Fuel Cells: Timing and limits to the transition to a hydrogen economy

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CO$_2$ levels projected

- Energy Consumption by Fuel
  - projected maximum levels 450-750 ppm in 15-20 years
LANL’s research portfolio supports the world’s need for increased efficiency and a diverse suite of energy sources.
Why a “Hydrogen Economy”?

- Climate change and air quality. Greenhouse gas emissions must be slowed dramatically—and soon
- Fossil fuels, although plentiful in supply, release carbon dioxide (CO₂), cause
  - Greenhouse gases
  - Global warming
  - Ozone layer depletion
- Population and economic growth will increase demand on energy resources
- Need to reduce dependence on foreign resources
- A hydrogen energy system is integrated
  - Production
  - Delivery
  - Storage
  - Conversion
  - End-use applications

The earth’s tolerance for CO₂ estimates are between 450-750 ppm
Current CO₂ levels are approaching 380 ppm
Why hydrogen and fuel cells?

- By the end of the 21st Century, a broad energy portfolio will be needed to stabilize the concentration of greenhouse gases
  - Hydrogen
  - Solar
  - Nuclear
  - Fuel Cells
  - Biomass

- Hydrogen and fuel cells are clean and efficient sources of energy, reducing dependencies on fossil fuels

Currently, power in the U.S. is generated predominantly with fossil fuels causing greenhouse gases.
Timing: Energy security by 2050

• Business as usual will bring trouble ahead
  – Global warming, Nuclear waste, Energy security
• Achieving energy security requires implementation of new energy sources and solutions that balance demand and environmental issues.

Renewable Energy, Hydrogen, Nuclear, Carbon Sequestration become major players in the energy portfolio

- Hydrogen is dominant for utility vehicles
- Energy requirements will double in the U.S.
- 65% of U.S. oil consumed is imported

Kyoto Protocol goals are met; 160 countries commit to climate change actions

No foreign imports

- CO₂ goals are met
- Hydrogen is economically produced from renewable sources
Hydrogen technical issues

• Key technical barriers
  – Domestic production
  – Delivery and distribution
  – Storage
  – Utilization: next generation of fuel cell technology, conversion of vehicles to receive hydrogen as a fuel
  – Safety, codes and standards, and environmental impacts

• Economic barriers
  – Production cost-prohibitive
  – Total capital infrastructure (national network of stations, distribution points) by 2100 will require major investments
  – Generating hydrogen economically from renewable sources

• Technology focus areas
  – Catalysis
  – Separations
  – Interfacial chemistry and materials
  – Polymer and materials chemistry
  – Theory and modeling
Hydrogen sources

• Hydrogen is separated from water, organic matter, fossil materials using
  – Steam Reformers
  – Partial Oxidation
  – Electrolytic processing

• Future production from water and renewable sources using
  – Thermochemical
  – Partial Oxidation/Ceramic Membrane Reactor
  – Pyrolysis
  – Photolytic
  – Nuclear

Although today most hydrogen is produced from fossil materials, such as from natural gas at this oil refinery, DOE is exploring a variety of ways to produce hydrogen from renewable resources.
Storing hydrogen

- Hydrogen can be stored as a liquid or a gas.
- **Liquid hydrogen** must be cooled to -423° F requiring more energy to maintain.
  - Limitation: To cool one pound (0.45 kg) of hydrogen requires 5 kWh of electrical energy.
- **Gas hydrogen** uses less energy, but must be pressurized.
  - Limitation: Large-scale use would require large caverns, gas fields, or mines then pumped to the source, making this an expensive option for transportation.
- **Hydrides** are potentially a more efficient method for storage.
  - Limitation: workable compounds are needed and focus of current research
The growing role of hydrogen and fuels cells

- Fuel cells can use hydrogen to produce useful energy without combustion but by chemical reaction
- Electrolysis is reversed by combining hydrogen and oxygen through an electrochemical process, which produces electricity, heat, and water.

Most fuel cell research focuses on advancing polymer electrolyte membrane (PEM) fuel cell systems, with emphasis in areas of:

- Fuel processing (reforming) technologies
- Improved catalyst and membrane designs
- Improved air, thermal, and water management systems
Limitations of fuel cells

• Limitations and technical challenges
  – Cost
  – Low demand inhibits production efficiencies
  – Proven durability
  – Fuel infrastructure
  – Hydrogen storage
  – System miniaturization
  – Fuels and fuel packaging