

## IX.1 Employment Impacts of Hydrogen and Fuel Cell Technologies

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### Overall Objectives

- Update 2008 DOE Report to Congress, *Effects of a Transition to a Hydrogen Economy on Employment in the United States* [1] to reflect current levels of technology advancement and anticipated fuel prices, economic activity and market success.
- Expand the 2008 Report by adding materials handling, backup power and other early market applications of fuel cells, and modeling the effects of market development between industries and regions.
- Estimate net impacts of hydrogen (H<sub>2</sub>) and fuel cell (FC) development on national and regional employment, earnings and economic output under alternative scenarios.
- Identify implications of scenario results on work force development.

### Fiscal Year (FY) 2017 Objectives

- Develop a reference scenario (“Core Multi-Market Scenario”) focusing on development of light-duty vehicles (LDVs) and hydrogen fueling for each of five regions over 35 years (2015–2050).
- Adjust existing industry cost vectors and define new cost vectors to enable economic modeling of the impact of that scenario.
- Estimate the magnitude of total and regional impacts and identify industries most heavily impacted by H<sub>2</sub> and FC development in LDVs. Examine occupational composition of affected industries.

### Technical Barriers

This project addresses the following technical barriers from the Systems Analysis section of the Fuel Cell Technologies Office (FCTO) Multi-Year Research, Development, and Demonstration Plan.

- (A) Future Market Behavior
- (B) Stove-piped/Siloed Analytical Capability
- (C) Inconsistent Data, Assumptions and Guidelines
- (D) Insufficient Suite of Models and Tools

### Contribution to Achievement of DOE Systems Analysis Milestones

This project will contribute to achieving the following milestones for the Systems Analysis section of the Fuel Cell Technologies Office Multi-Year Research, Development, and Demonstration Plan.

- Milestones 2.3–2.6: Develop and maintain models and tools.
- Milestones 1.7, 1.10, and 1.14: Perform studies and analyses of job impacts.

### FY 2017 Accomplishments

- Developed custom industries corresponding to FC stacks, FC systems, FC cars and FC light trucks at a level of detail to permit supply chain modeling for five regions (Western United States, zero emission vehicle (ZEV)/ Eastern United States, Central/Southern United States, Central/Industrial United States, and the rest of United States) from 2015 to 2050 in the Regional Economic Models, Inc. (REMI) Policy Insight model.
- Estimated the number and value of FC stacks, systems, cars and light trucks produced and sold by region under the Core Multi-Market Scenario and associated demands for hydrogen and retail fueling stations.
- Estimated gross impacts on regional employment by industry and occupation.



## INTRODUCTION

The project is analyzing economic impacts associated with the development of FCs and associated hydrogen infrastructure. Insights from this work will assist FCTO and its stakeholders in estimating employment and other economic impacts from DOE technology development and in

identifying FC markets and regions that are most likely to see economic gains from the advancement of these technologies. In earlier work, Argonne National Laboratory and RCF analyzed economic impacts associated with a large-scale transition to hydrogen and fuel cells. That work formed the basis for a 2008 DOE Report to Congress which is being updated and expanded in this effort.

## APPROACH

FCs are being developed for a range of demands and duty cycles, from small portable devices to megawatt-scale, from steady-state to variable power output, and from continuous to quick-start backup operation. Each of these applications represents a unique market with different packaging/integration, installation, and operation and maintenance needs. Not only do these markets differ in size and anticipated growth, they also displace incumbent technologies with different production locations and supply chains. Thus, modeling the effects of H<sub>2</sub> and FC development requires an understanding of likely applications and their anticipated growth; the penetration of FCs into those markets and their associated H<sub>2</sub> fueling needs; the cost of FCs, H<sub>2</sub> and the existing technologies currently serving those markets; and supply chains for H<sub>2</sub> and FCs as well as incumbent technologies.

## RESULTS

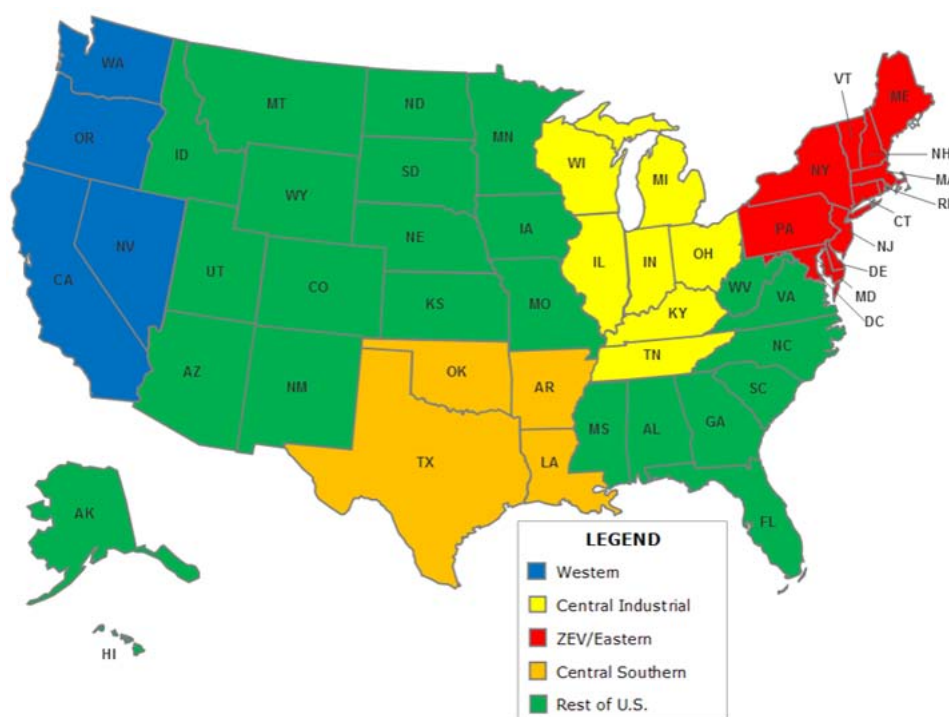
As the second year of a three-year project, FY 2017 efforts focused on data acquisition/enhancement to finalize

scenario parameters and industry cost vectors. These efforts produced initial, preliminary estimates of employment associated with the production and distribution/sale of FC cars and light trucks for a Core Multi-Market Scenario.

### Scenario Development and Data Enhancement

Several FCTO- and Vehicle Technologies Office (VTO)-supported tools and efforts were used to expand the Energy Information Administration's (EIA's) *Annual Energy Outlook* (AEO-2016) reference scenario for vehicle sales and energy prices, tailor it to the five regions shown in Figure 1, and add the anticipated cost and market performance of fuel cell technologies under a successful FCTO program. These tools include Autonomie (which provides estimates of vehicle and component costs over time); MA3T, ParaChoice and Lave-TRANS (which provide estimates of market shares for fuel cell electric vehicles [FCEVs] consistent with FCTO's analysis for the Government Performance and Results Act); and VISION (which translates regional estimates of FC and conventional vehicle sales into estimates of vehicle stocks and fuel use for each of the five regions). Other efforts that informed the scenario development process include findings from the H2USA Locations Roadmap Working Group and FCTO's Fuel Cell System Cost Analyses. Thus, the Core Multi-Market Scenario reflects key assumptions and methodologies not only from AEO-2016, but also from several related FCTO-affiliated tools and efforts.

Under the Core Multi-Market scenario, FC cars and light trucks represent 20% of LDV sales and nearly 10% of LDV stocks nationally in 2050. However, because of greater



**FIGURE 1.** Economic analysis regions

ongoing support in the Western and ZEV/Eastern regions, FC cars and light trucks represent a much larger share (35%) of 2050 sales in those regions. Similarly, FCEVs account for 32% and 28% of LDV stocks, respectively, in Western and ZEV/Eastern regions in 2050.

Estimates and assumptions from the Core Multi-Market Scenario provided the basis for adjusting industrial sectors in the REMI<sup>1</sup> model and for creating new sectors to reflect adaptation within the U.S. economy to changing demand and supply chains. Four additional sectors were constructed (FC stack, FC system, FC car, FC light truck) using data from related industries, the U.S. National Input and Product Accounts and the U.S. Censuses of Manufacturing, Wholesale and Retail Trade, and Construction. Two variants of the core scenario were examined, a case in which FCEV production reflects the current split between domestic and foreign assembly of *all LDVs* sold in the U.S., and a case in which production reflects the current split between domestic and foreign assembly of *plug-in hybrid electric vehicles* sold in the United States.

### Preliminary Results

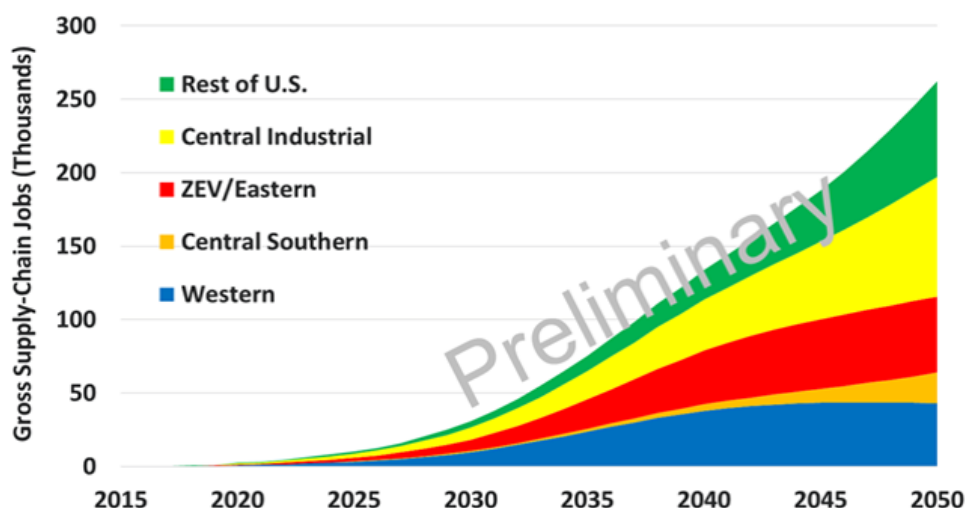
Figure 2 shows total gross employment associated with the Core Multi-Market Scenario. Initially, growth is strongest in the Western region in response to ongoing efforts to achieve clean fuel targets. However, since the Core Multi-

<sup>1</sup> Regional Economic Models, Inc. (REMI) is an econometric model. In this application of the model, 160 standard industries and six custom industries (FC car, FC light truck, FC stack, FC system, H<sub>2</sub> production from fossil sources, and H<sub>2</sub> production from renewable sources) are represented for each of five individual regions, and changes between that representation and a base case are calculated. Since industries are modeled in terms of transactions, outputs may be associated with supply chains and product distribution. When summed across regions, the results are estimates of employment, earnings and occupational impacts for the entire United States.

Market Scenario assumes that states achieve their deployment targets and that regions retain their historic shares of national LDV sales, ZEV/Eastern employment eventually exceeds FC-associated employment in the Western region (because while the two regions come to have comparable FCEV market shares, the ZEV/Eastern region has a larger population and thus higher LDV sales). Employment in other regions rises steadily over the forecast period, and total gross employment reaches approximately 260,000 in 2050.

Manufacturing employment (roughly 100,000 gross jobs in 2050) tends to be concentrated in states where manufacturing supply chains are most dense, generally in the Central Industrial region (Figure 3). The number of manufacturing jobs is very sensitive to domestic versus foreign assembly, with preliminary results varying from approximately 60,000 gross supply-chain jobs if FCEV assembly mirrors current U.S. LDV assembly shares to over 120,000 gross supply-chain jobs if the U.S. share mirrors current assembly patterns. Note that “manufacturing” jobs include not only direct employment in FC stack, system, and FCEV fabrication and assembly, but also “white collar” jobs and support service employment throughout the supply chain.

Unlike manufacturing, jobs associated with FC distribution and sales tend to be located in those regions where FCEV demand is greatest (Figure 4). By 2050 over 160,000 gross jobs in distribution/sales are associated with FC development. Most of these jobs are in retail sales. Note that FC “employment intensity” or jobs per 100,000 LDVs produced or sold declines over time in response to automation and other improvements in supply chain efficiency (Figure 5). Such improvements affect both FCs and conventional powertrain technologies.



**FIGURE 2.** Gross manufacturing, distribution & sales jobs associated with FCEVs (Core Multi-Market Scenario)

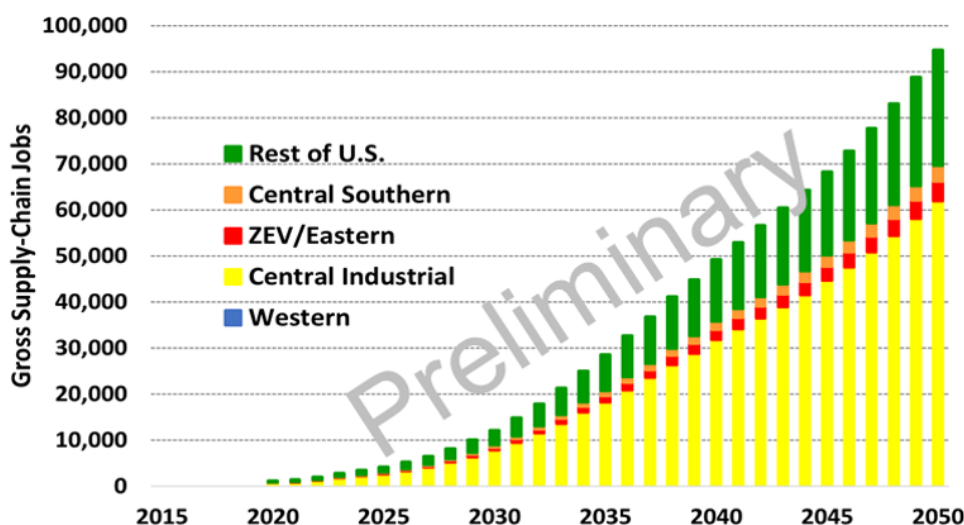


FIGURE 3. Gross manufacturing jobs associated with FCEVs (Core Multi-Market Scenario)

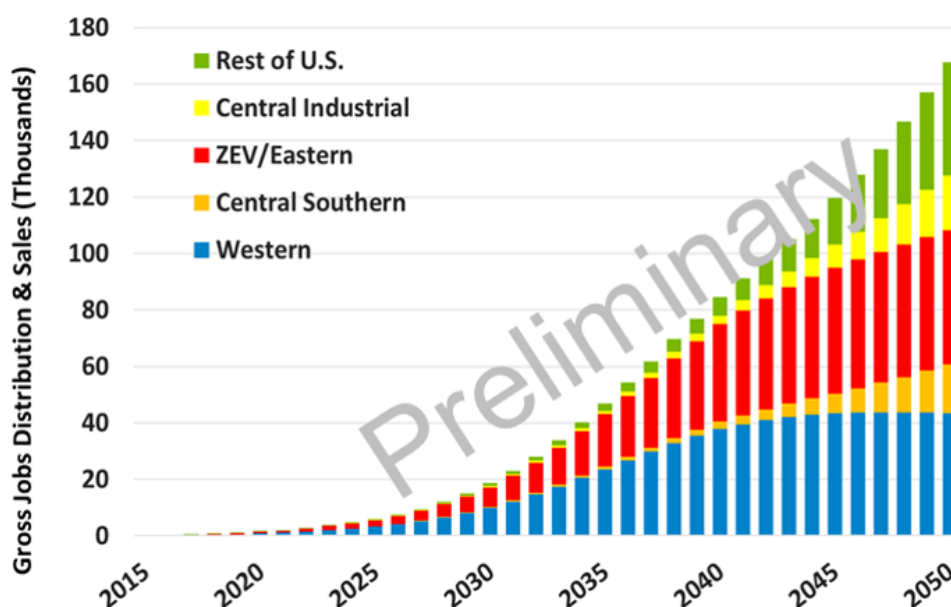


FIGURE 4. Gross distribution/sales jobs associated with FCEVs (Core Multi-Market Scenario)

## CONCLUSIONS AND UPCOMING ACTIVITIES

This project is a multi-year effort to update DOE's 2008 Report to Congress, (*Effects of a Transition to a Hydrogen Economy on Employment in the United States*) in order to reflect current levels of technology advancement and anticipated fuel prices, economic activity, and market success. FY 2017 work focused on finalizing a reference scenario of FCEV deployment in five U.S. regions and generating initial estimates of gross employment under two manufacturing assumptions. Under this scenario (called the

Core Multi-Market Scenario) approximately 100,000 jobs associated with manufacturing, and 160,000 jobs associated with distribution and sale of 3.7 million FCEV cars and light trucks were estimated nationally in 2050. Future work may include expanding the "core" scenario to include heavy-duty trucks and buses, and hydrogen production, distribution and sale to all FCEVs (light- and heavy-duty); and analyzing sensitivities and workforce development needs.



**FIGURE 5.** Gross jobs per 100,000 FCEVs produced or sold (Core Multi-Market Scenario)

## REFERENCES

1. U.S. Department of Energy, 2008. *Effects of a Transition to a Hydrogen Economy on Employment in the United States: Report to Congress*, July.