July 2008

Effects of a Transition to a Hydrogen Economy on Employment in the United States

Report to Congress

EFFECTS OF TRANSITION TO A HYDROGEN ECONOMY ON EMPLOYMENT IN THE UNITED STATES

TABLE OF CONTENTS

EFFECTS OF TRANSITION TO A HYDROGEN ECONOMY ON EMPLOYMENT IN THE UNITED STATES

EXECUTIVE SUMMARY

E.1 Background to the Study

Section 1820 of the Energy Policy Act of 2005, "Overall Employment in a Hydrogen Economy", requires the Secretary of Energy (Secretary) to carry out a study of the likely effects of a transition to a hydrogen economy on overall employment in the United States. This study, prepared by the Department of Energy (DOE or Department) in response to Section 1820, represents the Department's "best efforts" to predict the employment impacts of such a transition. Prior to publication, the study was reviewed by an independent panel of experts from industry and academia. While the panel provided valuable additional input,[1] any study of potential future impacts necessarily presents several difficult challenges, including the choice of a sound methodology and the identification of reasonable data inputs and factual assumptions, given the uncertainties. In addition, technological process is extremely difficult to predict and economic forecasts are often unreliable even over the short term. The results must be interpreted in light of these unavoidable limitations.

E.2 Methodology

This study estimated the employment impacts of a transformation of the U.S. economy to the use of hydrogen between 2020 and 2050. This time frame was selected because the ongoing efforts to develop hydrogen based transportation (or "mobile") and stationary technologies indicate that broad-based commercial and industrial use of and the first significant employment impacts from those technologies are most likely to emerge within the indicated time frame. More specifically, hydrogen production technologies are examined as of three dates-2020, 2035, and 2050-and the share of production contributed by each technology is estimated on the basis of DOE's Hydrogen Analysis (H2A) models.[2]

Because it is not possible to predict with precision the rate at which hydrogen technologies will be incorporated into the nation's economy on the above three dates, the study also considers the differences in employment by industry under two scenarios. The more rapid transformation scenario assumes the success of the President's Hydrogen Fuel Initiative (HFI)[3]

---

[1] The study was reviewed by and benefited from the advice and comments of the members of an industry advisory panel including Dr. John Johnston, former Planning Executive, Corporate Strategic Research Lab, Exxon-Mobil Research and Engineering; Dr. Alan Lloyd, President of the International Council on Clean Transportation; Dr. Walter McManus, Director Automotive Analysis Division, University of Michigan Transportation Research Institute; Mr. Gregory Morris, Senior Vice President, HydroGen, LLC and Executive Director, Cullen Engineering Research Foundation; and Dr. Robert Rose, Executive Director, U.S. Fuel Cell Council.

[2] DOE initiated its Hydrogen Analysis (H2A) initiative in February 2003 as a means of establishing a standard format and list parameters for estimating and comparing the lifecycle costs of hydrogen production and delivery technologies. See, http://www.hydrogen.energy.gov/h2a_analysis.html.

[3] President Bush announced the HFI in his 2003 State of the Union Address. The HFI consists of a $1.2 billion program to develop commercially viable hydrogen fuel cell and infrastructure technologies by the year 2020.

of saving 11 million barrels of oil per day by 2040 (the "HFI Scenario"), and the less rapid scenario follows DOE's analysis supporting its 2007 program benefits estimation (the "Less Aggressive Scenario").[4] Under the HFI Scenario, for example, the penetration of the light-duty vehicle stock with hydrogen powered vehicles by 2050 is 96%. Under the Less Aggressive Scenario, such penetration by 2050 is 38%.

The study further estimates national employment impacts from the transition to a hydrogen economy using an established economic impact analysis model called IMPLAN (an acronym for "Impact analysis for PLANning"). IMPLAN has been used in other contexts to derive economic impacts of long-term technological developments.[5] The current study uses the IMPLAN inter-industry model with 509 industrial sectors for the U.S. economy. Revised industry purchase vectors were constructed for three industries for the hydrogen scenarios—vehicle components, vehicle assembly, and hydrogen production. Stationary and portable fuel cells were assumed to be produced in the vehicle components vector together with the automotive fuel cells. The data for these revisions were derived from application of DOE's H2A production and delivery models and separate cost estimates for fuel cell vehicles and stationary fuel cells. Technological process is extremely difficult to predict and economic forecasts are often unreliable even for short term predictions. Though this study represents our best estimate, it is important to appreciate the tremendous uncertainties involved.

E.3 Scenarios Shaping Future Hydrogen Markets

HFI Scenario. The base case against which the employment impacts of hydrogen market expansion are compared is a predominantly gasoline economy. The HFI Scenario assumes rapid market penetration of hydrogen vehicles. The first sales occur in 2018. By 2020, 27% of new vehicle sales are hydrogen vehicles; by 2035, 89%; and 100% by 2050. This results in stocks of light duty hydrogen vehicles in use, respectively, of 3%, 60%, and 96% of the total of light duty vehicles in use in those years. For hydrogen production, it is assumed that distributed reforming of natural gas provides the greatest share of hydrogen production in 2020. Natural gas feedstocks are then largely superseded by 2035 and replaced by coal gasification with carbon sequestration and, to a lesser extent, by biomass gasification. By 2050, biomass and wind, combined, provide 35% of hydrogen supplies. Hydrogen production from nuclear resources provides small shares in both 2035 and 2050. Hydrogen will also be used to fuel stationary fuel cells. In 2020, stationary fuel cells are assumed to supply 1% of the post-2015 growth in national electricity demand. It is assumed that this will increase to 5% in 2035; and to 10% in 2050.

---

[4] Government Performance and Results Act, Public Law No. 103-62. This law requires Federal agencies to develop and report annually on performance measures and goals for each program activity of the agency. The 2007 report was prepared by DOE and the National Renewable Energy Laboratory and is entitled, Projected Benefits of Federal Efficiency and Renewable Energy Programs, FY 2007 Budget Request (March 2006) See, http://www1.eere.energy.gov/ba/pba/2007_benefits.html. (Projected Benefits FY 2007)

[5] For example, the IMPLAN model has been used for long term technology assessments in the following reports: Robert H. Beach and Martin T. Ross, *General Equilibrium Assessment of Regional Climate Change Policy*, Proceedings of the 2004 National IMPLAN User's Conference (MIG, Inc., Stillwater, MN (Oct. 2004) at 151-168; and Northwest Economic Associates, *Assessing the Economic Development Impacts of Wind Power* (Feb. 12, 2003).

Less Aggressive Scenario. Market penetration of hydrogen vehicles is slower under the Less Aggressive Scenario, reaching approximately 1% of new sales in 2020, 20% in 2035 and 63% in 2050, resulting in hydrogen vehicle stocks of ½%, 7% and 38%, respectively. The composition of hydrogen production technologies over time is similar to that in the HFI Scenario, but output is lower, in line with the smaller number of hydrogen vehicles. The shares of incremental electricity demand provided by stationary fuel cells are zero in 2020, 2% in 2035, and 5% in 2050.

Table E.1 summarizes the hydrogen vehicle adoption and stationary fuel cell use in 2050 under the two scenarios.

Table E.1: Hydrogen Fuel Cell Vehicles and Stationary Fuel Cell Uses in 2050 in the HFI and Less Aggressive Scenarios

Scenario		**HFI Scenario**	**Less Aggressive Scenario**
Sales	million light-duty vehicles sold/yr	23.9	15.1
	% of all light-duty vehicles sold	100%	63%
Stock	million light-duty vehicles in use	347.5	144
	% of all light-duty vehicles in use	96.0%	38.2%
Hydrogen fuel use	quads/yr[a]	8.02	3.73
	billion gge/yr[b]	64.1	29.95
Stationary fuel cells	percent of incremental electricity demand after 2015 supplied	10%	5%

[a]1 quad = 1 quadrillion Btu.
[b]gge = gallons of gasoline equivalent.

E.4 Employment Creation and Replacement at the National Level

By 2050, under the HFI Scenario, the transformational adjustments are fully completed, with no more anticipatory investment; U.S. employment is increased by a net of 0.37%, or 675,000 jobs out of a total projected base-case employment of 184 million. Under the Less Aggressive Scenario, the transformation is not fully completed by 2050 and U.S. employment is increased by a net of 0.20%, or 361,000.

The more significant changes occur under the HFI Scenario. Thus, under the HFI Scenario, net employment in the automotive industry is unchanged between the gasoline and hydrogen economies, but replacement of gasoline-related skills with hydrogen-related skills is substantial. For example, in automotive parts manufacturing, 10,000 white collar jobs are created by 2035, replacing an equal number of outmoded jobs. The figure is 12,000 by 2050. Blue-collar employment job creation and replacement in automotive parts manufacturing is 104,000 by 2035 and 117,000 by 2050. The greatest job creation and replacement is for automobile dealerships and repair: 436,000 by 2035 and 680,000 by 2050.

Training implications of the job changes vary by industry and skill, as indicated by a survey of industry opinions. The changes will be substantial in some cases, though many will be evolutionary, resulting partly from experience with hybrids. The needs for new skills will be spread over a number of years. Much of the obsolescence of skills will be met by normal retirement rates. Most of the needs for new skills can be supplied by normal rates of entry into the labor force as workers receive training in new, hydrogen-related skills.

With the automobile industry taking a small proportion of all engineers in the U.S., engineering schools easily have the capacity in the long run to respond to changes in the fields of engineering that will be required. This is also true for the most part in the shorter run, in view of university expertise currently being developed in hydrogen technology R&D.

Some but not all of the blue collar training needed to switch from gasoline to hydrogen vehicles can be provided on the job and by in-house classes. Automotive technicians and mechanics are a large group requiring much training and re-training. They are the group for which bottlenecks appear to be most likely. Up to 110,000 technicians and mechanics will need to be equipped with hydrogen-technology skills by 2020 to service new vehicles on the road by that year in the HFI Scenario. By 2035, the number is 335,000. By 2050, the number is 630,000, many of whom will have entered the labor force prior to the beginning of hydrogen market expansion.

E.5 Regional Variations in Economic Impacts

Five regions were selected for examination: 1) the Upper Midwest, consisting of Ohio, Michigan, Indiana, Illinois, and Wisconsin; 2) Lower New England and the Upper Mid-Atlantic, consisting of Massachusetts, Connecticut, Rhode Island, New York, Pennsylvania, and New Jersey; 3) California; 4) Tennessee; and 5) the Houston metropolitan area. Unique characteristics of these regions lead to impacts that differ from those at the national level. The Upper Midwest is America's long-established automobile manufacturing belt. The Lower New England and the Upper Mid-Atlantic regions are very diversified economically. California is also a very diversified state, but its industrial mix has been changing in the past decade. Tennessee represents the new automotive manufacturing region of the South. Houston is highly concentrated in petroleum production and is a net exporter of refined products.

Compared to the base case without a hydrogen market transformation, the HFI Scenario leads to a projected gain in the Upper Midwest of 110,000 additional jobs by 2050. The gains will be distributed across 41 industries. The region will lose 4,800 jobs concentrated in 14 industries. The region's net creation of 105,000 jobs is 0.44% of its 2050 base-case employment. Scientific and technical services employment would grow to support both the technical needs of hydrogen production and the technological changes in the automotive industry, while fabricated metals would lose employment.

The Lower New England and Upper Mid-Atlantic region is projected to increase its 2050 employment by 0.56% over what it would be in an all-gasoline economy. The gains are primarily in the production and delivery of hydrogen, while losses are in the corporate offices of upstream energy companies.

California experiences a 0.45% increase over the base case in the hydrogen market expansion under the HFI Scenario. Its high-tech sectors participate in the development of the new hydrogen technologies, as does carbon and graphite manufacturing. The state suffers some loss of employment in petroleum refining relative to the all-gasoline scenario.

Tennessee gains 0.5% in employment relative to the gasoline scenario under the HFI. The state has no significant losses to dampen the gains in hydrogen production and technological and engineering services.

Houston gains 0.37% in employment in the HFI Scenario relative to the base case. Its refining industry suffers in the hydrogen market expansion, compared to the all-gasoline base case scenario, but this impact could be cushioned by the relative ease of retrofitting the area's refineries. Houston's experience in a variety of energy industries helps it gain employment in hydrogen production and in the design and production of energy and chemical pipeline equipment.

E.6 International Competition

The transformation to a Hydrogen Economy will serve at least two major objectives in the international area. First, reduction in oil imports, with the attendant increase in energy independence, is a clear U.S. goal to which hydrogen will contribute. Second, if U.S. companies are able to forge a lead in hydrogen technologies, U.S. global competitiveness will be fostered. The movement to hydrogen in particular could well be an opportunity for U.S. automotive firms to recapture market share lost to foreign multinationals in recent years.

Due to overseas operations of U.S. and multinational corporations, with or without a hydrogen transformation, most vehicle production and employment will continue to be tied to countries with large automobile demands. Some effects on the international location of supplies of particular individual materials could be brought about by a transformation to hydrogen. If the production shares held by U.S. and multinational corporations are affected because some companies get ahead of others in introducing hydrogen vehicles, the location of automobile production within the U.S. could be affected in turn due to the fact that companies differ in their regional concentrations of production capacity. Hydrogen, however, will be produced domestically in either case and will be essentially a non-internationally traded commodity. Inasmuch as natural gas is not projected to be a significant long-term feedstock for hydrogen production, little effect on gas imports is projected.

Oil imports, on the other hand, will fall as gasoline is replaced with hydrogen. By 2050, the difference in oil imports between an all-gasoline economy and a hydrogen economy under the HFI Scenario is projected to be $370 billion per year, or 1% of the $38.12 trillion estimated gross domestic product in 2050. Some of the reduction in expenditures on imported oil will be redirected to a domestically produced, largely nontradable good—hydrogen. The $370 billion reduction in oil imports equals approximately 7.5% of projected total U.S. imports in 2050 if trade grows at the same rate as gross domestic product.

The oil import reduction introduces a trade imbalance that will lead to a combination of adjustments in non-oil imports and exports. The adjustments will be spread over the many non-oil commodities involved in U.S. trade. Considering that both import and export adjustments will occur over a 30-year hydrogen market expansion period, the average yearly quantity adjustment for a commodity will be less than 0.1 of one percent. Similar considerations apply to all countries adopting hydrogen. On-going globalization effects on trade over the coming years seem bound to overwhelm the small trade adjustments to the reduction in oil imports.

A similar conclusion applies to effects on world capital markets. With falling OPEC incomes, OPEC countries' purchases of U.S. assets would be reduced. Overall financial lending to industrialized countries would be lowered. Any effect on world interest rates is unlikely to be perceptible given that OPEC demand for financial assets is a small part of total world demand for assets.

Recommendations

This study identified possible employment impacts that could result from hydrogen market expansion in the transportation and stationary and portable power sectors. As noted previously, any study of potential future impacts necessarily presents difficult challenges and involves significant uncertainties. Results and recommendations should be considered with those issues in mind. The scenarios, hydrogen generation options, and regions selected for the study yielded a reasonable measure of the potential opportunities that hydrogen presents to U.S. employment. The study considers introduction of the fuel cell vehicle and supporting hydrogen infrastructure development that spans a period of approximately 40-50 years. The study highlights possible skill and education needs to support the associated industries and technologies. In addition to the specific skill requirements of the fuel cell industry, future education of the next generation should be focused on skill sets that have the ability to adapt to changing technologies.

Training implications of the job changes vary by industry and skill, as indicated by a survey of industry opinions. Most of the needs for new skills can be supplied by normal rates of new entry into the labor force as workers receive training in new, hydrogen-related skills. Considering the small proportion of all engineers in the U.S. that the automobile industry employs, engineering schools have the capacity to respond to changes in the fields of engineering.

Following are employment-related recommendations for a transition to a hydrogen economy.

1. <u>Training programs</u>.

    a. Training and retraining programs may be needed to help ensure that the U.S. workforce possesses appropriate skills and that sufficient numbers of trained personnel are available to meet the manufacturing requirements at the time that hydrogen fuel cell vehicles begin to come off the assembly lines. Development of these programs should involve close coordination between the fuel providers and auto manufacturers, and schools. At the appropriate time, university and vocational programs will need to be assessed to understand where opportunities lie and what additional curricula may be needed.

    b. Training and retraining programs may be useful in related aftermarket areas such as repair and recycling.

    c. Educational programs aimed at the general public could help to influence people to pursue jobs in the hydrogen and fuel cells industries.

2. Additional analysis.

    a. *Analysis of training needs*: The study found that training for new skills may be needed across a wide spectrum of industries. Most of the needs for new skills can be supplied by normal rates of new entry into the labor force as workers receive training in new, hydrogen-related skills. Some changes in skills appear to be relatively well defined, but many likely changes remain difficult to forecast, since many of the technologies are still maturing. Many job tasks remain unknown at present, making identification of training needs an interactive task with job definition.

    b. *Assessment of skill changes, with attention to industry adjustments in different regions*: Unemployment resulting from the elimination of jobs associated with obsolete technologies and industries is estimated to be slight. The supply of labor with technology-specific skill sets may or may not keep pace with the labor demands associated with the rapid growth in hydrogen-related industries. Even though this study indicated every region would gain jobs, surpluses and shortages of skilled workers could vary regionally.