VIII.7 Impact of Hydrogen Production on U.S. Energy Markets

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Objectives

- Develop a consistent, integrated framework for evaluation of impacts of hydrogen production within U.S. energy markets.
- Evaluate costs and timeliness of various scenarios for developing hydrogen supply infrastructure.
- Evaluate impacts on U.S. energy markets including price and consumption changes for coal, natural gas, renewables and electricity.
- Identify most economic routes and financial risks of hydrogen production infrastructure.

Technical Barriers

This project addresses the following technical barriers from the Systems Analysis section (4.5) of the Hydrogen, Fuel Cells and Infrastructure Technologies Program Multi-Year Research, Development and Demonstration Plan:

(B) Lack of Consistent Data, Assumptions, and Guidelines

(C) Lack of a Macro-Systems Model

(E) Lack of Understanding of Transition of a Hydrocarbon-Based Economy to a Hydrogen-Based Economy

Technical Targets

The technical targets for this project include data and algorithms that characterize:

- Potential regional hydrogen demand scenarios through time in the U.S.
- Regional coal supply resources and costs, foreign import potential.
- Inter-regional coal transportation costs and future capacity.
- Regional natural gas supply and costs, foreign import potential.
- Inter-regional natural gas transportation costs and future capacity.
- Regional geologic carbon sequestration potential, costs.
- Carbon dioxide transportation costs.
- Regional biomass production potential.
- Biomass transportation costs.
- Cost and performance of coal conversion technologies for hydrogen and other products.

The other technical targets include the revised MARKAL model itself and analyses made with the current and revised model.

Accomplishments

In the first year of this project (May 2005–June 2006) the following items have been accomplished:

- Created initial scenarios for metropolitan market area hydrogen demand through 2060 to develop infrastructure design and cost algorithms.
- Researched regional coal resource base descriptions, size estimates and cost distributions.
- Researched historical coal transportation costs and developed modeling algorithms.
- Created more consistent performance and cost inputs for coal-to-hydrogen and other coal conversion technologies in MARKAL.
- Researched geologic sequestration cost and maximum storage capacities by region.
- Developed algorithms for carbon dioxide transportation.
- Researched biomass resource base descriptions, regional availability estimates and cost distributions.
- Developed suite of distance-based costing algorithms for hydrogen and its feedstocks to allow specification of cost tradeoffs of infrastructure location and size.

- Used current version of the MARKAL model to investigate integrated hydrogen scenarios based on the 2005 and 2006 versions of the DOE Annual Energy Outlook (AEO). Initiated the modification of MARKAL to incorporate the latest and most consistent cost and performance data for alternative hydrogen production technologies.

Introduction

The objectives of this project are 1) to develop a consistent, integrated framework for the evaluation of the impacts of hydrogen production within U.S. energy markets, and 2) to use that framework to evaluate how various scenarios for developing a hydrogen supply infrastructure will impact U.S. energy markets including price and consumption changes for coal, gas, renewables, and electricity. Through scenario analysis, this project seeks to identify the routes to hydrogen production with the lowest economic costs and financial risks.

Approach

The EEA, together with BNL and PEAR, will create a new regionalized version of the MARKAL model to conduct an analysis of options and tradeoffs involved in the establishment of a hydrogen production infrastructure. MARKAL is an integrated, inter-temporal analytical tool capable of evaluating changes in energy markets over the long-term (2005 - 2050). For this project, the MARKAL model will be modified to incorporate the latest and most consistent cost and performance data for alternative hydrogen production technologies and will be built out to represent separate regions of the U.S. A key focus of the work will be to evaluate impacts of an evolving hydrogen economy on U.S. energy markets including price and consumption changes for coal, natural gas, renewables, nuclear and electricity.

Results

Hydrogen Demand Scenarios

The MARKAL model will require estimates of transportation-related hydrogen demand by region as well as the spatial dispersion of demand within each MARKAL demand region. In addition, the new version of the MARKAL is planned to have at least two demand-density classes (e.g., urban and rural). EEA processed census data on fuel retailing businesses to determine historic gasoline and diesel sales by metropolitan area and that portion of each state's sales that occur in rural areas. Key statistics such as population and surface area of each metropolitan area and state were also collected. Based on the 2006 Annual Energy Outlook, EEA also collected regional sales forecasts. EEA then allocated the AEO forecast to metropolitan areas and state rural areas so that the geographic pattern of future gasoline and diesel sales volumes could be determined within each region through 2030. These data will be used to estimate demand-density statistics for each MARKAL region and to develop infrastructure distance parameters for the model. These data have been placed into a GIS system and used to prepare maps. An example of such a map is shown in Figure 1.

U.S. and World Coal Reserves, Resources and Production Costs

EEA compiled and evaluated EIA data on U.S. coal reserves by state including:

- Reserves in producing mines.
- Estimated recoverable reserves.
- Demonstrated reserves base.
- 2003 coal production by coal type and underground versus surface mines.

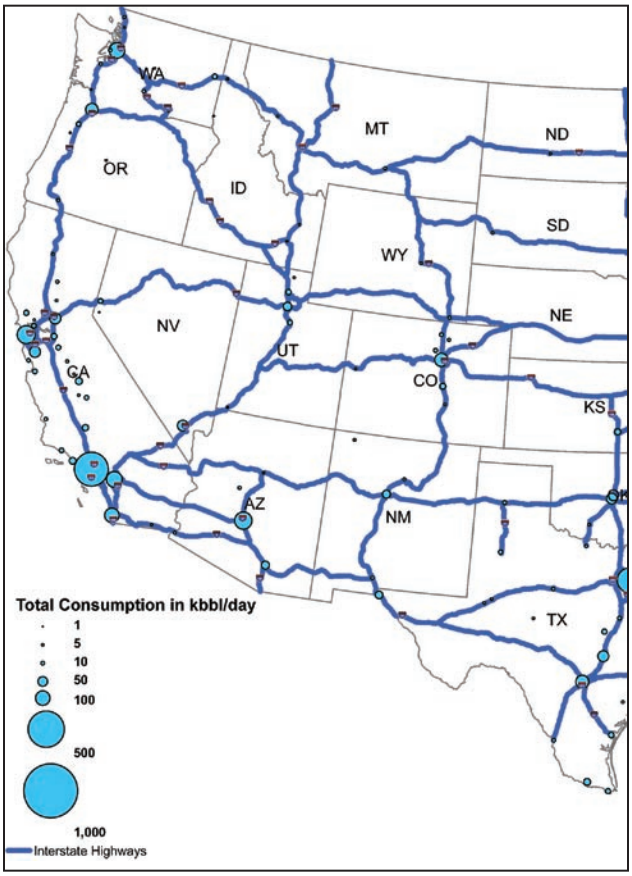


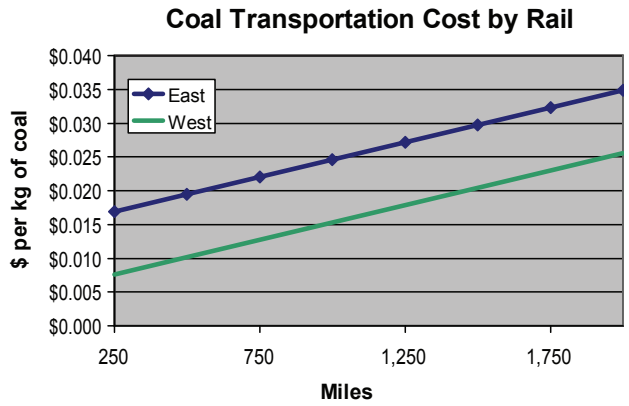
FIGURE 1. Total 2003 Gasoline and Diesel Consumption by Metropolitan Area (only the left half of map shown)

We also compiled EIA international data on country level world estimated recoverable coal and production broken out by coal rank. EEA also evaluated historical EIA series on U.S. coal production, prices, exports, consumption and stocks and the coal supply and price forecasts contained in the AEO.

EEA also summarized the most recent U.S. Geological Service coal resource assessment of the United States. Resources were summarized by area, depth interval, and resource category (measured, indicated, inferred, and hypothetical). Results of this effort were summarized into tables, charts and brief write-ups that will become part of EEA's final report to DOE. The data will also be used to set resource limits and costs with the MARKAL model.

U.S. Coal Transportation Costs

Analysts at PEAR Inc. produced an initial estimate of inter-regional coal transportation costs. This included analysis of rail and barge costs per ton between coal supply and demand regions. The regions and coal types were defined by the standard designations used in other PEAR analysis. Costs were prepared for historical years and for a twenty-year forecast horizon using component cost escalation factors. Average cents per ton-mile and cents per MMBtu-mile were also computed. These data will be used to set up the initial version of the inter-regional coal transportation algorithms in MARKAL including expected future escalation rates. In addition, EEA created generic coal transportation algorithms to estimate feedstock delivery costs within each region. The algorithms are shown in Figure 2. These generic algorithms will be used to investigate the placement of infrastructure within each region and total infrastructure costs as the market share for hydrogen grows.



Eastern rate per short ton = 11.50 + .0093*Miles + .0025*$/gallon*Miles
Western rate per short ton = 3.10 + .0093*Miles + .0025*$/gallon*Miles
Fuel cost in $/gallon of diesel fuel

FIGURE 2. General Coal Transportation Cost Algorithms

Coal Conversion Technologies

EEA developed a preliminary summary of technical and cost data for coal-to-hydrogen and other coal conversion technologies. These cost factors were put into a standard summary format. These data were compared against the H2A cost and performance data to develop a consistent set of coal technology assumptions for MARKAL.

CO_2 Capture and Sequestration Research

EEA evaluated literature on CO_2 sequestration cost curve development for the U.S. EEA also researched and summarized IEA assessments of U.S. CO_2 sequestration potential and compiled information on U.S. CO_2 pipeline costs by component and evaluated information on existing CO_2 pipelines in the U.S. In addition, EEA researched the U.S. "NATCARB" GIS database of CO_2 sources and sinks and contacted the database developers for future plans. Our intent is to use this information to develop estimates of the maximum underground sequestration potential by region and the approximate cost distribution of each sink type (enhanced oil recovery in active oil fields, enhanced gas recovery in non-conventional gas areas, depleted gas/oil fields and aquifers). The pipeline cost data will be used to estimate CO_2 transportation cost between MARKAL regions and typical intra-regional costs between CO_2 sources and sinks. EEA databases were used to estimate the potential volumes of CO_2 that can be used for enhanced oil recovery. See Figure 3 for an example of a map created from such data.

Biomass Resource Base and Costs

BNL researched biomass resource base descriptions, regional availability estimates and cost distributions. These will be used to develop regional cost curves in MARKAL. The objective is to determine the quantity of each biomass resource type of interest at a range of selected production costs, in at least two population density areas. Transportation costs will be factored into the final cost of each feedstock type.

Regional Shipping and Distribution Cost Algorithms

EEA developed cost algorithms that will be used to assess how infrastructure could be built in each region to supply the market with hydrogen. The algorithms are all distance-based and may include additional factors accounting for fuel cost such as diesel fuel (for trains and trucks) and electricity (for hydrogen storage and pipeline transportation). The objective is to locate infrastructure within each region so as to minimize the cost of providing feedstocks, distributing hydrogen, storing

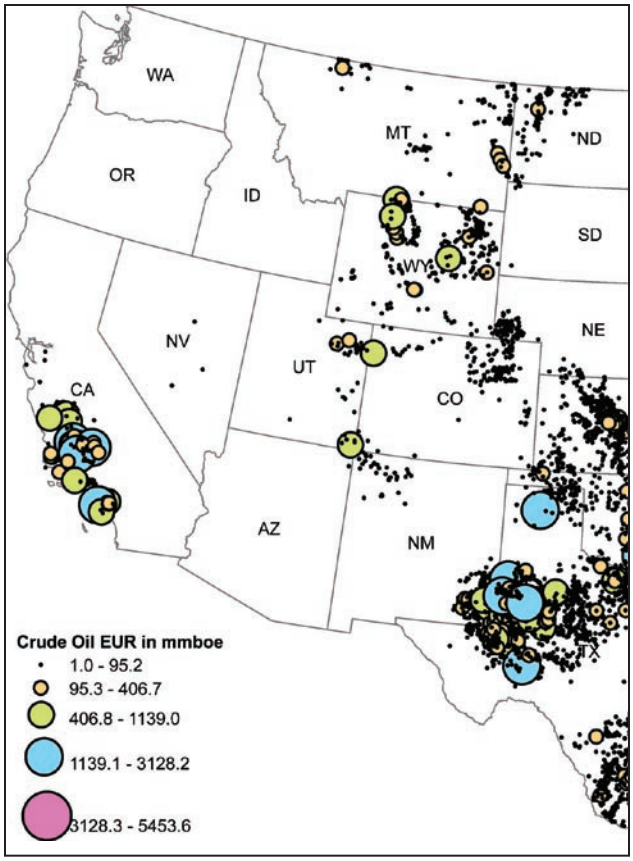


FIGURE 3. Map of Oil Fields in which Carbon Dioxide Sequestration May Be Possible (only the left half of map shown)

hydrogen and disposing of carbon dioxide created in manufacturing the hydrogen for any given technology.

MARKAL Analysis

BNL used the current version of the MARKAL model to investigate integrated hydrogen scenarios based on the 2005 and 2006 AEO assumptions extrapolated further into the future. An example of results is shown in Figure 4. The cases examined include:

- H2PE: HFCIT Program goals for fuel cell costs.
- H2PSTE: H2P + vehicle subsidy ($3,000 for 2015 & 2020, $1,500 for 2025) and hydrogen fuel taxes at ½ the level of gasoline.
- H2PSTEC: H2PSTE + $50 carbon tax.

All the scenarios presented are based on AEO 2006 Reference Case economic activity, vehicle fleet and fuel prices. Hydrogen fuel cell vehicles are assumed to be 3.0 times as efficient as conventional gasoline vehicles. The cost for hydrogen distribution, storage and dispensing

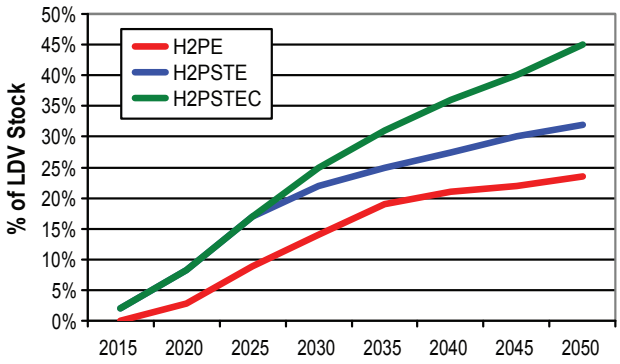


FIGURE 4. Preliminary LDV Market Shares Assuming HFCIT Fuel Cell Cost Goals are Met

costs are set at HFCIT Program goals. The results show a potential market size in 2050 for hydrogen of approximately 25 to 45 percent of light duty vehicles. Other cases examined with MARKAL conclude that even higher penetration rates are possible under higher oil price scenarios.

Conclusions and Future Directions

During the next year, EEA and BNL will complete the alternative scenario design for hydrogen demand by region and year and translate these scenarios into daily volumes by geographic market area. We will also develop production, distribution, storage and dispensing "design" and cost estimates of each region based on natural gas, coal and biomass feedstocks. These regional analyses will include carbon sequestration costs and regional geologic capacities for enhanced oil recovery use and for disposal options. These data will underlie the MARKAL algorithms for various levels of hydrogen market penetration in each region. BNL and EEA will implement and test the regionalized version of MARKAL, including the inputs developed in this project. We will also examine alternative integrated scenarios and sensitivities with MARKAL and will prepare the final report for the project.

Publications/Presentations

1. Presentation on project goals and approach entitled "Impact of Hydrogen Production on U.S. Energy Markets", P. Friley, E. H. Vidas, T. Huetterman, International Energy Workshop, Tokyo Japan, July 2005.

2. Presentation on project progress entitled "Impact of Hydrogen Production on U.S. Energy Markets", H. Vidas, P. Friley, DOE Annual Merit Review Meeting, Arlington, VA, May 2006.