

## Executive Summary

The bulk of the hydrogen business revolves around hydrogen's use as an industrial chemical, for petroleum refining, in fertilizer production, and in other settings where hydrogen is sold in very large quantities. Within this merchant hydrogen business is a smaller set of market activities where hydrogen is produced, stored and used for non-chemical and non-industrial needs. This subset of the market (the focus of this report) produces, stores and uses hydrogen as a fuel, a gas that stores energy for immediate or later use.

Published reports exist that deeply examine hydrogen's chemical and industrial uses; this report focuses on presenting today's best dataset on

- merchant hydrogen pricing and typical volumes;
- pipelines and distributed hydrogen production;
- renewable energy to hydrogen projects;
- hydrogen light- and heavy-duty vehicles;
- hydrogen material handling vehicles; and
- hydrogen education and jobs.

This report presents consolidated U.S. data for 2008 only and represents a baseline of data for comparison in future years. Many of the resources used to develop this report were secondary, but this report adds new primary research and consolidates the findings in one comprehensive publication.

### **Production, delivery, and pricing**

More than 20 billion kilograms (kg) of hydrogen were produced in the United States in 2008. Of this total, the percentage classified as merchant hydrogen is reported to be either 14 percent or 52 percent, depending upon the source and interpretation of the data available. This difference could not be resolved in this study, although some explanations for the disparity in reporting are included.

The method of delivery for merchant hydrogen varies primarily with the volume required by the user. For the smallest quantities (individual deliveries of 0.5-50 kg), hydrogen is often bought and sold as a compressed gas in cylinders. Larger quantities (50+ kg) are commonly delivered by tube trailers (with gaseous hydrogen that has been compressed after production) and liquid tanker trucks (with cryogenic liquid hydrogen that has been chilled after production). To satisfy extremely large demand, hydrogen can be delivered by pipeline.

The price of delivered hydrogen, under varying settings, is presented in this report with all the variables that affect pricing, particularly hydrogen delivered as merchant hydrogen to users. The variation results from the volume delivered, the distance it has traveled, the

state in which it is delivered (liquid or gas), pressure, purity, method of delivery, additional equipment necessary, regulatory fees and the competitive environment.

### **Distributed production**

A small but growing segment of merchant hydrogen customers are using solutions that avoid the need for delivery. These customers satisfy their need for hydrogen by producing it onsite. The two most common methods utilized for this purpose are electrolysis and reformation. In 2008, 18 new electrolyzers were installed representing 145 kg/day of hydrogen production capacity (a 5 percent growth in electrolyzer production capacity from 2007). By the end of 2008, the total production capacity of installed electrolyzers in the U.S. was 2,300 kg/day, from 215 units (representing 0.030 percent of total U.S. merchant hydrogen production<sup>2</sup>). In 2008, 11 new reformers were installed representing 1,479 kg/day of hydrogen production capacity (and 45 percent growth from the small reformer production capacity installed at the end of 2007). By the end of 2008, the total production capacity of installed reformers in the U.S. was 4,198 kg/day (representing 0.050 percent of total U.S. merchant hydrogen production<sup>3</sup>).

### **Renewable production**

In 2008, 30 projects actively produced hydrogen from renewable resources, more than half of which were located in California. Overall, most projects are small demonstrations (with a production capacity of less than 3 kg/hour) that are designed to verify the commercial readiness of renewable energy hydrogen production or a new production technology.

### **Transportation**

By the end of 2008, there were approximately 210 hydrogen-powered light-duty vehicles on U.S. roads. In 2008, they drove a total of 1.1 million miles, fueled 11,000 times, and consumed 26,000 kilograms of hydrogen. 12 hydrogen-powered buses were operational in 2008, representing the entire heavy-duty hydrogen vehicle fleet. In 2008, these buses traveled 176,000 miles, fueled 1,670 times, consumed 29,000 kg of hydrogen fuel, and transported 366,000 passengers.

The National Hydrogen Association keeps an online database of fueling stations in North America. As of October 2009, 67 public and private hydrogen fueling stations were in operation in the U.S.; six of these hydrogen fueling stations entered operation in 2008.

### **Material handling and stationary power**

By the end of 2008, there were 200 hydrogen fuel cell-powered forklifts operating in the U.S. These forklifts consumed at least 20,000 kg of hydrogen and were in operation at 16 sites in nine states.

For stationary appliances, at least 13,000 kilowatt (kW) of PEM fuel cells were operational in the U.S. in 2008. Of these, at least 10,000 kW were installed to provide backup power, whereas only a handful of sites (totaling 300 kW) used PEM fuel cells to

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<sup>2</sup> Assuming the merchant hydrogen market is 14% of total U.S. hydrogen production.

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provide primary power. Auxiliary power appliances are more numerous, providing 2,761 kW.

### **Education and careers**

More than 130 institutions of higher education offer courses in fuel cell or hydrogen technology, in 40 states and the District of Columbia. California and New York lead the other states, with 16 and 14 institutions, respectively. The number of degree programs has steadily increased from 2006 to 2009, and in 2009, nine institutions offered hydrogen or fuel cell technology degrees. In this same three-year period, the number of students enrolled in specialized hydrogen and fuel cell degree programs increased by 82 percent annually.

Through the data collection and analysis performed for this report, U.S. hydrogen-related employment figures, related to the sectors covered in this report, total nearly 7,000 U.S. full-time equivalent (FTE) employees. The number does not represent the entire number of people employed in the U.S. hydrogen industry in 2008 (e.g. employees engaged in captive hydrogen production—the other 48-86 percent of U.S. hydrogen production).

This first annual report focuses on the lesser reported areas of the hydrogen industry to provide a baseline against which, future years' data can be compared to reveal trends in the energy-related production and use of hydrogen. While the hydrogen energy business is small compared to the existing industrial hydrogen business in refining, fertilizer production and many other chemical processes, it is growing. Moreover, the data collected for this report suggest certain sectors of the hydrogen economy will see significant growth in the next one to two-year timeframe.