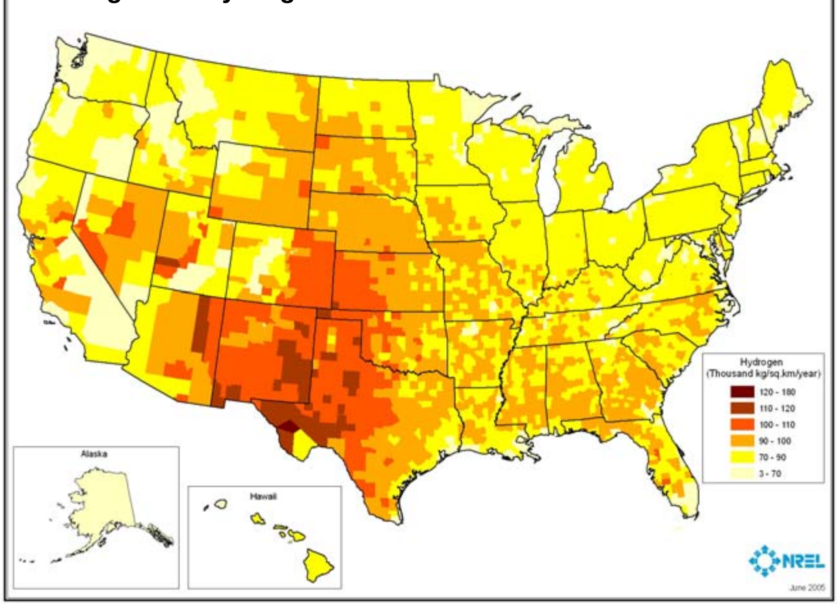
DOE Hydrogen Program Record	
Record #: 5011	**Date:** December 15, 2005
Title: **Hydrogen Potential from Solar and Wind Resources**	

Items:

- Data/resource maps indicate that the potential exists to use wind and solar resources to produce more than 15 times the amount of hydrogen needed to displace the petroleum used by light duty vehicles in 2040.
- About one billion metric tons of hydrogen could be produced by renewable electrolysis annually, based upon solar and wind resource potential.
- The other three solar pathways — thermochemical, photoelectrochemical, and photobiological — would have similar or possibly higher productivity per unit of land area.

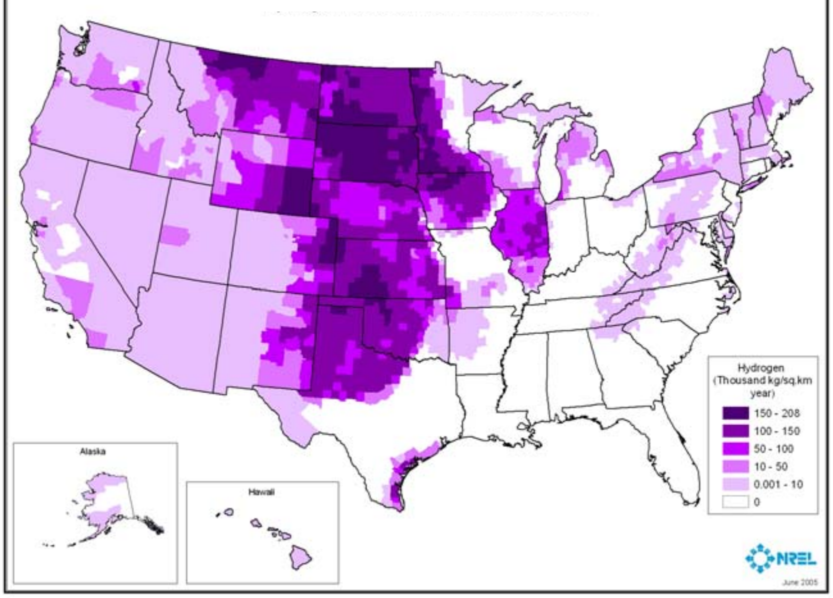
Data:

Figure 1: Hydrogen Potential from Solar Resources



Note: Map shows total kilograms of hydrogen per county, normalized by county area. Some environmental and land-use exclusions were applied in developing this map. Source: National Renewable Energy Laboratory.

Figure 2: Hydrogen Potential from Wind Resources



Note: Map shows total kilograms of hydrogen per county, normalized by county area. Some environmental and land-use exclusions (e.g., wetlands, forests, national parks, and urban areas) were applied. Source: National Renewable Energy Laboratory.

References/Calculations:

- "About one billion metric tons of hydrogen could be produced by renewable electrolysis annually, based upon solar and wind resource potential."

  Reference: Levene, J., et al., *"An Analysis of Hydrogen Production from Renewable Electricity Sources."* ISES 2005 Solar World Congress: Proceedings of the 2005 Solar World Congress, International Solar Energy Society, 2005. In section 2.3 the report states, "The potential for hydrogen production from solar and wind for the entire country is 1,110 billion kilograms of hydrogen." The value in the text above comes from the following calculation:

  1,100 billion kilograms x (1000 metric tons/1 kg) = 1.1 billion metric tons

- "Data from the resource maps indicate that the potential exists to use wind and solar resources to produce more than 15 times the amount of hydrogen needed to displace the petroleum used by light duty vehicles in 2040."

  Calculation: Using one billion metric tons from above and dividing by roughly 64 million metric tons required annually to displace the petroleum used by the 300 million light duty vehicles projected to exist in 2040 (see Record 5008), the calculation is:

1 billion metric tons (1000 million / 1 billion) / 64 million metric tons = 15.6

Assumptions/Methodology:

The references for both maps are the Renewable Energy Atlas of the West, The Hewlett Foundation and The Energy Foundation, http://www.energyatlas.org. For the wind capacity factors, the reference is the Power Technologies 2003 Databook, http://www.nrel.gov/wind/uppermidwestanalysis.html.

Solar:

Data Information: This analysis uses solar resources available for non-tracking flat plate collectors oriented at latitude tilt. Estimates of annual average daily total global radiation falling on a fixed, flat-plate collector oriented at latitude tilt are modeled using inputs derived from satellite and surface cloud cover observations as well as other key meteorological variables. The cloud cover observations are on a 40-km resolution grid representing the period 1985 – 1991. Values range from about 3,500 Watts/m^2/day in the Pacific Northwest and portions of Alaska to about 7,000 Watts/m^2/day in portions of the Southwest.

Exclusions:

- Environmental and land use exclusions: 100% excluded are all National Park Service areas; Fish and Wildlife Service lands; all federal lands with a specific designation (parks, wilderness, wilderness and study areas, wildlife refuge, wildlife area, recreational area, battlefield, monument, conservation areas, recreational areas, and wild and scenic rivers), conservation areas, water, wetlands, and airports/airfields.
- 100% exclusions of a 3km area surrounding environmental and land use exclusions, except water exclusion

Analysis Methodology: We assumed that any given 40km by 40km cell will have no more than 10% of it's land area dedicated to PV development, 30% of this area will actually be covered with solar panels, and solar energy can be converted to electricity at an average system efficiency of 10%. Using this assumption the solar data was processed, an average formula of 58.8kWh/kgH_2 (see Reference 1) was applied, and the total kilograms of hydrogen per county per year were calculated.

Wind:

Data Information: This analysis uses a combination of updated wind resource data where available (California, Connecticut, Delaware, Idaho, Illinois, Maine, Maryland, Massachusetts, Montana, New Hampshire, New Jersey, New Mexico, North Carolina, North Dakota, Oregon, Pennsylvania, Rhode Island, South Dakota, Vermont, Virginia, Washington, West Virginia and Wyoming) and the low resolution 1987 U.S. wind resource data. The grid cell resolution of these data varies from 200m – 1km for the high-resolution data to 25km for the low resolution 1987 wind data.

Exclusions:

- Completely exclude areas with slope greater than 20% for the high-resolution data. These areas are considered too steep for siting wind turbines.
- Environmental and land use exclusions: Environmental exclusion areas were defined as federal and state lands where wind energy development would be prohibited or severely restricted. The land exclusions were estimated to account for transportation right-of-ways, locally administered parkland, privately administered areas, and proposed environmental lands. To be consistent with the moderate environmental exclusions documented in the 1991 windy lands assessment, the following classes of land were excluded:
    - 100% excluded are all National Park Service areas; Fish and Wildlife Service lands; all federal lands with a special designation (parks, wilderness, wilderness and study areas, wildlife refuge, wildlife area, recreational area, battlefield, monument, conservation areas, recreational areas, and wild and scenic rivers), conservation areas, water, wetlands, urban areas and airports/airfields.
    - 50% exclusions were applied to the remaining Forest Service, Department of Defense lands, and non-ridge crest forest.
- Entirely excluded is the 3km area surrounding 100% environmental and land use exclusions, except water exclusion.

Analysis Methodology: The high and low resolution datasets were treated differently. Minimum density criteria of 5 km^2 per 100 km^2 of class 3 or better wind resource was applied to the high-resolution data. The low-resolution data has an exposure factor, which indicates the percent of each grid cell that is well exposed to the stated wind power class. The exposed values are 5% (ridge crest), 35% (hilly terrain), 65% (rolling terrain) and 90% (flat). The low and high resolution data were merged together to create the final wind resource file used to summarize the data by county. Then installed nameplate capacity was calculated, using 5 MW/km^2 conversion (see Reference 2), and applied to the class 3 or better lands:

Class	Year	Capacity Factor
3	2000	0.2
4	2000	0.251
5	2000	0.3225
6	2000	0.394
7	2000	0.394

An average relationship formula of 58.8kWh/kgH_2 was applied to the final wind dataset, and the total kilograms of hydrogen per county per year were calculated.

References:

1. J. Ivy, "Summary of Electrolytic Hydrogen Production", report # NREL/MP-560-36734 (Sept 2004). See Appendices A&B.

2. Levene, J., et al., "An Analysis of Hydrogen Production from Renewable Electricity Sources." ISES 2005 Solar World Congress: Proceedings of the 2005 Solar World Congress, International Solar Energy Society, 2005.

Originator: Roxanne Garland		
Approved by: JoAnn Milliken	**Date:** January 3, 2006	
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