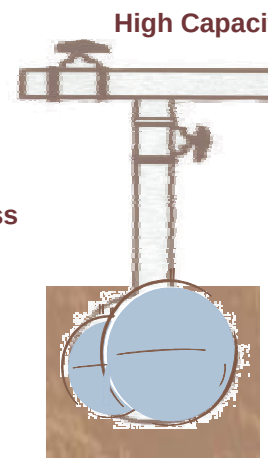
$H_2O \rightarrow H_2 + \frac{1}{2} O_2$

O_2

Industrial H2 Users

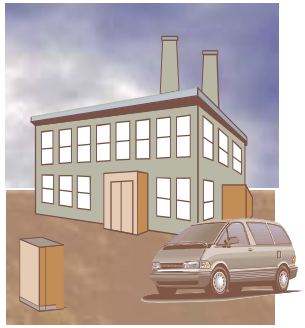
High Capacity H2 Pipeline

H_2



Time of Day/Month H_2 Storage

Hydrogen Fueled Future



Distributed Power

Transport Fuel

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Nuclear energy can help provide the hydrogen by several routes

- Electric power generation → Electrolysis
  - Proven technology
  - Overall efficiency ~24% (LWR), ~36% (Hi T Reactors)

- Electricity + Heat → High temperature electrolysis (HTE) or Hybrid thermochemical cycles
  - Need both electricity generation and high temperature process heat
  - Efficiencies up to ~ 50%
  - Developing technologies (based on solid oxide fuel cells)

- High temperature heat → Thermochemical water-splitting
  - A set of chemical reactions that use heat to decompose water
  - Net plant efficiencies of up to ~55%, avoid cost of electricity generation
  - Developing technology

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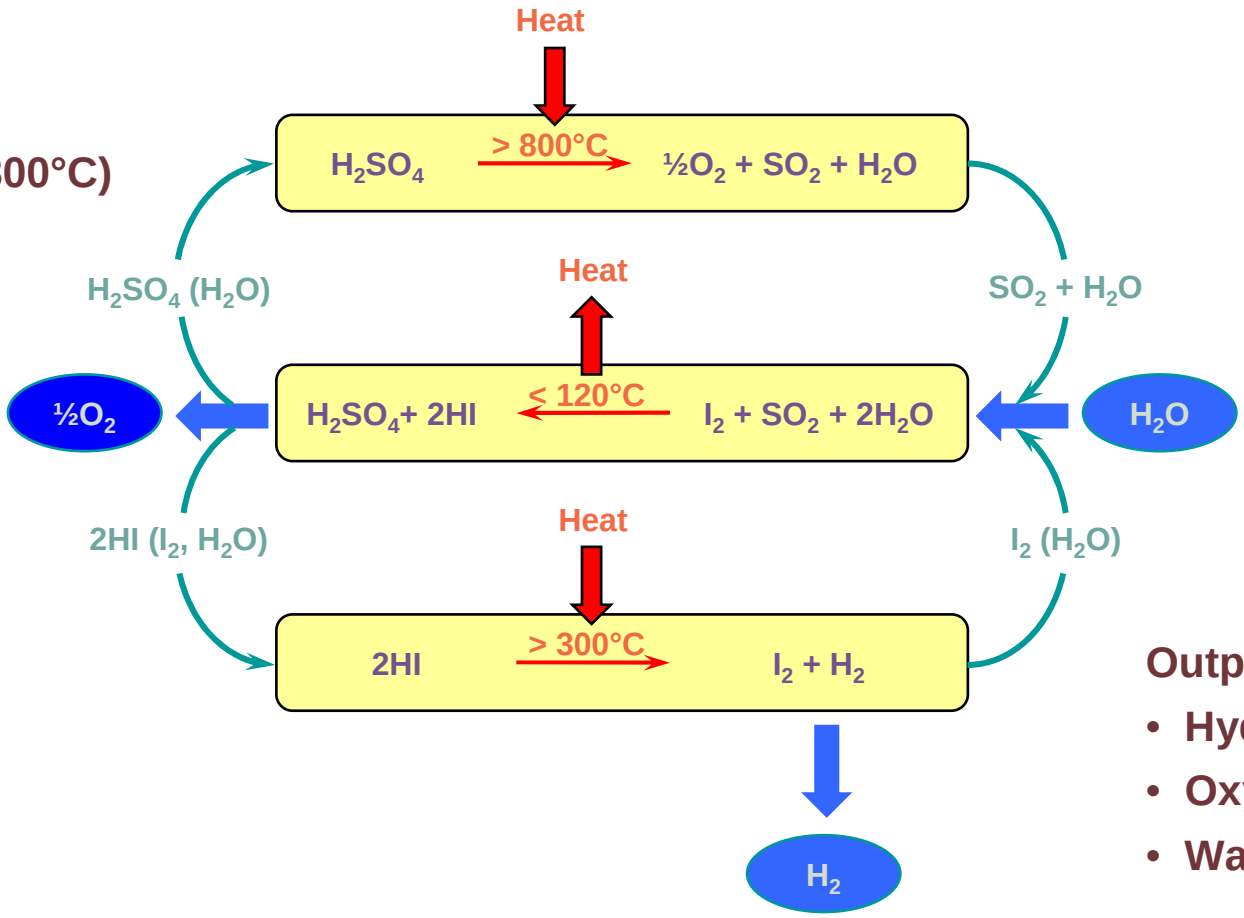
Sulfur-Iodine (SI) Thermochemical Cycle

Inputs:

- **Water**
- **Heat (>800°C)**



Outputs:

- **Hydrogen**
- **Oxygen**
- **Waste heat**

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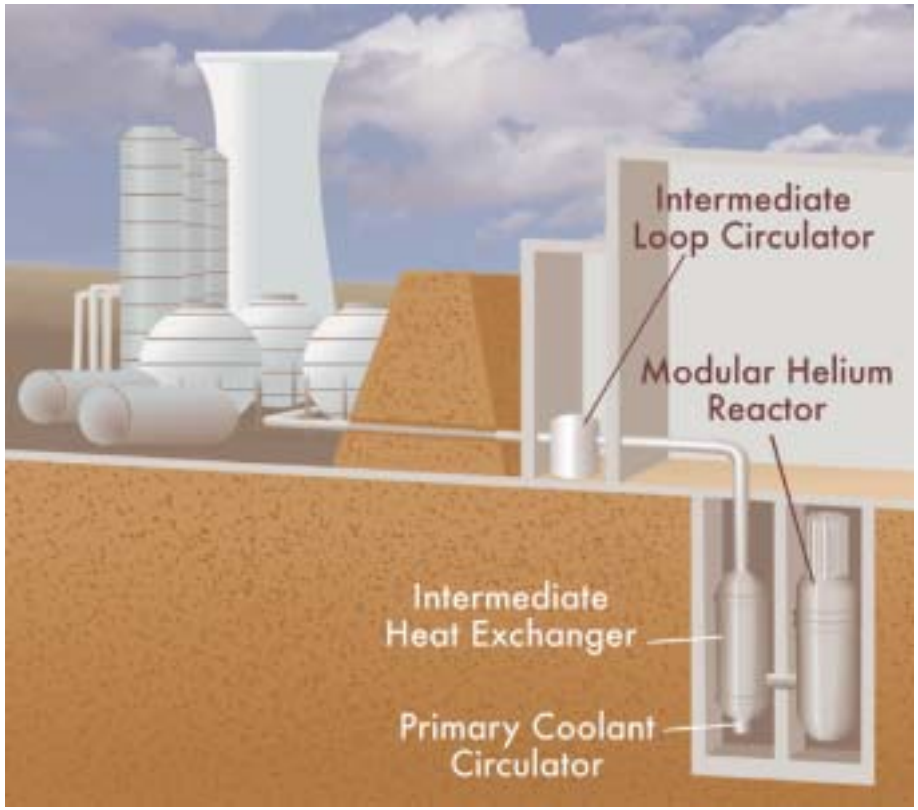
Baseline Nuclear Hydrogen Production Plant



Courtesy of General Atomics

- Centralized Plant using Sulfur-Iodine Process
- Modular 600 MW_{th} Helium cooled nuclear reactors (4 per site)
- Overall thermal efficiency = 52% (Heat-to-H_2, HHV basis)
- H_2 Output = 760 TPD with energy content of 1.25 GWe
- Major challenges: high temperatures, corrosive chemicals, current state of technology (bench-scale) and cost.

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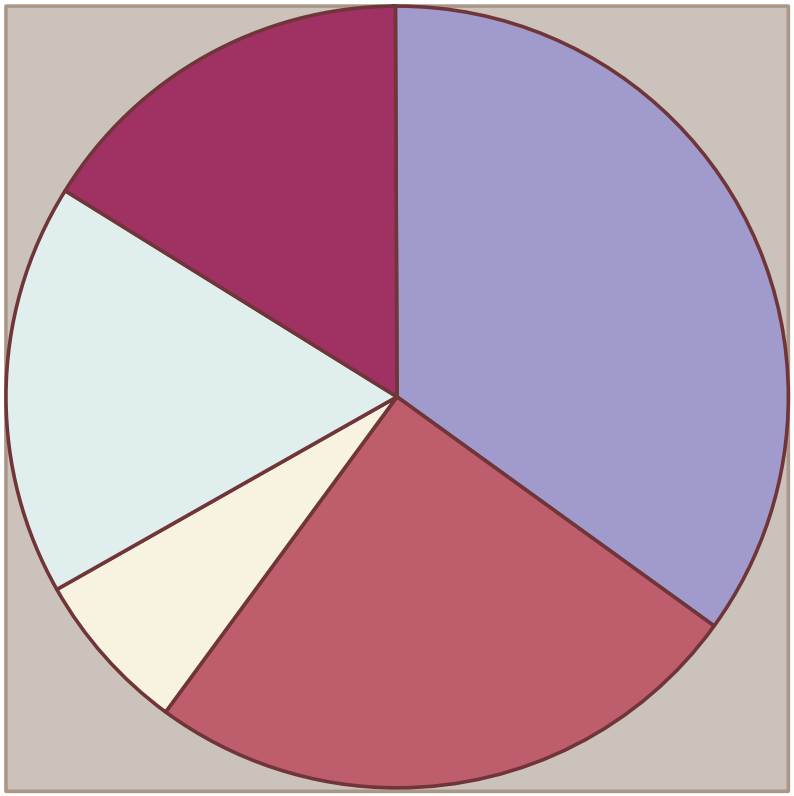
NuH2 production costs appear attractive

Levelized H_2 Cost = $1.65 per kg

(or $1.36/kg with O_2 Credit)

Contributions due to:

- Reactor Capital
- S-I Capital
- Reactor O&M
- S-I O&M
- Nuclear Fuel



(nth of a kind plant & only plant gate hydrogen cost considered)

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Summary

- Hydrogen can be the “Fuel of the Future”.
- Major worldwide developments in fuel cell technology as well as hydrogen storage and production will be required.
- Several sources of energy: renewable, fossil (clean coal) and nuclear will ALL be needed.
- Savannah River National Laboratory has assembled a world-class team that can work with regional and national universities and industry to lead the nation in transitioning to a secure, clean hydrogen future.

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