

II.D.4 Hour-by-Hour Cost Modeling of Optimized Central Wind-Based Water Electrolysis Production

Genevieve Saur (Primary Contact),
Chris Ainscough.

National Renewable Energy Laboratory (NREL)
15013 Denver West Parkway
Golden, CO 80401-3305
Phone: (303) 275-3783
Email: genevieve.saur@nrel.gov

DOE Manager

HQ: Erika Sutherland
Phone: (202) 586-3152
Email: Erika.Sutherland@ee.doe.gov

Project Start Date: October 1, 2010
Project End Date: Project continuation and direction
determined annually by DOE

can approach the DOE 2015 centralized cost per gasoline gallon equivalent (\$/gge) target of \$3.10/gge only when taking advantage of wind energy incentives such as the production tax credit, investment tax credit, and Treasury grant [1]. See Table 1 for more details. Using 2010 wind electricity prices, a Class 6 wind resource could produce hydrogen at \$3.60/gge (all hydrogen costs in 2007 dollars, exclusive of compression, storage, and dispensing costs), without the wind incentives. With the incentives, the cost of hydrogen drops to approximately \$2.60/gge.

TABLE 1. Progress toward Meeting Technical Targets for Distributed Water Electrolysis Production

Characteristics	Units	2015 Target	2020 Target	Status
Hydrogen cost	\$/gge	3.10	<2.00	2.76–4.79 (with wind incentives)

Fiscal Year (FY) 2012 Objectives

- Corroborate recent wind electrolysis cost studies using a more detailed hour-by-hour analysis.
- Examine consequences of different system configuration and operation for four scenarios, at 42 sites in five electricity markets across the contiguous United States.
- Initiate understanding of sizing implications between electrolyzers and wind farms.
- Identify areas for further analysis and cost reduction.
- Determine the sensitivity of the cost of hydrogen to various inputs, such as turbine cost, electrolyzer efficiency, electrolyzer capital cost, capacity factors, and availability.

Technical Barriers

This project addresses the following technical barriers from the Production section (3.1) of the Fuel Cell Technologies Program’s Multi-Year Research, Development and Demonstration Plan:

- (G) Capital Cost
- (H) System Efficiency
- (J) Renewable Electricity Generation Integration

Technical Targets

This analysis shows that using current prices for electricity from Class 3–6 wind resources, the hydrogen cost

FY 2012 Accomplishments

- Completed hourly analysis of a central wind electrolysis production facility (50,000 kg/day), at 42 sites in five electricity markets across the contiguous 48 states.
- Determined that Class 3–6 wind sites can produce renewable hydrogen for \$2.76–\$4.79/gge.
- Published a technical paper: G. Saur, and C. Ainscough, *U.S. Geographic Analysis of the Cost of Hydrogen from Electrolysis*. NREL/TP-5600-52640. Golden, CO: NREL; December 2011.
- Developed an interactive website allowing exploration of results and self-guided what if analysis: http://www.nrel.gov/hydrogen/production_cost_analysis.html.



Introduction

This work is aimed at understanding the barriers and costs associated with large-scale (50,000 kg/day) wind-based hydrogen generation plants. Such plants can take electrical energy from the wind or from the grid and use it to split water molecules into hydrogen and oxygen. The hydrogen can then be used for a variety of purposes, including vehicle fuel, fertilizer feedstocks, petroleum upgrading, metal processing, and other industrial processes. The hydrogen can also be stored, converted back to electricity, and sold to an electric utility.

Approach

The approach used in this analysis was to review a range of wind sites from Class 1 to 6 for their ability to produce hydrogen economically by electrolysis. Forty-two sites were chosen across the contiguous 48 states including five different electricity markets. Further, each site was analyzed under four different scenarios, defined as follows:

- Cost balanced: \$ grid purchased electricity = \$ wind electricity sold.
- Power balanced: kilowatt-hour (kWh) grid purchased electricity = kWh wind electricity sold.
- Same as A, but no purchase of summer peak electricity.
- Same as B, but no purchase of summer peak electricity.

In addition to these scenarios, sensitivities to various inputs were analyzed, including wind turbine capital cost, wind electricity costs, electrolyzer efficiency, electrolyzer capital cost, capacity factor, and availability.

Results

This analysis found that in power-balanced scenarios, the cost of hydrogen can range from nearly \$5.84/gge down to \$3.92/gge, depending on the class of the wind site. It is only at wind sites of Class 4 or better that such a plant begins to approach DOE technical targets for hydrogen cost production. This analysis included electricity prices in the California, New England, Texas, Midwest, and Pennsylvania, New Jersey, Maryland markets. See Figure 1 for more detail on how hydrogen cost varies by wind class.

In places with low-cost electricity, <\$0.08/kWh, hydrogen can be produced for approximately \$3.82–\$4.77/gge. This is true of both power and cost-balanced scenarios. Scenarios purchasing no summer peak electricity resulted in lower

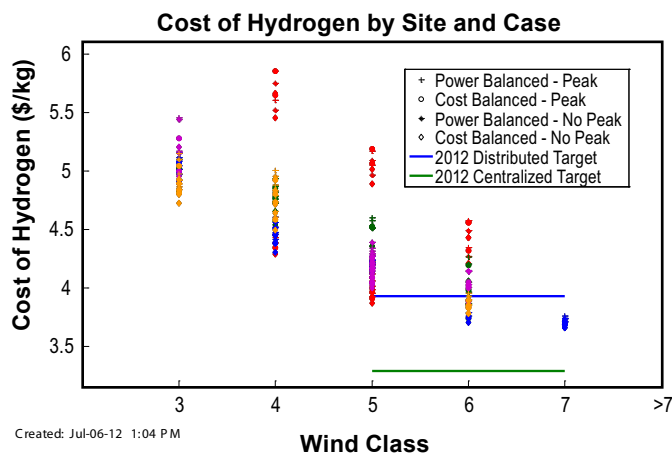


FIGURE 1. The cost of wind-based hydrogen varies greatly by wind resource class. Class 5 and better are required to approach DOE cost targets.

hydrogen costs but could also result in unmet hydrogen demand. See Figure 2 for more detail on how hydrogen cost varies by wind electricity cost.

The required installed wind capacity needed to produce 50,000 kg of hydrogen per day varies greatly with the wind class, which also affects the cost of wind electricity. The installed capacity can be as low as 200 megawatt (MW) (Class 6), and as much as 850 MW (Class 1). See Figure 3 for more detail on how hydrogen cost varies by wind farm size.

Sensitivity analysis was run to see what effect electrolyzer efficiency, availability, capital cost, wind capital cost, and wind availability have on the cost of hydrogen. This analysis showed that the largest hurdles to hydrogen cost from water electrolysis remain wind turbine capital cost and electrolyzer efficiency.

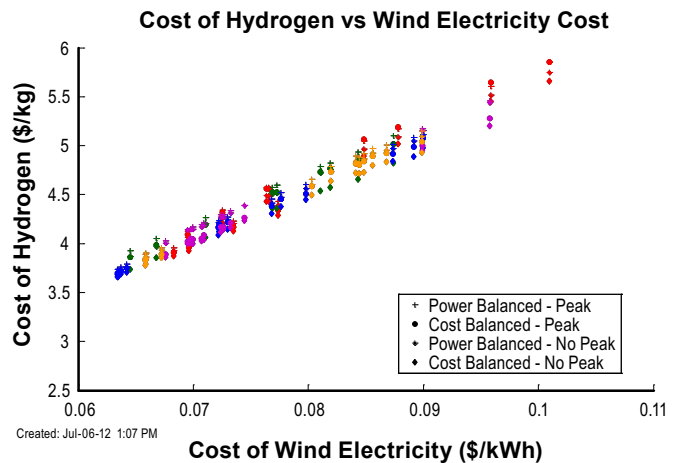


FIGURE 2. The overall cost of wind electricity has a strong influence on the cost of wind-based hydrogen, regardless of the analysis scenario.

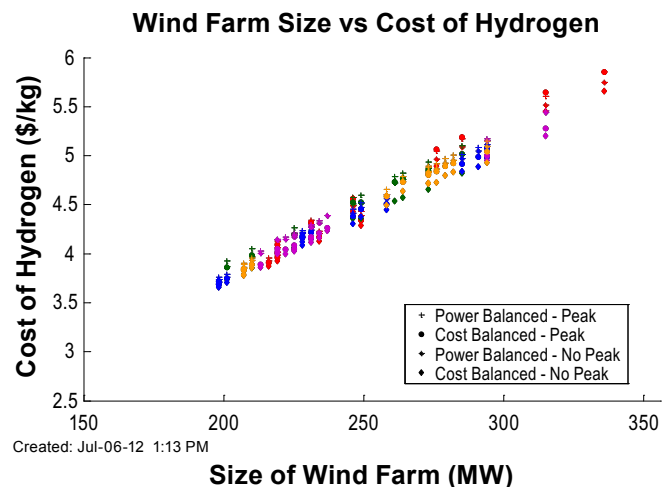


FIGURE 3. The installed capacity of a wind farm needed to produce 50,000 kg/day of hydrogen varies with the wind class. Lower quality winds require greater installed capacity, and thus result in more costly hydrogen.

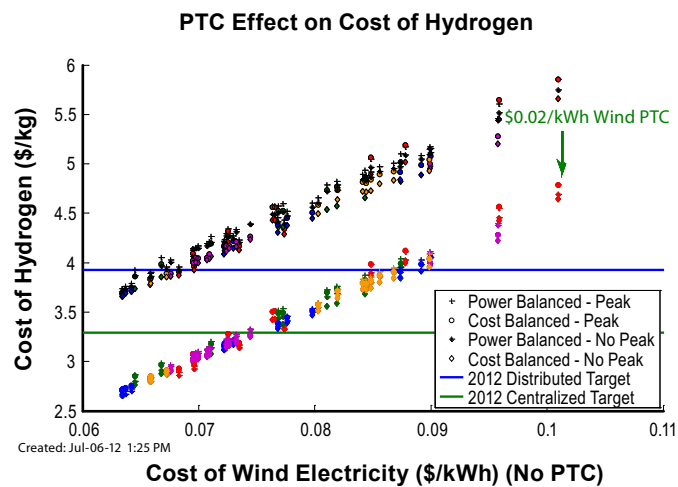


FIGURE 4. The effect of wind power incentives such as the production tax credit (PTC), investment tax credit, and Treasury grant can reduce the cost of wind-based hydrogen by approximately \$1/kg.

In summary, the presence of wind power incentives has a significant impact on the cost of hydrogen produced by central wind electrolysis of approximately \$1/kg as shown in Figure 4. With these incentives, wind sites with good resource quality may meet DOE cost targets.

Conclusions and Future Direction

No future work is currently funded. However if funding were available, the following additions to this analysis would be pursued.

- Add more sites on land
- Add additional electricity markets
- Add offshore wind sites
- Examine solar integration
- Add emphasis on smaller or forecourt-sized renewable electrolysis targeted to the vehicle end use market, with 700 bar storage
- Explore other optimal electricity/hydrogen production balance scenarios
- Explore other electrolyzer types in close collaboration with manufacturers

FY 2012 Publications/Presentations

1. *Hour-by-Hour Cost Modeling of Optimized Central Wind-Based Water Electrolysis Production*, presented at DOE Annual Merit Review, May 14-18, 2012, Washington, D.C.
2. Saur, G. and C. Ainscough, *U.S. Geographic Analysis of the Cost of Hydrogen from Electrolysis*. NREL/TP-5600-52640. Golden, CO: NREL; December 2011.

References

1. Saur, G. and C. Ainscough, *U.S. Geographic Analysis of the Cost of Hydrogen from Electrolysis*. NREL/TP-5600-52640. Golden, CO: NREL; December 2011.