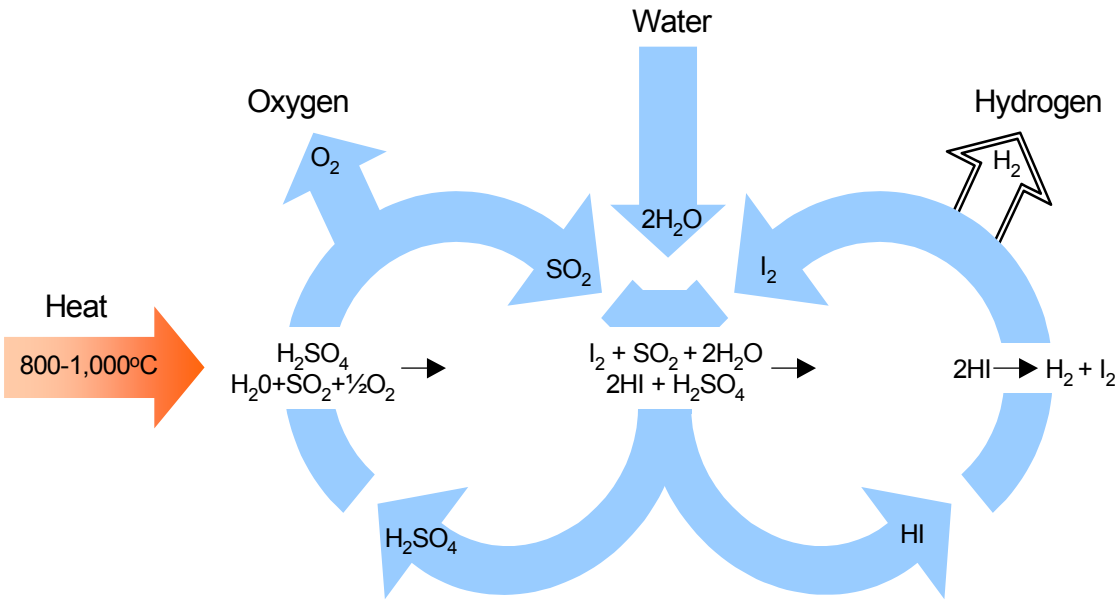
2.2 HYDROGEN

2.2.1 HYDROGEN PRODUCTION FROM NUCLEAR FISSION AND FUSION

Technology Description



Hydrogen is a carbon-free fuel that can be produced from hydrogen-containing compounds, such as fossil fuels or water, and used in vehicles, homes, businesses, and power plants, or as a chemical feedstock. When hydrogen is produced from fossil fuels, CO_2 appears as a concentrated byproduct. However, advanced nuclear fission and fusion systems can be used to produce hydrogen without generating CO_2. Very high-temperature, high-efficiency nuclear power plants can either produce electricity to electrolyze water vapor or supply high-temperature process heat to drive chemical cycles for hydrogen production. Implementing these hydrogen-production technologies will reduce carbon emissions significantly below what is possible with nuclear-generated electricity alone.

System Concepts

- Very high-temperature, high-efficiency nuclear systems can be used to produce hydrogen either by electrolysis of water vapor or chemical cycles for water decomposition.

Representative Technologies

- Advanced, high-temperature fission reactors such as those being developed by the Generation IV Nuclear Energy Systems Initiative (including high-temperature gas-cooled reactors)
- Fusion reactor using gas, liquid-metal, or molten-salt cooling.

Technology Status/Applications

- Very high-temperature reactors cooled by gas or molten salts are being developed.
- Fusion technology is in development and making steady progress.
- Gas-cooled reactors operate in Japan at the temperatures of interest.
- Chemical cycles for the decomposition of water to yield hydrogen are being developed.
- Electrolysis of water vapor rather than liquid water is being developed.
- Fuel-cell-powered vehicles using hydrogen are being developed and demonstrated by industry in partnership with the Department of Energy.

Current Research, Development, and Demonstration

RD&D Goals

- By 2030, reduce thermochemical facility costs by two-thirds by 2030 and high-temperature electrolysis facility costs by 85% in the same time frame.

- By 2030, decrease operating costs by three-fourths for both technologies, while thermal efficiency would increases from levels as low as 30% to 40% to more than 50%.

RD&D Challenges

- Develop reactor designs and materials that operate at temperatures high enough to achieve needed efficiencies.
- Overcome barriers to economic hydrogen generation by electrolysis.
- Develop chemical processes for water decomposition that operate efficiently and reliably.
- Demonstrate production and large-scale storage of hydrogen using a nuclear power plant.

RD&D Activities

- Development of high-temperature materials, separation membranes, advanced heat exchangers, and supporting systems relating to hydrogen production using the sulfur-iodine (S-I) thermochemical cycle and high-temperature electrolysis.
- Design and development of gas-cooled and lead-bismuth-cooled reactors and hydrogen-production systems are underway, through the Generation IV Nuclear Energy Systems Initiative and the Nuclear Hydrogen Initiative.
- Concept development for high-temperature blanket/cooling systems is underway as part of the fusion program.

Recent Progress

- Chemical cycles for hydrogen production are being developed, and the conceptual design is being prepared for a gas-cooled reactor to couple to the most promising cycles.
- Japan's gas-cooled, high-temperature test reactor operates at 850°C with periodic testing up to 950°C.
- Recent analyses indicate that, because of low fuel costs, fission systems could provide cost-effective off-peak electricity for electrolysis at either onsite or offsite filling stations.

Commercialization and Deployment Activities

- High-temperature, high-efficiency test reactors are being operated in China and Japan.
- Fuel cell-powered vehicles will create demand for hydrogen in addition to existing demand of the process chemical and petrochemical industries.
- High-temperature reactor designs are being developed through the Generation IV Nuclear Energy Systems Initiative. High-temperature operation will make reactors competitive with other methods of electrical power generation.
- Partnering with industry to demonstrate hydrogen production using electricity during off-peak demand periods has been proposed.
- Fusion plants could be commercialized late in the second quarter of this century.

Market Context

- The potential for carbon emissions reductions using these technologies is enormous, including consideration of the GHG reduction from the significant improvements in the efficiency of electrical power generation.
- Hydrogen fuel cell vehicles will create a demand for hydrogen as a transportation fuel in addition to the demand by the process chemical industry. Petrochemical industry demand for hydrogen will grow as the use of lower-quality crude oils becomes more common in refining.
- Extends the applicability of large fission energy resources and essentially unlimited fusion energy resources to the transportation sector.