Executive Summary

The use of hydrogen as an energy carrier has the potential to reduce U.S. dependence on foreign petroleum, diversify domestic energy sources, and decrease pollution and greenhouse gas emissions. Fuels cells operating on hydrogen produced from renewable resources, nuclear energy, and coal-based systems with carbon sequestration result in reduced air pollutants and near-zero emissions. In addition, natural gas-derived hydrogen offers a cost-competitive near-term option that results in lower carbon emissions than gasoline or hybrid-electric vehicles. Hydrogen's use in fuel cell vehicles can reduce oil demand in the transportation sector, and its use in central and distributed electric power generation can provide a more efficient and diversified energy infrastructure.

The central mission of the Department of Energy Hydrogen Program is to research, develop, and validate hydrogen production, delivery, storage, and fuel cell technologies. This document describes the status, challenges, and RD&D activities of the DOE program. The current focus of the Program is to address both key technical challenges (for fuel cells and hydrogen production, delivery, and storage) and institutional barriers (such as hydrogen codes and standards to maximize safety, training, and public awareness). The DOE Hydrogen Program is a partnership between a number of DOE program offices: Energy Efficiency and Renewable Energy (EERE), Fossil Energy (FE), Nuclear Energy (NE), and Science (SC). The Program is currently conducting basic and applied research, technology development and learning demonstrations, as well as underlying safety research, systems analysis, and public outreach and education activities. These activities include cost-shared, public-private partnerships to accelerate the high-risk, critical path technologies essential to the widespread use of hydrogen and fuel cell technologies.

Positive Attributes of Hydrogen as an Energy Carrier

- Can be derived from diverse domestic resources (renewable, nuclear, fossil)
- Can be used with high-efficiency fuel cells, combustion turbines and reciprocating engines to produce power with near-zero emissions of criteria pollutants
- Produces near-zero emissions of greenhouse gases from renewable and nuclear sources and from fossil fuel-based systems with carbon sequestration
- Can serve all sectors of the economy (transportation, power, industrial, and buildings)

Challenges for Hydrogen as an Energy Carrier

The transition from our current energy infrastructure to a clean and secure energy infrastructure based on hydrogen and other alternative fuels will take decades as the difficult challenges posed by technological, economic and institutional barriers are addressed and overcome. For hydrogen, the "critical path" barriers are listed below.

Technology Challenges

- Compact, lightweight, and low-cost storage systems must be developed. For vehicles, technologies must enable greater than 300-mile driving range across all vehicle platforms without reducing performance or interior space.

- The cost of producing and delivering hydrogen from zero or near-zero carbon sources must be reduced. Low-cost and environmentally sound CO_2 capture and sequestration technologies must be developed.
- The cost of fuel cells must be reduced and their durability improved, to be competitive with current technologies.

Economic and Institutional Challenges

- Investment risk of developing a hydrogen delivery infrastructure is high, given technology status and current absence of hydrogen vehicle demand.
- Investment risk of developing manufacturing capability for hydrogen and fuel cell technologies is high.
- Uniform model codes and standards to ensure safety and insurability do not exist.
- Local code officials, policy makers and the general public lack education on hydrogen benefits and on safe handling and use.

Program Progress

As a result of the Hydrogen Program, significant progress in overcoming the "critical path" challenges has been made since 2004. The accomplishments include:

- Cost of automotive fuel cells has been significantly reduced from $275/kW in 2002 to $73/kW in 2008, based on projections of high-volume manufacturing costs.
- Durability of fuel cells systems in vehicles operating under real-world conditions has doubled (data in 2006 showed 950-hour durability – today, this number is 1900 hours, equivalent to approximately 57,000 miles of driving.)
- Cost of distributed hydrogen production from natural gas has been reduced to $3.00/gallon of gas equivalent (gge).
- New materials that show an improvement of more than 50 percent in on-board storage capacity have been identified and are under development.
- Learning demonstrations have provided valuable data on the current performance of fuel cell vehicles and hydrogen stations in real world applications.

"Critical-Path" Technologies Necessary for Developing a Hydrogen Infrastructure

- More compact, lighter weight, lower cost, safe, and efficient higher storage systems
- Lower cost, more durable materials for advanced conversion technologies, especially fuel cells
- Lower cost methods for producing and delivering hydrogen
- Technologies for low cost carbon capture and containment for fossil-based production (a separate DOE program coordinated with the Hydrogen Program)
- Designs and materials that maximize the safety of hydrogen use

Developing hydrogen as a major energy carrier will require a combination of technological breakthroughs, market acceptance, and large investments in infrastructure. Success will be incremental over decades; and it will require an evolutionary process that phases hydrogen in, assisted by government policies, as the technologies and their markets mature.

Early market and niche applications (e.g., forklifts, stationary and portable power) can help pave the way for automotive fuel cells by accelerating development of manufacturing capability and facilitating customer acceptance. The successful development of hydrogen energy from diverse domestic resources will ensure that the United States has an abundant, reliable, and affordable supply of clean energy to maintain the nation's prosperity throughout the 21st Century.