



A Hydrogen/Electric Economy?

**South Dakota Energy Conference
May 13, 2009**

**Frank Novachek
Director, Corporate Planning**

Discussion Outline

- **Introduction/hydrogen basics**
- **Hydrogen-electric economy value chain**
- **Possible roles for electric utilities**
- **Q & A**

Introduction

- Interest initially prompted by January 2003 State of the Union Address
- A hydrogen/electric economy could provide one of the nation's most comprehensive solutions:
 - ▶ Energy Security
 - ▶ Environment
 - ▶ Economic Vitality
- Utilities will have a major stake in the “hydrogen/electric” infrastructure

H2-Electric Economy Benefits

- **Energy security - primary driver**
 - ▶ Dependence on foreign oil
 - ▶ Potential enabler for more distributed energy system
 - ▶ Energy storage enables more renewables
- **Environmental benefits (assuming renewable power and significant carbon sequestration)**
 - ▶ Greenhouse gases & other pollutants
 - ▶ Hazardous wastes
- **Economic Viability**
 - ▶ Feedstock diversity = price control
 - ▶ Potential for regional solutions = resource optimization

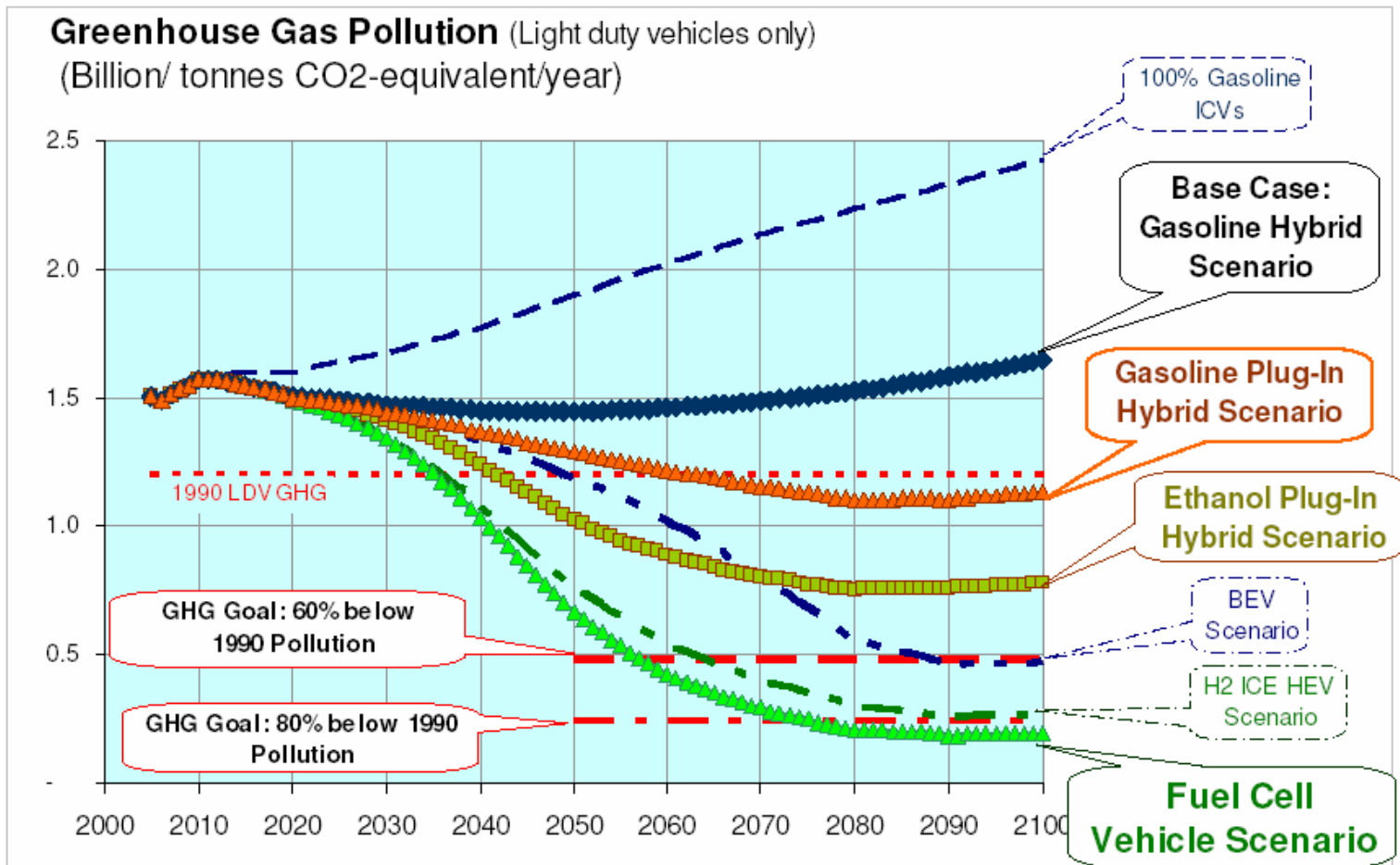


Figure 1. Projected greenhouse gases for different alternative vehicle scenarios over the 21st century for the US light duty vehicle fleet, assuming that both the electrical grid and hydrogen production reduce their carbon footprints over time (BEV= battery electric vehicle; H₂ ICE HEV = hydrogen internal combustion engine hybrid electric vehicle)

¹ C.E. Thomas, "Comparison of Transportation Options in a Carbon-Constrained World: Hydrogen, Plug-in Hybrids and Biofuels," the National Hydrogen Association Annual Meeting, Sacramento, California, March 31, 2008.

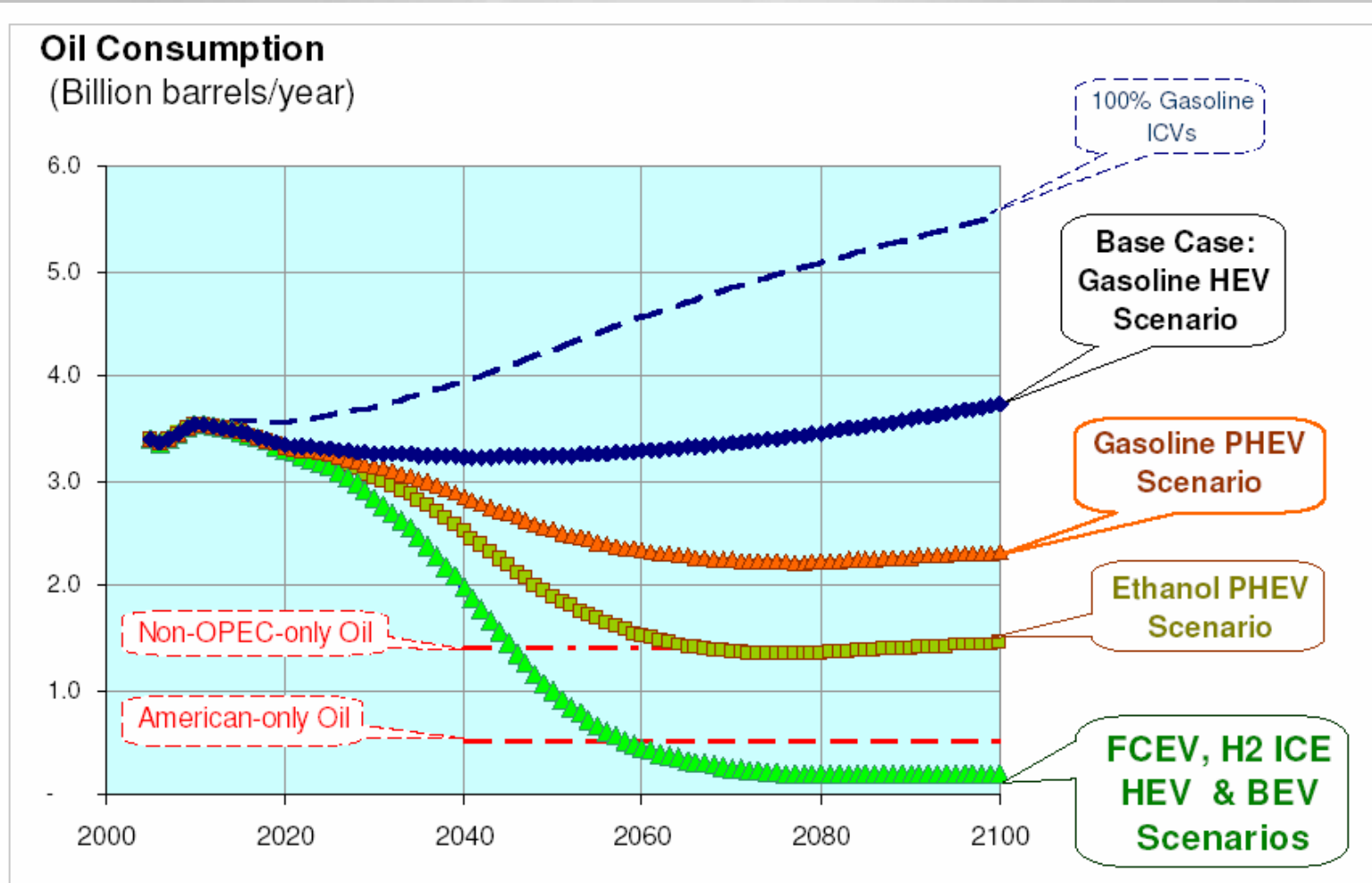


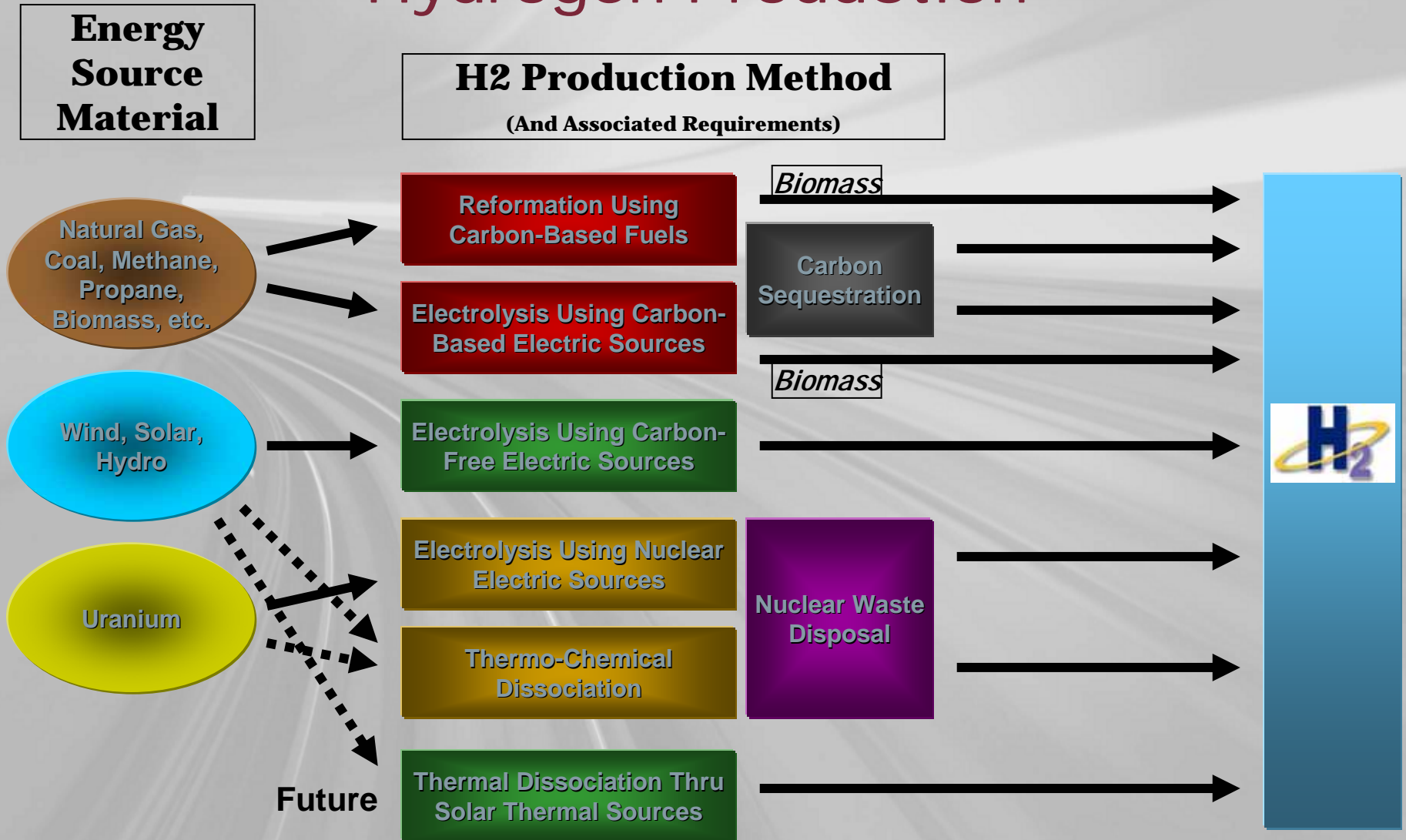
Figure 2. Oil consumption from US light duty vehicles over the 21st century for different alternative vehicle scenarios

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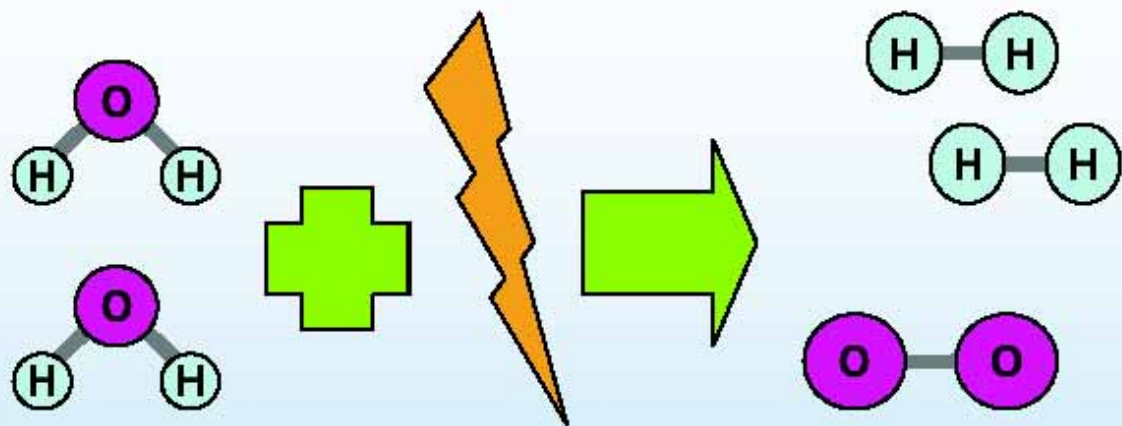
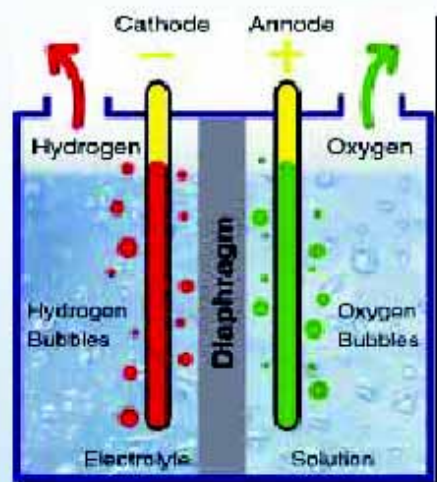
Hydrogen Economy Value Chain



Hydrogen Production



Electrolysis Overview



Liquid
Water
(H₂O)

Electricity
39 kWh/kg H₂
@ 25 C and 1 atm

Hydrogen (H₂)
and
Oxygen (O₂)

Low-Temperature Electrolyzer Technologies: Alkaline and PEM

DOE Hydrogen Pathway Target of \$2-\$3/gge* delivered

*1 gge ~ 1kg H₂

Hydrogen Basics

Extraction of Energy From Hydrogen

**Burn (Oxidize)
(With or without NG
in ICE's or turbines)**



OR

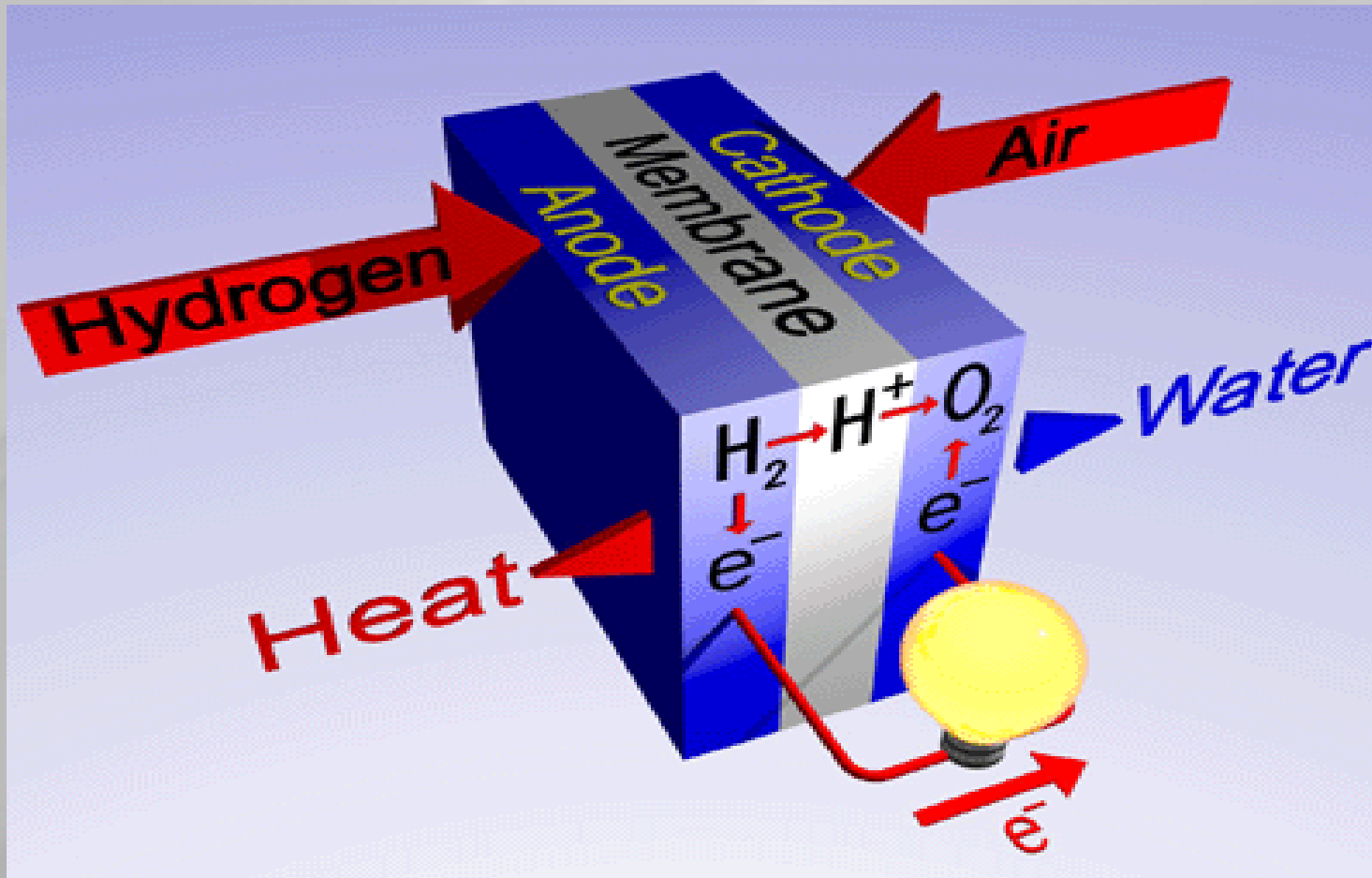
**Chemically Combine
w/Oxygen
(Fuel Cell)**



Heat
Electricity
Water

* When hydrogen burns in air (mostly nitrogen), some oxides of nitrogen (NOx) but much fewer than when normal hydrocarbon fuels are burned. Because no carbon is involved, using hydrogen fuel eliminates carbon monoxide, carbon dioxide, and does not contribute to global warming.

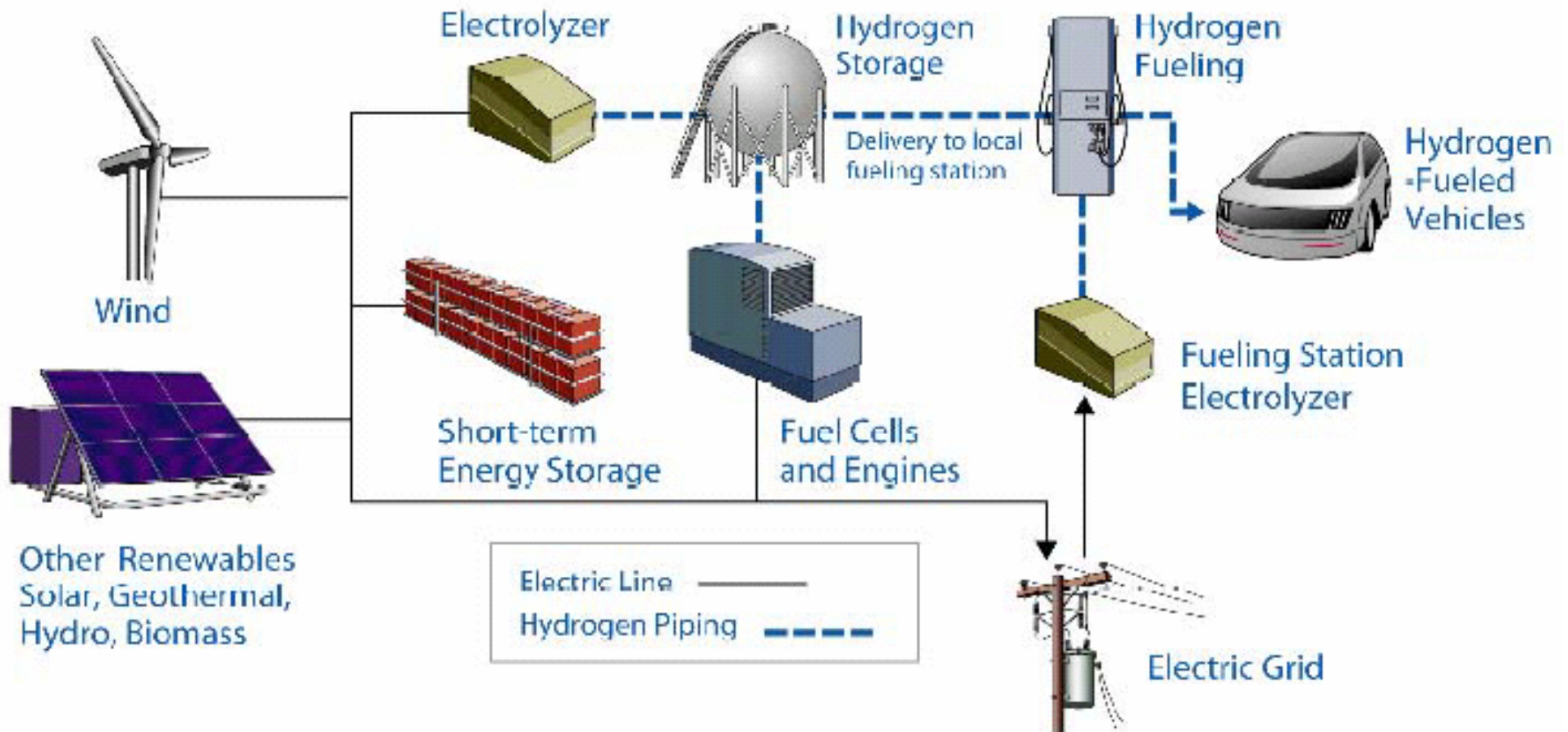
Source: Hydrogen Now!



Fuel Cell Illustrated

Source: Fuel Cell Today

Renewable Electrolysis Options



Barriers

- **Capital “chicken & egg” dilemma**
 - ▶ **Need lower costs to increase demand**
 - ▶ **Need more demand for costs to come down**
- **Uncertain technologies put investments at risk**
 - ▶ **Primary options for production and distribution of hydrogen not clear**
 - ▶ **Will require government funding and incentives to make it economical for companies to participate**
- **Public acceptance not easy**
 - ▶ **Safety**
 - ▶ **Convenience**

Conclusions

- **Hydrogen can significantly improve the nation's situation**
 - ▶ **Energy security**
 - ▶ **Environment**
 - ▶ **Economy**
- **Utilities are a natural participant in the hydrogen-electric infrastructure**
 - ▶ **Hydrogen energy storage systems enable renewables**
 - ▶ **Hydrogen production & distribution competencies similar to existing utility competencies**
 - ▶ **Existing regulatory framework for natural monopoly type activities**

