Global Status & Trends of The Hydrogen Economy

Dr. Robert K. Dixon
Head, Energy Technology Policy Division
International Energy Agency
Paris, France
World 2004
Total Primary Energy Supply

Source: IEA-ESD Energy Balances

- Coal 25%
- Oil 35%
- Natural Gas 21%
- Nuclear 6%
- Hydro Renewables Other 12%
- Other 10%
Imbalance Between Oil Demand & Reserves

Oil Reserves

- Saudi Arabia: 21%
- Canada: 14%
- Iran: 10%
- Iraq: 9%
- Kuwait: 8%
- U.A.E.: 8%
- Venezuela: 6%
- Russia: 5%
- Libya: 3%
- Nigeria: 2%
- U.S.: 2%

Oil Demand

- U.S.: 25%
- Japan: 7%
- China: 7%
- Germany: 3%
- Russia: 3%
- India: 3%
- Canada: 3%
- Brazil: 3%
- S. Korea: 3%
- France: 3%
- Mexico: 3%

Global CO₂ Emissions Increasing

Source: IEA WEO
Environmental Impacts of Fossil Energy Use

World Leaders Launch Hydrogen Fuel Initiatives

National Initiatives:

- US ~ $1 700 mill. over 5 years
- Japan ~ $300 mill. a year
- EC (EU) ~ €200-300 mill. a year in the 6th FP
- plus: Brazil, Canada, China, India and many others
Hydrogen is a Possible Key to a Secure and Clean Energy Future

Energy Security
Produced from a variety of domestic sources

Environmental
Criteria pollutants from mobile sources eliminated
Emissions from stationary H\textsubscript{2} production sites easier to control
Greenhouse gas emissions significantly reduced

Economic Competitiveness
Abundant, reliable, and affordable energy is an essential component in a healthy, global economy
Timeline for the Hydrogen Economy

I. Technology Development Phase
II. Initial Market Penetration Phase
III. Infrastructure Investment Phase
IV. Fully Developed Market and Infrastructure Phase

Phase I: R&D
Phase II: Transition to the Marketplace
Phase III: Expansion of Markets and Infrastructure
Phase IV: Realization of the Hydrogen Economy

Timeline:
- 2000: Start of R&D
- 2010: Commercialization Decision
- 2020: Transition to the Marketplace
- 2030: Expansion of Markets and Infrastructure
- 2040: Realization of the Hydrogen Economy
Barriers to a Hydrogen Economy

Critical Path Technology Barriers:
- Hydrogen Storage (>300 mile range)
- Hydrogen Production cost ($1.50 - 2.00 per gge)
- Fuel Cell cost (<$50 per kW)

Economic/Institutional Barriers:
- Safety, Codes and Standards (Safety and global competitiveness)
- Hydrogen Delivery (Investment for new distribution infrastructure)
- Education
Hydrogen Storage

3-8x gap between today’s storage system cost and target

- Compressed Gas (10,000 psi) Systems
- Complex Hydride Systems
- Compressed Gas (5000 psi) Systems
- Chemical Hydride Storage Systems
- Liquid Hydrogen Storage Systems

High volume fabrication of compressed and cryogenic tanks

New technologies for advanced materials/systems

Volumetric & Gravimetric Energy Density

- 2015 target
- 2010 target
- Chemical hydride
- Complex hydride
- Liq. H2
- 10000 psi gas
- 5000 psi gas

$\text{kWh/l}$ vs $\text{kWh/kg}$

3-8x gap between today’s storage system cost and target
H₂ Production Strategies

Distributed natural gas & electrolysis economics are important for the “transition”

Energy resource diversification is important for the long-term
Hydrogen Production

3-4x gap between today’s high volume cost and target

Cost goal of $1.50-2.00 approximates the projected cost of conventional fuels (gasoline, untaxed)

- Heat Integration
- Improved Catalyst Performance
- Component Scalability
- Manufacturability
- Operational flexibility
- Remote operation

$/kg ($/gge)

2005 2010 2015
High volume production defined as 500,000 units per year. Cost estimated by TIAx with enhanced hydrogen storage.

Through 1990, PEM cost was dominated by platinum loading (~20g/kW).

Today's high volume estimate is $225/kW and is attributed to platinum and membrane cost.

Cost goal of $30/kW approximates the cost of conventional engine technology.

Reduced catalyst loading
Advanced membrane material

Standardized modular design
Improved membrane fabrication

7x gap between today’s high volume cost and target
Stationary Fuel Cells

- Can meet the demand for combined heat & power in commercial and residential buildings
- Robust technology option, not sensitive to energy policies and competing technologies
- Up to 200-300 GW by 2050, equal to 2-3% of global power capacity in 2050
- Mostly fuelled by natural gas only $\text{H}_2$)
FutureGen
FutureGen Industrial Alliance signed agreement to build FutureGen in 2005

- Alliance officially formed and recognized
- 8 charter members
- Open membership policy with an active recruiting effort
- Alliance has initial capital

- Produces electricity and H₂ with near zero emissions (including CO₂)
- Output of 275 MWe, 1 million metric tonnes of CO₂/year
- Cost: $950 million [private sector $250 M and government $700 M]
- To begin operating in 2012
Review of National Programs

2004 summary of public R&D and policy efforts in the IEA countries
Prospects for H₂ and Fuel Cells

2005 analysis of H₂/FC potential using the IEA ETP model (scenarios to 2050)
H₂ Production Cost

- Decentralised gas reforming & electrolysis: < $15-20/GJ *
- Later, centralised H₂ from gas & coal with CCS < $10-12/GJ
- Higher cost, longer term for nuclear, biomass and solar H₂
- GJ-basis comparison is deceptive: FCV efficiency = 2.5xICE
- Fuel cost/km (ex tax) same as current ICE vehicles *

* Today: H₂ > $35-50/GJ; Oil ($40/bbl) $7/GJ; Gasoline ($2/g) $16/GJ
Transport Sector Fuel Demand

Hydrogen is favored by CO₂ policies
($50/t CO₂ abatement incentive)
When will Hydrogen Powered Autos Reach the Market?

A - Weak CO\textsubscript{2} policy and tech. development
B - Strong CO\textsubscript{2} policy in Kyoto countries and tech. development
C - Strong CO\textsubscript{2} policy in Kyoto countries and tech. lag
D - Strong CO\textsubscript{2} policy world wide and tech. development

Up to 30% H\textsubscript{2} fuel cell vehicles by 2050
Regional Markets

H₂ Use - Scenario D

Per capita H₂ use in 2050 - (GJ H₂/pc)

- **North America**
- **Europe**
- **OECD Pacific**
- **China**
- **Others**

**Best scenario:** 60% FC vehicles in China by 2050, 42% India and US, 36-48% Europe, 35% Canada, 22% Japan, 10% Australia

Differences across regions due to discount rate, fuel taxes, infrastructure, consumers’ attitude for capital-intensive investment, mobility needs, car-mileage.
Energy Technology Perspectives
Scenarios & Strategies to 2050
Primary oil demand is below 2030 baseline level and is returned to about today’s level in TECH Plus.
Map Scenario: Two-thirds of CO₂ emissions reduction is from improved fuel efficiency and one-third from biofuels.
CO₂ Emissions
Baseline and Map Scenarios

OECD

- 2003 Baseline: +70%
- ACT Map 2050: -32%

Developing Countries

- 2003 Baseline: +250%
- ACT Map 2050: +65%

Map: OECD Emissions 32% below 2003 level, while emissions in Developing Countries are 65% higher.
Hybrid vehicles are a bridge technology that can reduce pollution and our dependence on oil until long-term technologies like hydrogen fuel cells are market-ready.

Hybrid/Hydrogen FCV Strategy

- Near-term focus on hybrids
- Transition Phase to Hydrogen - decentralized $H_2$ production from distributed natural gas
- Long-term hydrogen fuel production from diverse domestic carbon-free sources such as renewables, nuclear, and coal with sequestration
International Partnership for the Hydrogen Economy
Unprecedented International Cooperation

California Fuel Cell Partnership

… a collaboration of auto companies, fuel providers, fuel cell technology companies, and government agencies that is placing fuel cell electric vehicles on the road.
Hydrogen Demonstration Project Atlas

- name of project, partners, project dates, type of fuel, …
- submission form for additional projects
- http://www.iphe.net/

Submit Project Data to the IPHE Demonstration ATLAS
Click Here

Hydrogen project at Munich airport
Munich International Airport, Germany
Technology: Onsite CGH2 from electrolysis and NG reformer, Trucked in LH2 to filling station. Gaseous and liquid refuelling systems
Partners: Consortium of 13 private companies
Budget: 35 MEUR
Comments: Transport - 1 filling station, 3 H2ICE buses, 1 FC bus, several ICE cars, 1 fork lifter
IEA & Hydrogen Co-ordination Group
Current Work

Review national R&D programmes in IEA countries.
“Hydrogen & Fuel Cells – Review of National R&D Programs”
Report by IEA, published December 2004

Review IEA R&D activities and collaborations.
“Hydrogen Production & Storage - R&D Priorities and Gaps”
Paper by the Hydrogen IA, published January 2006

Policy Analysis to Help Guide the IEA Work
“Prospects for Hydrogen and Fuel Cells”
Report by IEA published December 2005
Thank you!

robert.dixon@iea.org