A national laboratory of the U.S. Department of Energy
Office of Energy Efficiency & Renewable Energy

NREL National Renewable Energy Laboratory

Innovation for Our Energy Future

Modeling the Market Potential of Hydrogen from Wind and Competing Sources

BACKGROUND/OVERVIEW

The Hydrogen Deployment Systems (HyDS) model estimates the U.S. market expansion of hydrogen production from wind and other sources over the next 50 years. HyDS builds from and expands on the Wind Deployment Systems (WinDS) model by including the production of hydrogen from three competing technologies — wind, steam methane reforming (SMR), and distributed electrolysis powered by electricity from the grid — along with storage and transportation of hydrogen.

MODELING HYDROGEN PRODUCTION

HyDS incorporates all the wind details of the WinDS model, but expands the focus to include hydrogen production and transportation. As shown in **Figure 1**, HyDS includes not only the production of hydrogen from wind electrolysis, but also the transport of that hydrogen to load centers—and competition at those load centers with hydrogen from distributed electrolysis and steam methane reforming. The model also provides for fuel cells at the wind sites and at distributed electrolyzers to firm up the wind power and to provide general energy storage for the electric grid.

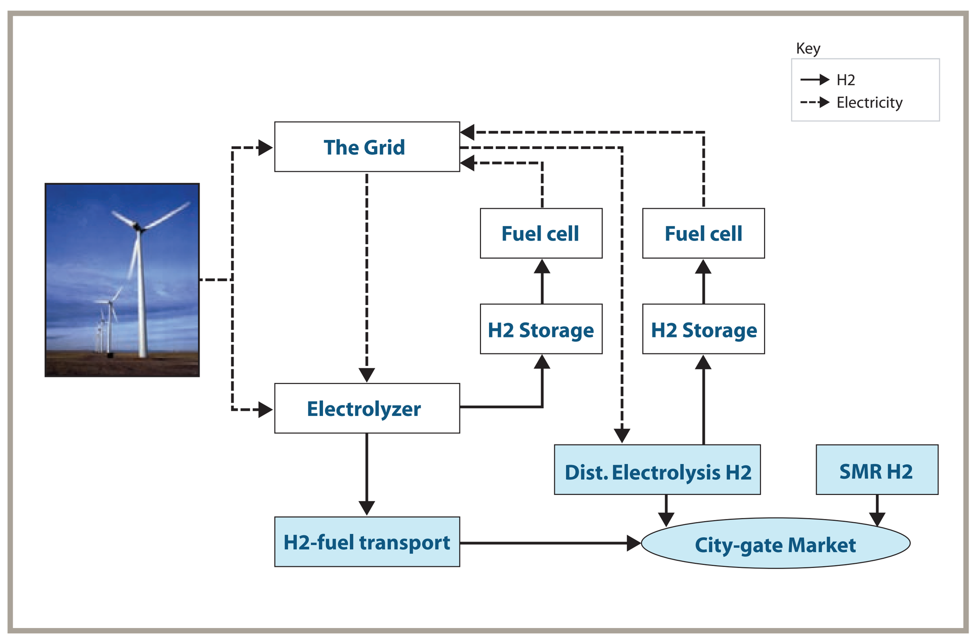

Figure 1. Hydrogen and Electricity Production and Transport from Wind

Similar to WinDS, HyDS addresses the critical issues of hydrogen transport by using a much higher level of geographic disaggregation than other models. As **Figure 2** represents, HyDS includes 358 different regions in the United States. Much of the data inputs to HyDS are tied to these regions and derived from a detailed GIS model/database of fuel demands, the wind resource, transmission grid, and existing plant data.

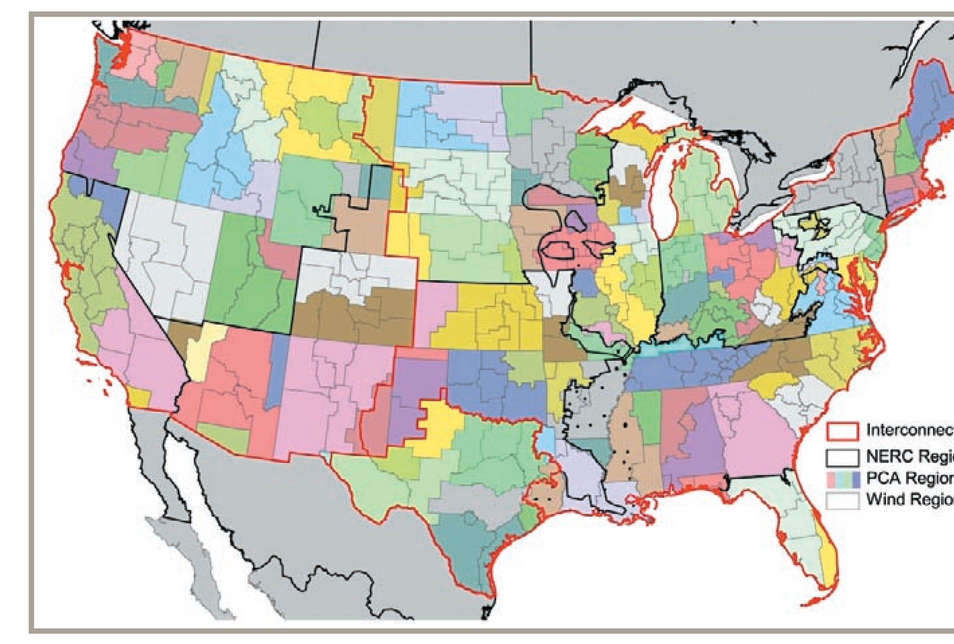

Figure 2. Regions within HyDS

BASE CASE RESULTS

In this analysis, the Base Case is a business-as-usual case that relies heavily on the Reference Case scenario of the U.S. Energy Information Agency (EIA) Annual Energy Outlook for 2004 to determine inputs that fall outside the scope of HyDS. These include electricity demand, fossil fuel prices, existing federal energy policies, and the cost and performance of non-wind electric-generating technologies. Using base case inputs, HyDS projects that wind will provide about 210 GW of electricity capacity to the grid in 2050, far larger than today's 6 GW (see top slice of graph in **Figure 3**).

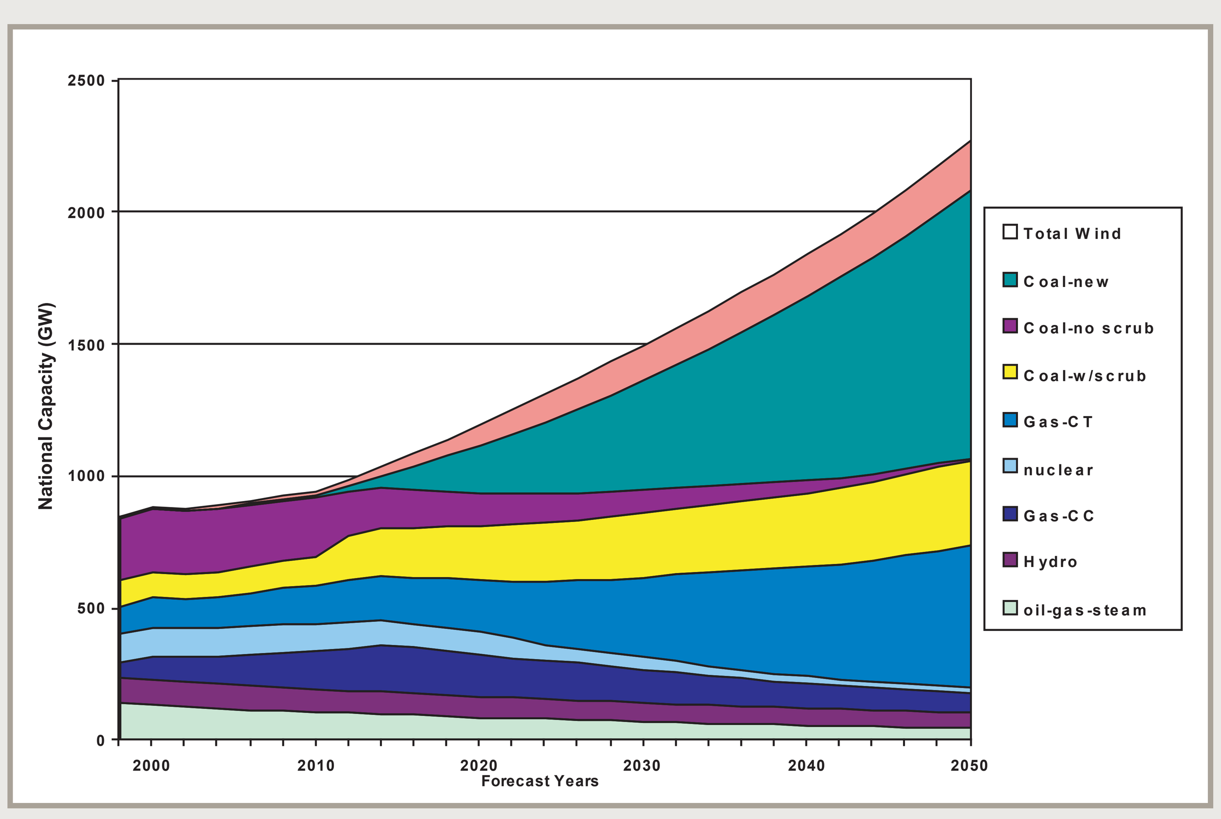

Figure 3. National Capacity Projections for the HyDS Base Case

Additional wind capacity is constructed in this base case to generate a limited amount of hydrogen at the wind sites. As the map in **Figure 4** shows, hydrogen production in 2050 from this base case is greatest where there is a reasonable wind resource near a significant population center. For example, southeastern California near the Los Angeles region, western Iowa near Chicago, and southwestern New York state near New York City all have areas with annual hydrogen production greater than 195 kilotons in 2050. Additionally, wind hydrogen production is seen in areas with significant wind resources such as the north-central United States and the Midwest.

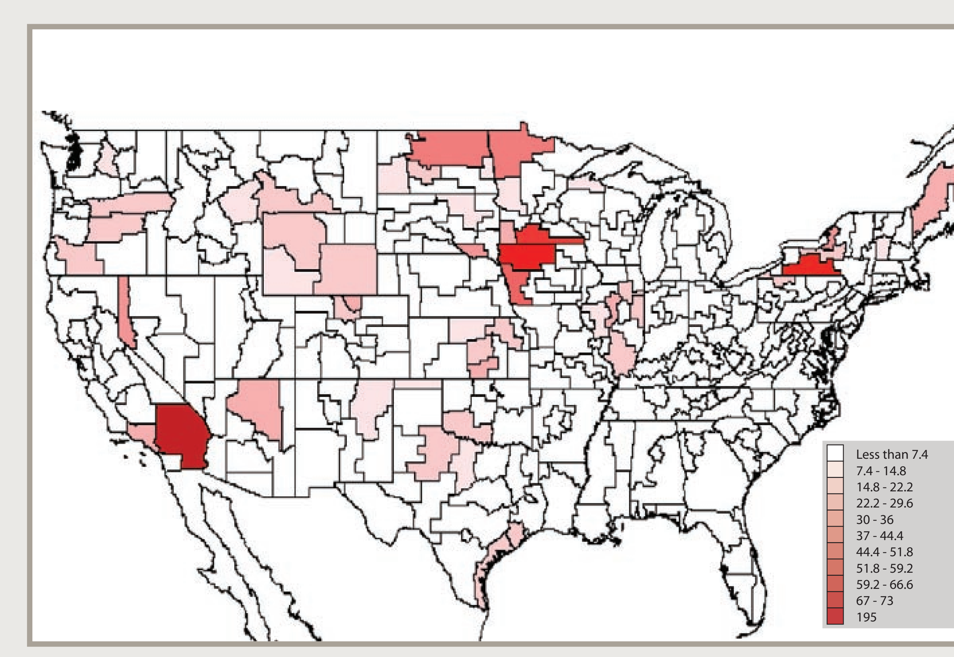

Figure 4. Annual H2 Production from Wind in 2050 (kilo tons)

From the Base Case, we can also examine the viability of various hydrogen production pathways. For example, **Figure 5** shows that, by 2050, approximately 28 GWe of distributed electrolyzers are deployed to produce hydrogen. To help meet the additional electricity demand of these distributed electrolyzers, approximately 25 GWe of additional wind energy are deployed by 2050, as shown in Figure 5. Much of the electricity from these new wind turbines is transported to the distributed electrolyzers, as the transport of electricity across regions is generally moreeconomical than the transport of hydrogen.

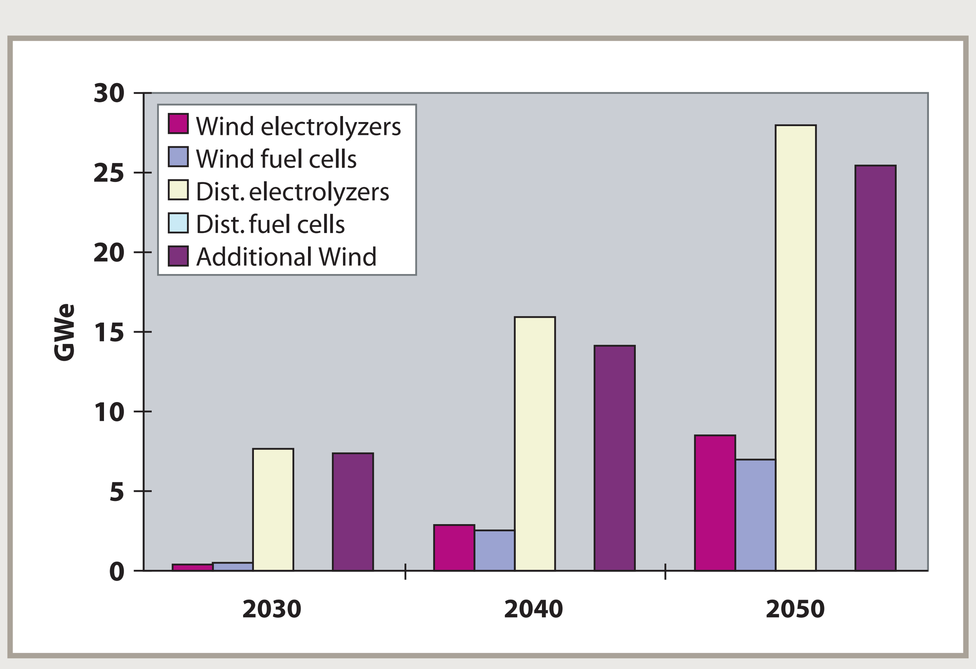

Figure 5. Base Case Hydrogen Technology Capacity

While the distributed electrolyzers provide more hydrogen, hydrogen is also produced at wind sites for use as a transportation fuel and to shore up wind power in 2030 and beyond. Also shown in Figure 5, colocated wind turbine/electrolyzer systems are deployed with approximately 9 GWe of capacity in 2050. In addition, fuel cells are deployed at wind sites with approximately 8 GWe of capacity by 2050.

Figure 6 shows the amount of hydrogen produced by each technology, and reveals that a majority of the electricity fed to the wind-sited electrolyzers is drawn from the grid when the wind is not blowing. This grid power allows the amortization of the wind-sited electrolyzer costs over a substantially larger output. Figure 6 also shows that, in 2050, the bulk (1.3 Bkg) of the hydrogen produced by the wind-sited electrolyzers (1.4 Bkg) is used as a transportation fuel, with the remainder (0.1 Bkg) stored on-site for generation of power through a fuel cell at times of peak electric load.

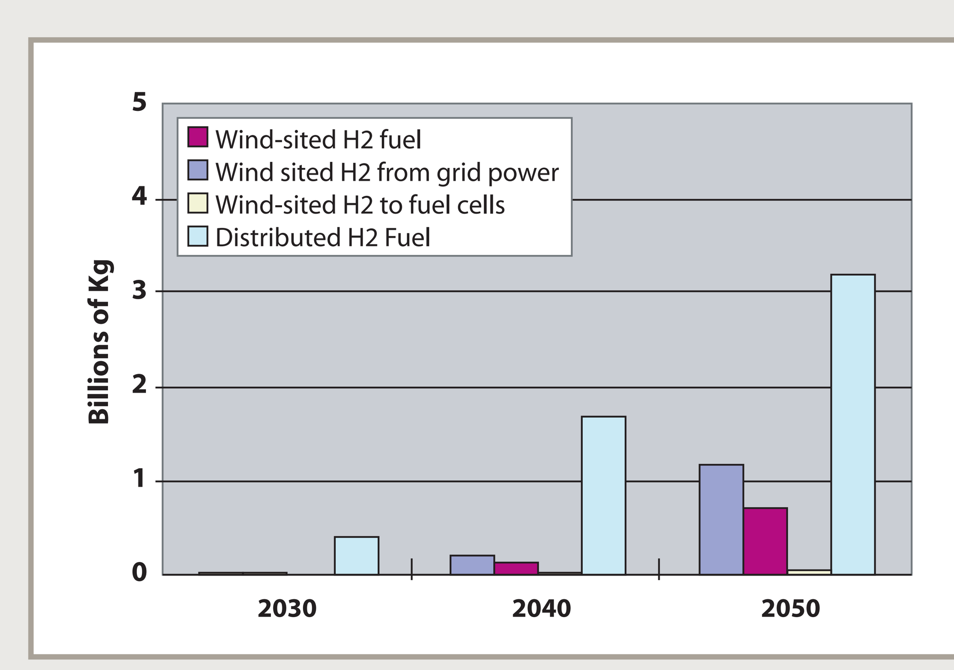

Figure 6. Base Case Hydrogen Fuel Production

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