II.I Analysis

II.I.1 Moving Toward Consistent Analysis in the Hydrogen, Fuel Cells and Infrastructure Technologies Program: Hydrogen Analysis (H_2A)

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Objectives

- Improve the transparency and consistency of analysis of hydrogen systems.
- Improve the understanding of the differences among analyses.
- Seek validation from industry on consistent analysis methodology.
- Develop a tool for the consistent reporting and analysis of the cost of hydrogen production and delivery technologies.

Technical Barriers

This project addresses the development of consistent analysis methodologies mentioned in the Hydrogen, Fuel Cells and Infrastructure Technologies Program Multi-Year Research, Development and Demonstration Plan, with the aim of providing direction, focus, and support to the development and introduction of hydrogen production, storage, and end-use technologies. The types of analyses that the current H_2A effort has focused on are technology feasibility and cost analysis of hydrogen production and delivery systems.

Approach

- Develop a cash flow analysis tool.
  - Estimates the levelized price of hydrogen for a desired internal rate of return
  - Takes into account capital costs, construction time, taxes, depreciation, O&M, inflation, and projected feedstock prices
- Estimate production costs for several key hydrogen production technologies.
  - Current, mid-term (~2015), and long-term (~2030) technologies
  - Natural gas, coal, biomass, nuclear, electrolysis
- Determine cost of current delivery components.
- Refine inputs and results based on peer review and input from key industrial collaborators (KIC).
- Identify key cost drivers using sensitivity analysis.

Accomplishments

- Developed central and forecourt (filling station) standard reporting spreadsheets.
  - Documented assumptions, inputs, and results
- Completed base case cost analyses with sensitivity analyses for current, mid-term, and long-term technologies.
  - Natural gas reforming: central and forecourt
  - Coal
  - Biomass
  - Nuclear
  - Central wind/electrolysis
  - Distributed (forecourt) electroysis
  - Cryogenic liquid hydrogen (LH_2) and compressed hydrogen gas (cH_2) (tube trailer and pipeline) delivery
- Worked with key industry collaborators to establish parameters, process designs, and technology assumptions.
- Demonstrated ability to calculate levelized hydrogen price and document a consistent set of assumptions.
- Results are not meant to "select" one technology over another, but to provide R&D guidance.

Future Directions

- Incorporate energy efficiency and environmental measures into tool.
- Post spreadsheet tool, results, and detailed documentation on DOE website.
- Complete delivery component and scenario cost analysis.
- Complete remaining cases.
- Issue a peer-reviewed paper.
- Plan for next phase of hydrogen analysis (H_2A).

Introduction

A significant need exists for the analysis of hydrogen production and delivery technologies and systems in order to guide research and development efforts. In reviewing the public information available in this area, several common aspects of the suite of analysis efforts come to light:

- Many excellent analyses have been conducted.
- Many analyses of the same or similar routes to produce or deliver hydrogen appear on the surface to yield different results. Principal discrepancies lie in the basis and assumptions used in the analysis.

H_2A, which stands for Hydrogen Analysis, was formed in 2002 to better leverage the combined talents and capabilities of analysts working on hydrogen systems, and to establish a consistent set of financial parameters and methodology for cost analyses. The foundation of H_2A is to improve the transparency and consistency of approach to analysis, improve the understanding of the differences among analyses, and seek better validation of analysis studies by industry. To accomplish this, a group of approximately fifteen analysts identified the following objectives of H_2A:

- Establish a standard format and list of parameters for reporting analysis results. Do this for production, delivery, and end-use.
- Seek better validation of public analyses through dialog with industry.
- Conduct better demand analyses and factor demand into supply/infrastructure analysis interactively.

- Enhance understanding of the differences among current and publicly available analyses and make these differences more transparent.
- Establish a mechanism for facile dissemination of all public analysis results.
- Improve the understanding of the purpose of hydrogen production and delivery analyses and identify analysis gaps.
- Work to reach consensus on specific analysis parameters for production, delivery, and end-use.

To-date, H_2A has made significant advancements on objectives 1, 2, 4, 6, and 7. Objectives 3 and 5 may be undertaken in subsequent H_2A phases.

Approach

The H_2A Cost Analysis Tool

In order to address the need for transparent reporting and a consistent cost methodology, H_2A developed a modeling tool to assess the minimum hydrogen selling price for central and forecourt hydrogen production technologies. This tool requests the user to define several characteristics of the process being studied, including process design, capacity, capacity factor, efficiency, and feedstock requirements. While the tool includes agreed upon H_2A reference values for several financial parameters, the user is also given the opportunity to vary parameters such as internal rate of return, plant life, feedstock costs, and tax rate to examine the technology using their own basis. The calculation part of the tool uses a standard discounted cash flow rate of return analysis methodology to determine the hydrogen selling price for the desired internal rate of return (10% is the H_2A reference value). Some of the more significant H_2A parameter reference values are:

- Reference year (2000 $)
- Debt versus equity financing (100% equity)
- After-tax internal rate of return (10% real)
- Inflation rate (1.9%)
- Effective total tax rate (38.9%)
- Design capacity (varies according to technology and market)
- Capacity factor (90% for central (exc. wind); 70% for forecourt)

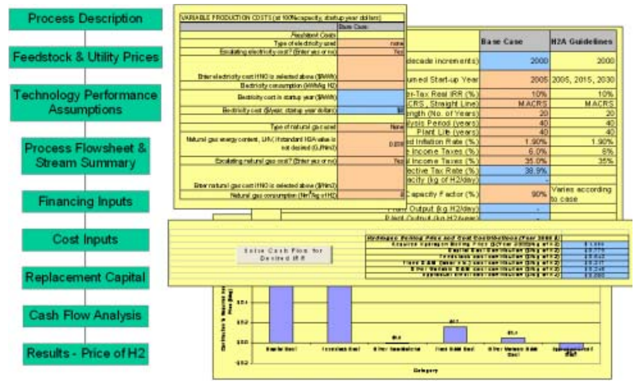

Figure 1. H_2A Cash Flow Analysis Tool

- Length of construction period (0.5 – 3 years for central; 0 for forecourt)
- Depreciation period and schedule (MACRS — 20 yrs for central; 7 yrs for forecourt)
- Plant life and economic analysis period (40 yrs for central; 20 yrs for forecourt)
- Cost of land ($5,000/acre for central; land is rented in forecourt)
- Burdened labor cost ($50/hour central; $15/hour forecourt)
- G&A rate as % of labor (20%)

A flow of how the H_2A cost analysis model is structured and example screenshots are shown in Figure 1.

Delivery Analysis

The H_2A delivery sub-group is working on the analysis fundamentals for increased understanding of delivery costs and infrastructure development options. The first effort is the development of a delivery component cost and performance model to serve as a resource for economic analyses of delivery systems. To begin such studies, H_2A has developed several delivery scenarios for major markets and demand levels. These scenarios are shown in Figure 2. Three modes of transport are being studied: compressed gas truck, liquid hydrogen truck, and gas pipeline. Delivery costs are calculated to be based on the lowest cost components that meet the demands of the market. The components being included into the delivery component cost and performance model are:

- Compressed Hydrogen Gas Truck (Tube trailer)

Market Type	Early Fleet Market (1%)	General Light Duty Vehicles: Market Penetration		
		Small (10%)	Medium (30%)	Large (70%)
Metro	X	X	X	X
Rural			X	
Interstate			X	

Figure 2. H_2A Delivery Analysis Scenarios

- Liquid Hydrogen Truck
- H_2 Compression (single-stage)
- H_2 Compression (multi-stage)
- Hydrogen pipeline
- Liquefiers
- LH_2 Storage Dewars
- Gaseous H_2 Storage Cylinders
- Compressed Hydrogen Gas Truck Terminal
- Liquid Hydrogen Truck Terminal
- Gaseous H_2 Underground Geological Storage

Demand growth and population density distributions have been defined for each scenario, and costs are now being determined.

Review of H_2A Methodologies and Analysis:

H_2A established a key industrial collaborators (KIC) group to provide data and review of the analysis tool and initial cases studied. KIC members were drawn from energy and hydrogen companies, as well as those who are working on the development of novel technologies for hydrogen generation. The KIC provided a significant amount of very useful data and insights and is expected to be a key feature of future H_2A efforts.

Using the H_2A cost analysis tool, several key technologies were studied by members of the H_2A team with relevant experience in the design and advancement of these technologies. The technologies studied were:

- Natural gas reforming: central and forecourt
- Coal

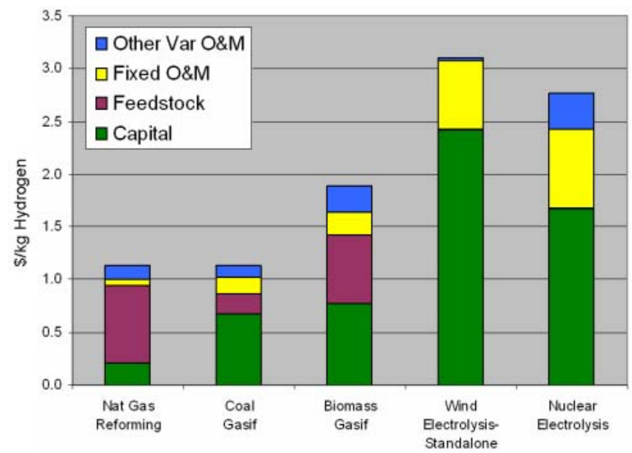

Figure 3. Mid-term Central Technology Preliminary Results

- Biomass
- Nuclear
- Central wind/electrolysis
- Distributed (forecourt) electroysis
- LH_2 and cH_2 (Tube Trailer and Pipeline) Delivery

Results

Initial results from the H_2A effort were presented at the 2004 National Hydrogen Association Conference and at the DOE Hydrogen, Fuel Cells, and Infrastructure Technologies Program Annual Review. As of this writing, minor modifications are being made to the cost analysis tool, although it now contains most of the features necessary for distribution. Preliminary results of the central and forecourt cases are shown in Figures 3 and 4. Review and analysis of these cases is now being finalized, and some of these results may change. Delivery analysis results are forthcoming. It is expected that the central and forecourt case results and the cost analysis tool will be available by the end of the summer 2004. H_2A delivery analysis results will be available by the end of fiscal year 2004.

Conclusions

The H_2A effort has been extraordinarily successful in pulling together technology analysis expertise, industry review, and DOE support. Of primary importance for the necessary analysis of

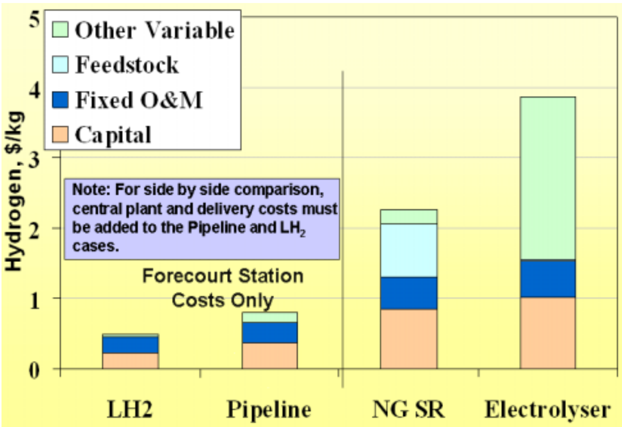

Figure 4. Mid-term Forecourt Technology Preliminary Results

hydrogen pathways, was the development of a standard methodology and tool for performing consistent analyses of hydrogen production technologies. Additionally, H_2A has formed a quantitative basis for consistent analysis of hydrogen delivery options. The future efforts of H_2A are now being discussed by its participants and DOE; subsequent analysis work on hydrogen systems will use the H_2A methodology and results such that the goals of consistency and transparency can be realized.