II.I.2 Hydrogen Transition Modeling and Analysis: HYTRANS v. 1.0

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Objectives

- This project is developing the HYTRANS model, a tool for coherently and consistently analyzing market transitions toward a hydrogen transportation system. Version 1 was to be developed as a proof of principal.
- Rapidly create an integrated model of the transition to hydrogen as a transportation fuel using methods developed for the Transition Alternative Fuels and Vehicles (TAFV) Model.
- Produce a national-level model, HYTRANS v. 1, by April 2004.

Technical Barriers

This project addresses the following technical barrier from the Hydrogen Delivery section of the Hydrogen, Fuel Cells and Infrastructure Technologies (HFCIT) Program Multi-Year Research, Development and Demonstration Plan:

- A. Lack of Hydrogen/Carrier Infrastructure Options Analysis

Key technical challenges for this project are:

- To assemble a consistent set of data summarizing technological costs and capabilities;
- To synthesize those data into a set of forms usable in an integrated, dynamic model that relies on market principles and producer and consumer behavior as its central organizing construct;
- To account in the model for the principle transitional phenomena and barriers that the technologies may face;
- To assess the usefulness of the model as a tool for developing plausible scenarios, evaluating hydrogen infrastructure options, and assessing the costs and benefits of alternative policy options.

Accomplishments

- The principal accomplishment in this time period was the completion of a working version 1.0 of the HYTRANS Model, developed as a proof of principal. This involved substantial data gathering and analysis. An innovative representation of the hydrogen fuel production and delivery activities was developed, addressing the issues of how cost and technology selection depend on evolving production scale and geographical density of demand.

- The components for the production of new hydrogen and fuel cell vehicle (FCV) types were also implemented, as was a new representation of the demand for hydrogen vehicles and other advanced technology vehicles.
- The components were integrated and the ability of the assembled components to function together was confirmed in test runs.

Future Directions

A more complete and regionalized representation is now being developed as version 2. FY 2005 activity will study possible pathways or scenarios by which a transition to the hydrogen light-duty vehicle transportation system may develop, using the HYTRANS model to ensure that the scenarios are physically achievable and economically self-consistent with an identified set of policies or market conditions. The goal is to explore policies and identify and analyze "economically, environmentally, and politically plausible scenarios" for the transition. We will also assess the costs and benefits of alternative pathways to transition, measured from the perspective of the government budget, the U.S. economy, and U.S. society as a whole. If additional funding is available from HFCIT, the work will also encompass significant advances in the benefits assessment capability of HYTRANS, and in the HYTRANS representation of international and non-vehicle markets for hydrogen and related fuels.

Next steps:

- Test HYTRANS v 1.0 and produce 2-3 scenarios of market evolution.
- Produce a regional model by September 2004.
- Test and generate 2-3 regional transition scenarios.
- Publish model documentation and scenarios.
- Incorporate National Academy of Science data for pathway costs, obtain and incorporate H_2A technology data as available.

Introduction

Understanding how a transition to hydrogen can be achieved efficiently and effectively is critically important to the success of the hydrogen program. Working in collaboration with HFCIT, the Planning Budget and Analysis office of DOE's Office of Efficiency and Renewable Energy is taking a staged approach to developing the needed methods and models. The HYTRANS modeling project is one thrust in that program.

The “chicken or egg” problem is a key barrier to energy transitions, but economic models generally do not address the real barriers that create it. Potential barriers that the HYTRANS model seeks to represent and explore include:

- Limited fuel availability depresses vehicle demand, limited fuel demand depresses fuel availability;
- Vehicle and fuel infrastructure investments are large, and not explicitly coordinated;
- Scale economies, implying high costs at low production;
- Limited vehicle model diversity (availability on only a few makes/models limits demand);
- Technological learning-by-doing
- Slow capital stock turnover.

HYTRANS represents all these interdependent barriers.

Approach

The HYTRANS market-equilibrium model approach represents interdependent decisions of hydrogen suppliers, vehicle manufacturers & consumers from 2000 to 2050. It finds competitive market solutions by maximizing producers’ profits and consumers’ welfare. Decision-making to 2050

can be based on perfect foresight, myopia, or other expectation models.

Pending the availability of data on production, delivery, and forecourt technologies from the H_2A working group, version 1.0 of HYTRANS is based largely on technological data from SFA, Inc. Activities and costs for supplying hydrogen were divided in to production, delivery, and forecourt. Detailed cost and performance parameters for each of these categories were assembled. A simple functional form for summarizing these technologies was identified that allows a faithful replication of their reported cost behavior, and is amenable to the inclusions of returns to scale and learning by doing. In the model, delivery costs depend on both production scale and density of demand.

Results

A working hydrogen transition model based on optimization has been created. It includes a complete mathematical representation of hydrogen production (3 technologies), delivery (3 methods), forecourt (1) systems as a function of scale and demand density.

Representation of vehicle choice and fuel demand, including hydrogen FCVs, FCVs with onboard reformers operating on conventional hydrocarbon fuels, hydrogen vehicles with internal combustion engines, as well as hybrids, diesels, conventional gasoline vehicles.

The working, integrated HYTRANS v. 1 was completed May 2004. At this point it is not intended to be an accurate representation of future technology, and the scope of technologies represented is limited:

- SFA cost estimates are used with the assumption of no technological breakthroughs
- Only 3 production technologies: Centralized steam methane reforming (SMR), Forecourt SMR, Forecourt Electrolysis
- Considers only light-duty vehicle hydrogen demand
- National scale market structure

Conclusions

The general approach of market equilibrium modeling has proven workable for hydrogen transition analysis, at least for the range of technologies and degree of technological and regional detail included thus far. It is anticipated that the HYTRANS method, which integrates fuel and vehicle producer economic behavior, will provide useful insights into the prospects for a transition to hydrogen.

Initial results show that at high densities, pipelines do appear to dominate as a delivery mode, but many questions remain.

A better understanding of the likely structure, evolution, and costs of regional pipeline systems is needed. The question of how a hydrogen pipeline system would evolve, what its spatial configuration will be, and what that implies for delivered cost at different scales and density deserves more careful consideration.

FY 2004 Publications/Presentations

A draft of the model documentation was completed:

1. "HYTRANS – HYDROGEN TRANSITION MODEL: BUILDING VERSION 1.0," Draft, David L. Greene, Paul N. Leiby, Sujit Das, David Bowman, Sanjana Ahmad, and Elzbieta Tworek, June 17, 2004.

2. "Hydrogen Transition Modeling and Analysis: HYTRANS v. 1.0," David Greene and Paul Leiby, Oak Ridge National Laboratory, National Hydrogen Association, Los Angeles, California, April 28, 2004.

3. "Hydrogen Transition Modeling and Analysis: HYTRANS v. 1.0," David Greene & Paul Leiby (Oak Ridge National Laboratory), Elzbieta Tworek (Univ. of Tennessee & StrataG), David Bowman (Econotech), Washington, DC, May 10, 2004.

4. "2004 DOE Hydrogen, Fuel Cells & Infrastructure Technologies Program Review Presentation, Hydrogen Transition Modeling and Analysis: HYTRANS v. 1.0," David Greene, Paul Leiby, Elzbieta Tworek, and David Bowman, Philadelphia, Pennsylvania, May 25, 2004.