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Hour-by-Hour Cost Modeling of Optimized Central Wind-Based Water Electrolysis Production




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This presentation does not contain any proprietary, confidential, or otherwise restricted information

Acknowledgements

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  http://www.eere.energy.gov/topics/hydrogen_fuel_cells.html
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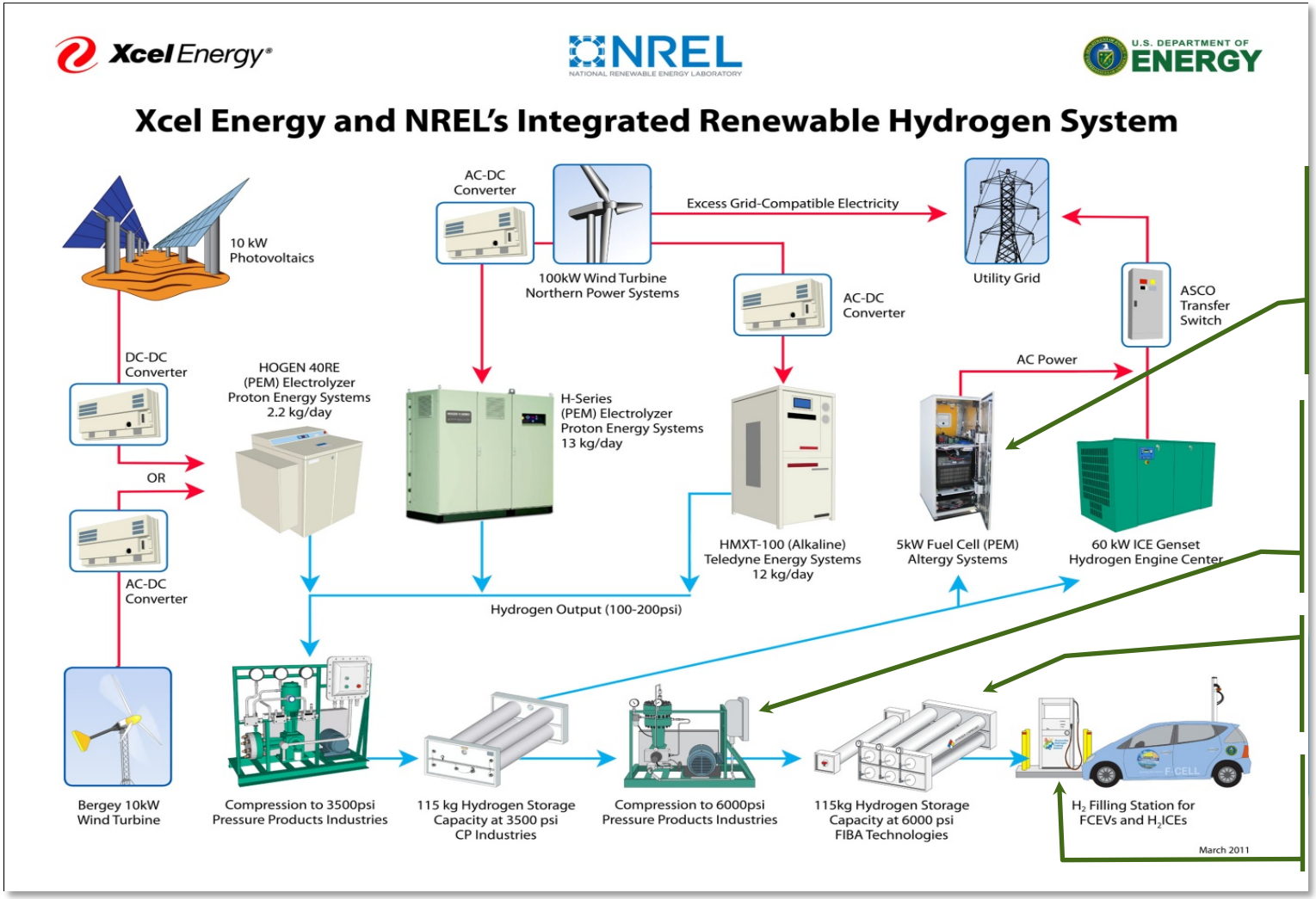
Brief History of the Wind2H2 Project

- In 2006 NREL and DOE, in partnership with Xcel Energy, launched the wind-to-hydrogen (Wind2H2) demonstration project at the National Wind Technology Center in Boulder, Colorado.
- The overall aim of the project is to reduce the cost of producing domestic, sourced hydrogen.
- The project has an experimental activity and an analysis activity. The latter is the topic of this webinar.

Brief History of the Wind2H2 Project

The project takes an integrated approach to a renewable hydrogen system and has evolved to meet changing industry, NREL, and DOE needs.



5-kW fuel cell gives another option for putting stored energy back on the grid

High pressure compressors being tested for reliability; also give 350-bar filling

350-bar cascade doubles storage capacity

Filling station allows car and bus fueling

Why do this analysis?

Hour-by-Hour Cost Modeling of Optimized Central Wind-Based Water Electrolysis Production

- **Cost**
  - **Problem:** Wind electrolysis production cost estimates are limited geographically.
  - **Solution:** Analyze a variety of wind class sites across the country to show a full range of hydrogen costs based on wind.
- **System efficiency**
  - **Problem:** System efficiency remains a barrier to further cost reductions.
  - **Solution:** Sensitivities examine what components and factors have biggest effect on system performance and efficiency.
- **Renewable integration**
  - **Problem:** Optimal sizing relationships between wind capital and electrolyzer capital are not well understood.
  - **Solution:** Components sized based upon hydrogen demand, wind farm size needed for hydrogen demand, and different operation scenarios

Wind2H2 Analysis Objectives

- Expand previous analysis beyond California to a variety of wind resources and electricity markets in the U.S.
- Examine consequences of different system configurations and operation scenarios
- Initiate understanding of sizing implications between electrolyzers and wind farms throughout the country
- Identify areas for further analysis and cost reduction

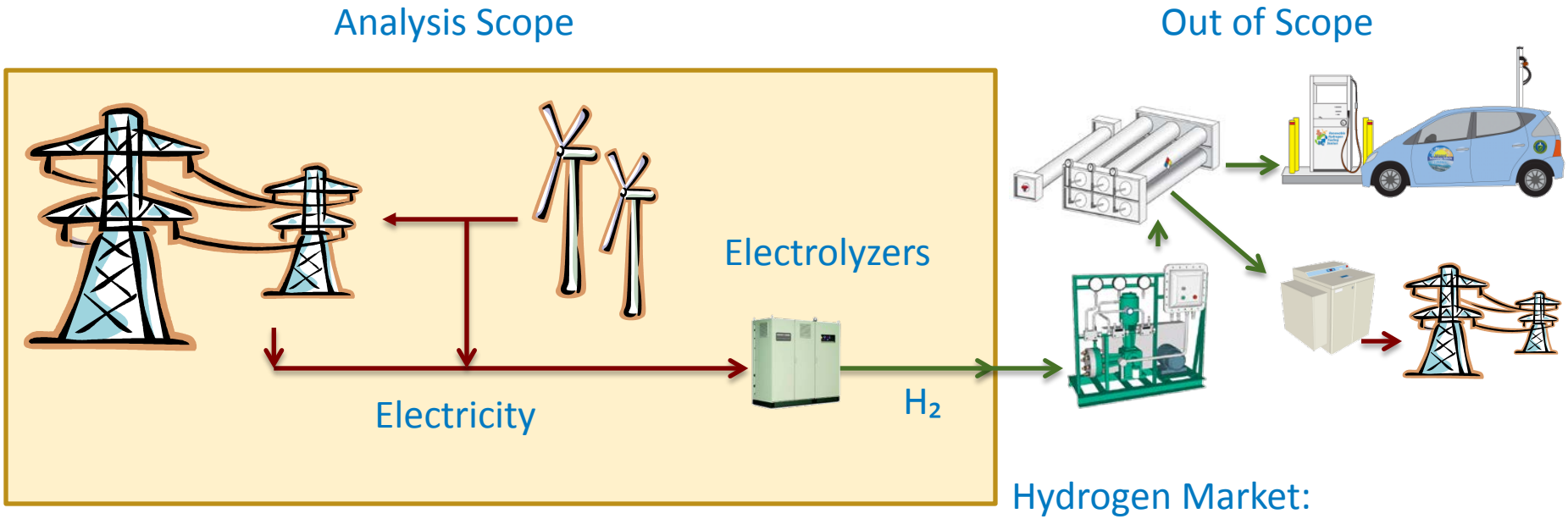
Analysis Scope at a Glance

- **Expanded analysis to include 42 sites in 11 states, spanning five electricity markets**
  - Wind classes ranged from 3 to 6
  - System size ranged from 1,000 to 50,000 kg/day
  - Updated financial year to 2007 to harmonize with DOE targets

Model Parameter	Range in 2011	Range in 2012
Regional grid pricing structures and location(area)	CA	CA ISO, Midwest ISO, ISO New England, ERCOT (TX), Pennsylvania, New Jersey, Maryland (PJM) ISO
Sites (number)	8	42
Size (kg/Day)	50,000	1,000 to 50,000
Wind Capital Costs	$2086/kW Installed	$2067/kW Installed

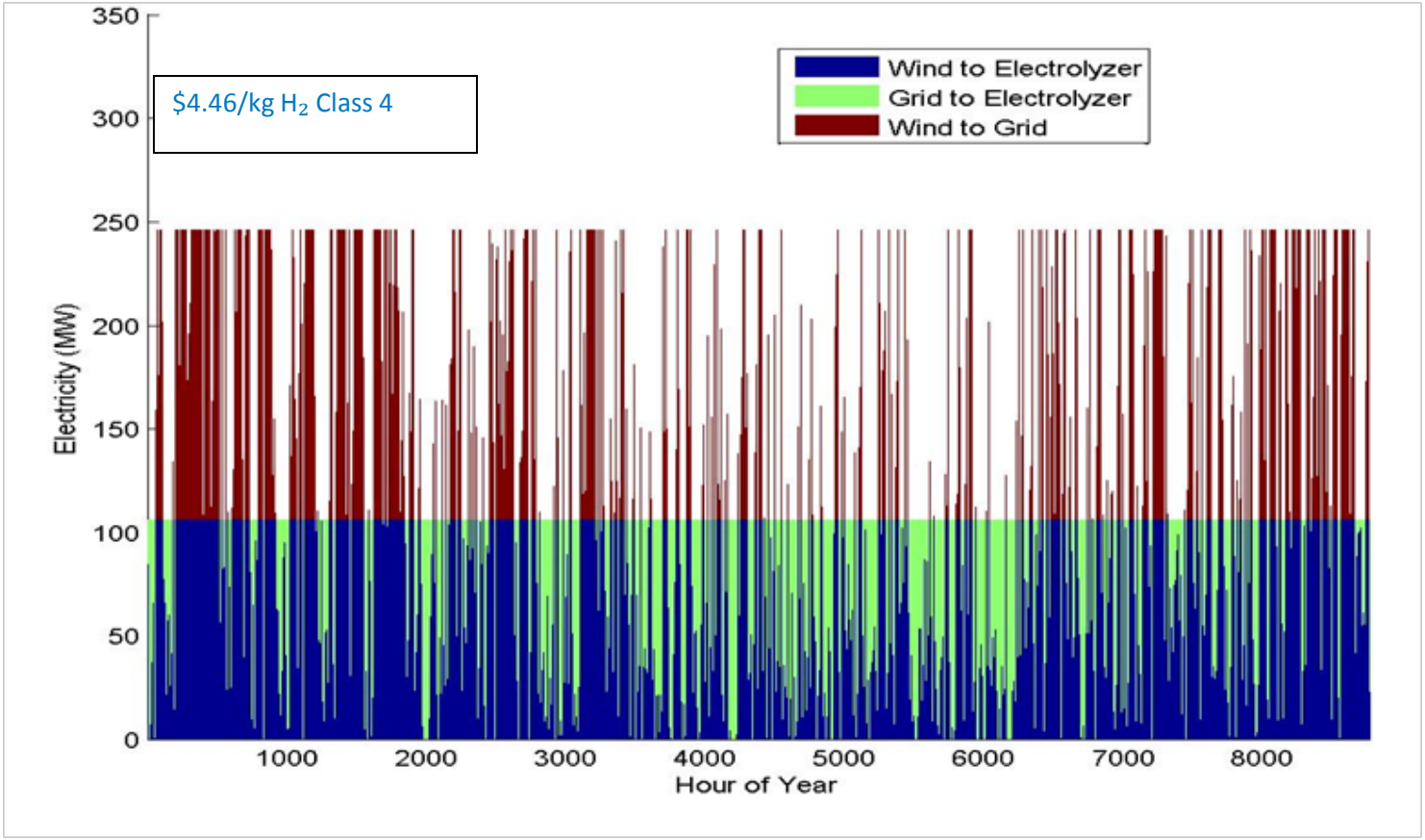
Analysis scope

- **The scope of the analysis is limited to a centralized production plant. Other analysis efforts are looking at factors such as large scale storage, pipeline transport, compression and dispensing economics.**



Key Parameters – System

- **8,760 hourly analyses based upon NREL's H2A Production and Fuel Cell Power models**
  - Using hourly electricity market pricing and hourly wind data



Key Parameters – System

- **Hydrogen production facility**
  - 50,000 kg H2/day nominal
- **4 grid-connected wind electrolysis scenarios**

Scenarios	
A) Cost balanced: $ grid purchased = $ wind sold	
B) Power balanced: kWh grid purchased = kWh wind sold	★
C) Same as A) but no summer peak grid electricity purchased	
D) Same as B) but no summer peak grid electricity purchased	★

"Net Green" Hydrogen

Key Parameters – Components

Electrolyzers

- Design capacity of ~51,000 kg/day with 98% capacity factor
- 106 MW electricity requirement (50 kWh/kg)
- $53.2M total depreciable capital cost
- Replacement, O&M costs also included

Wind Farm

- Multiples of 3 MW turbines
- Design performance based on class 4 wind site
- Wind costs updated to reflect latest available costs (2010)

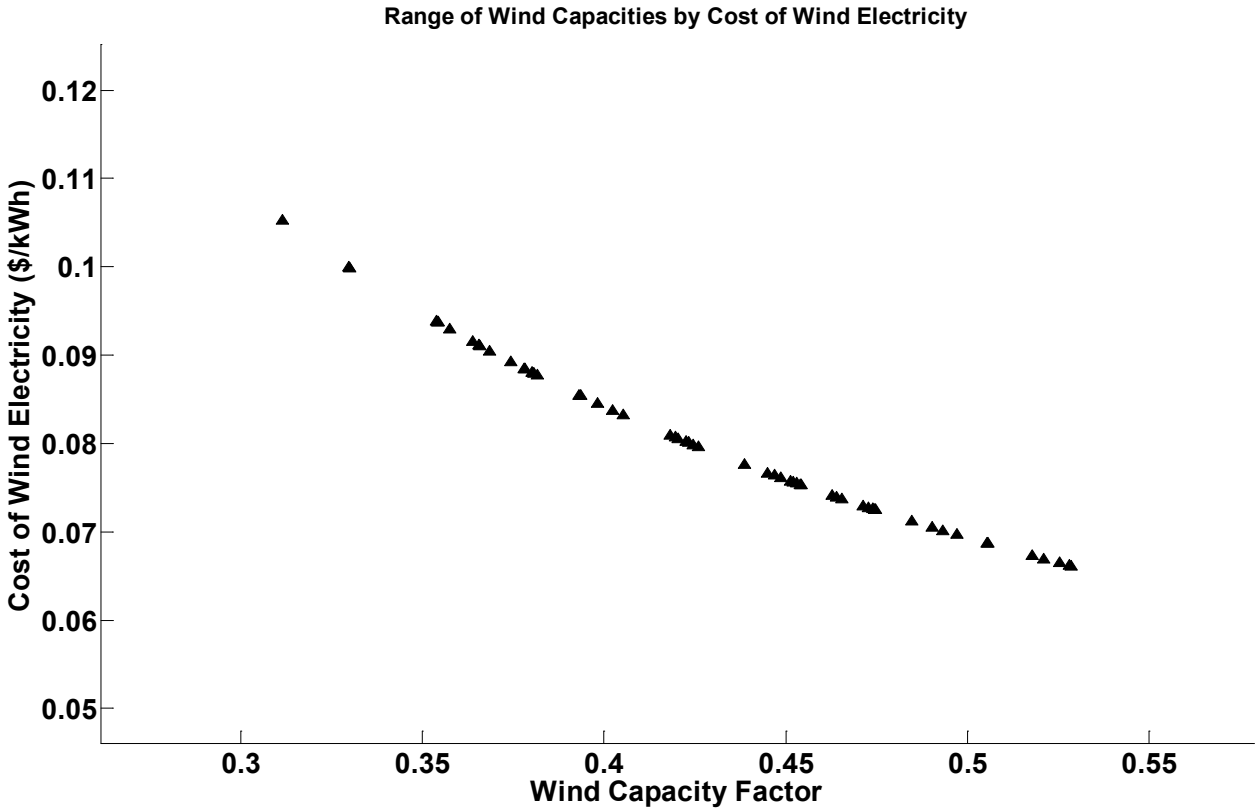
	2009 Cost[1]	**2010 Cost[1,2]**
Installed wind turbine	$2085/kW	$2067/kW
O&M (incl. replacement)	$0.0078/kWh	$0.0087/kWh

1. Costs adjusted to $2007
2. Wiser, R., Bolinger, M., 2010 Wind Technologies Market Report. DOE/GO-102011-3322. Golden, CO: NREL, 2011.

Key Parameters – Wind

Wind Profiles

- Model input from eastern and western wind data sets, and published 2010 wind costs [Wiser & Bolinger, 2010].

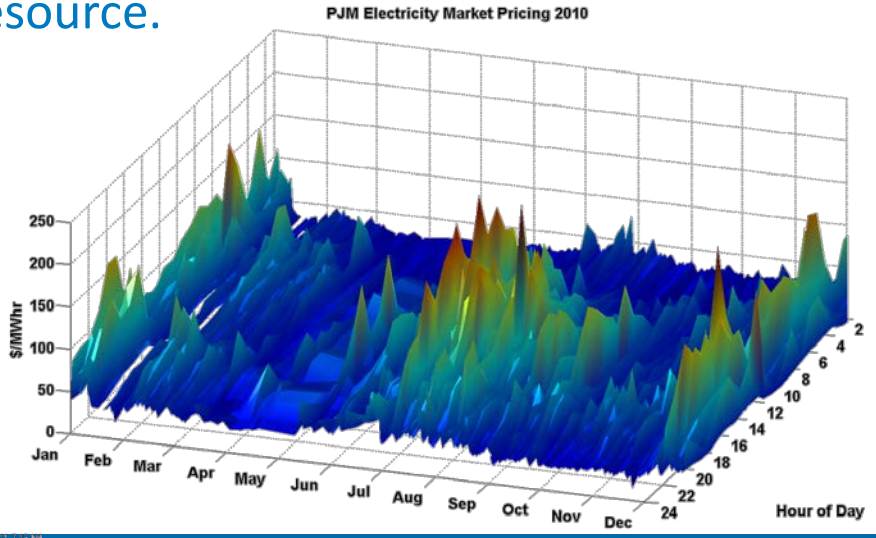


3. Wind Costs shown without any subsidies such as the ITC, PTC, or treasury grant

Key Parameters – Grid

Grid Electricity Pricing

- Raw Locational Marginal Price (LMP)[4] was gathered for five electricity energy markets.
  - Pennsylvania, Maryland, and New Jersey (PJM)
  - The Electrical Reliability Council of Texas (ERCOT)
  - Midwest ISO
  - ISO New England
  - California ISO (updated for 2010)
- Ancillary markets were not considered; after completing this analysis, NREL demonstrated the ability of electrolyzers to provide ancillary support as a demand-response resource.

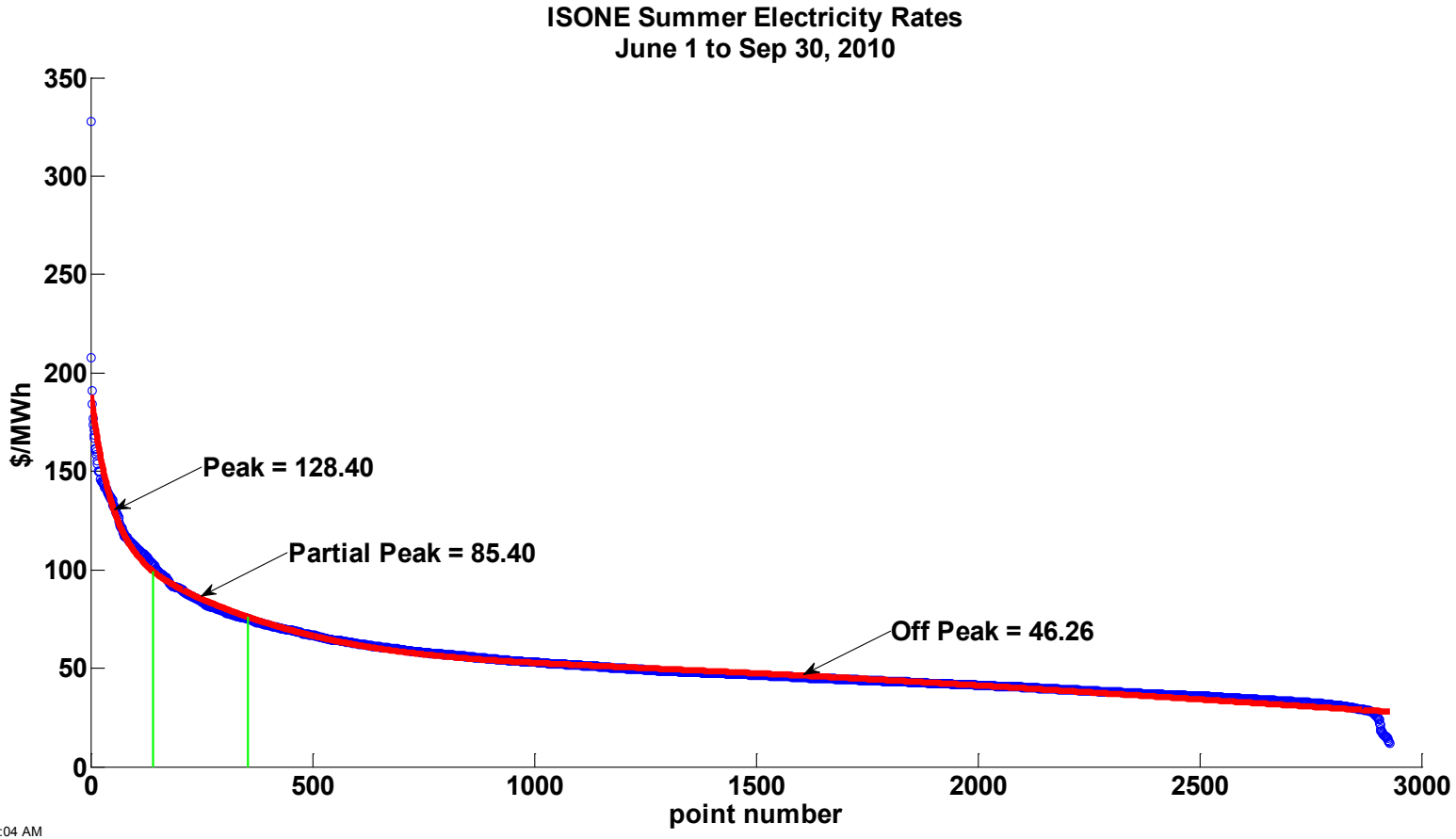


4. ERCOT used market clearing price since it switched pricing methods during the analysis year.

Key Parameters – Grid

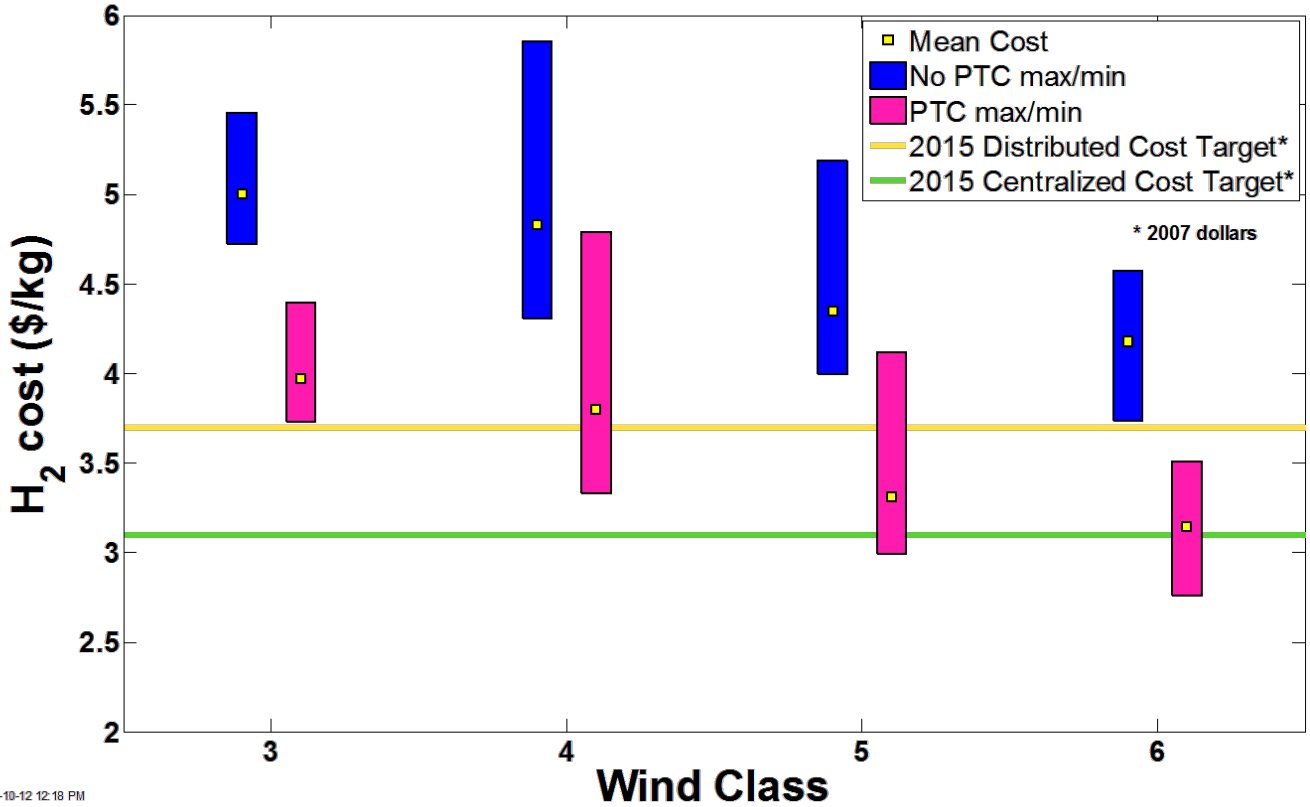
Grid Electricity Pricing

- Raw data were classified into six tiers; peak, partial peak, and off peak for both summer and winter



Results

- Base hydrogen costs ranged from $3.74/kg to $5.86/kg
- Hydrogen costs accounting for the combined effects of tax credits for wind power of 0.02 $/kWh[5] resulted in hydrogen costs of $2.76/kg to $4.79/kg



5. The combined effects of the production tax credit (PTC), Investment Tax Credit (ITC), and Treasury Grant reduce wind electricity prices $0.02/kWh. Refer to: Wiser, R., Bolinger, M., 2010 Wind Technologies Market Report. DOE/GO-102011-3322. Golden, CO: NREL, 2011.

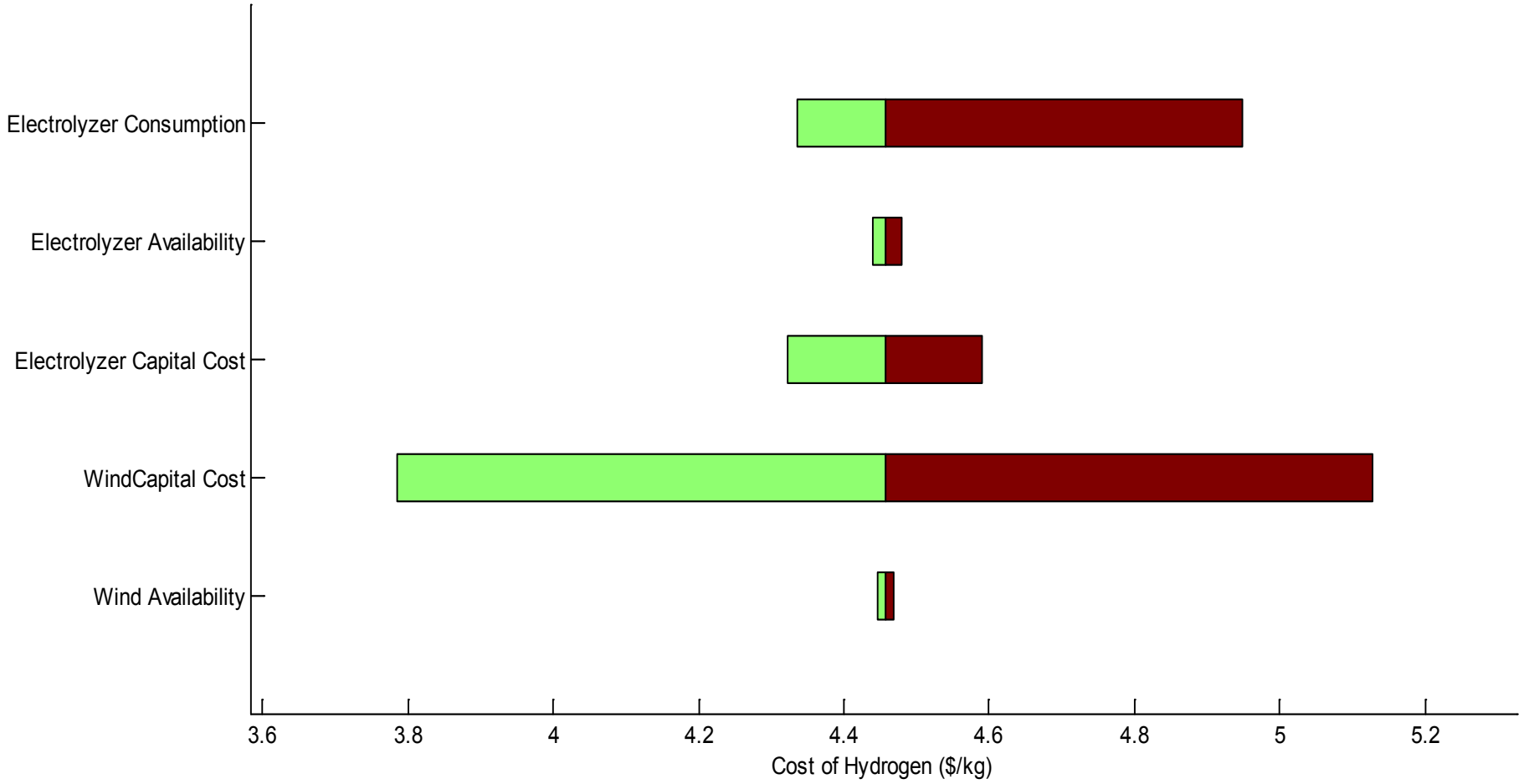
Sensitivities

- **Investigated a three-level, five-factor sensitivity analysis around the base case.**

Variable Name	Base Case Value	Low Value	High Value
Wind Turbine Capital Cost ($/kW)	2067	1654	2481
Electrolyzer Energy Use (kWh/kg)	50	47.5	60
Electrolyzer Capital Cost ($/kW)	408	326	489
Wind Farm Availability (%)	88	90	86
Electrolyzer Capacity Factor (%)	98	99.5	96

Sensitivities

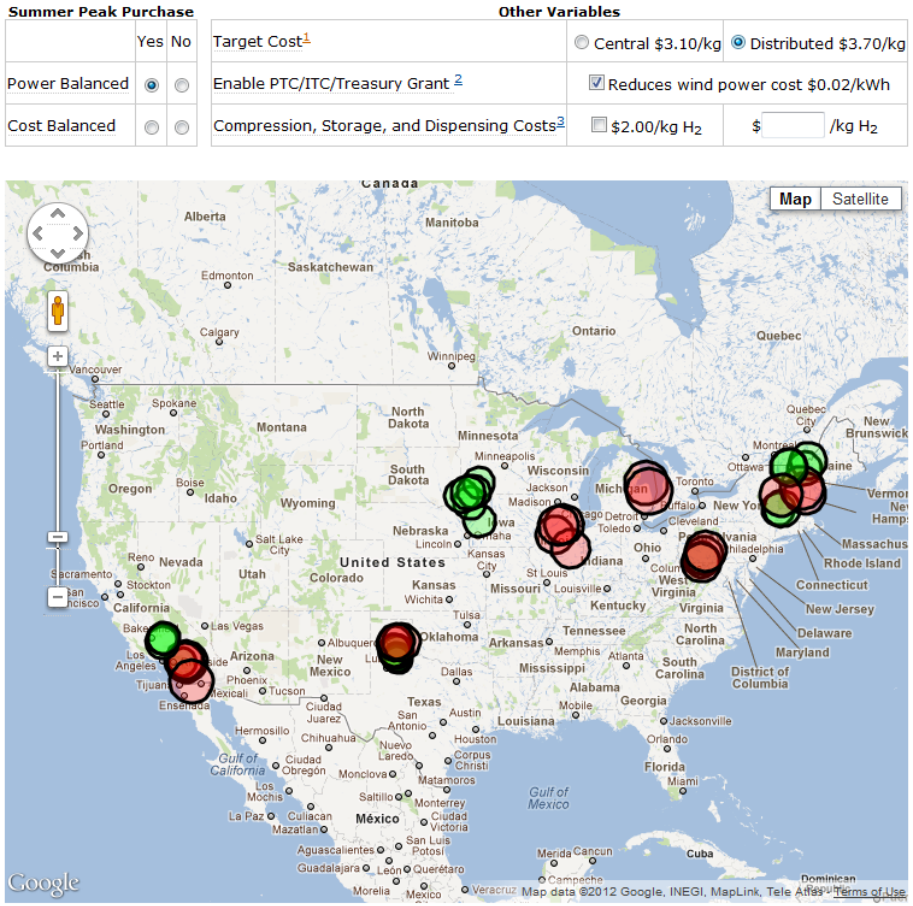
- **Example cost sensitivity for a wind site in New England.**

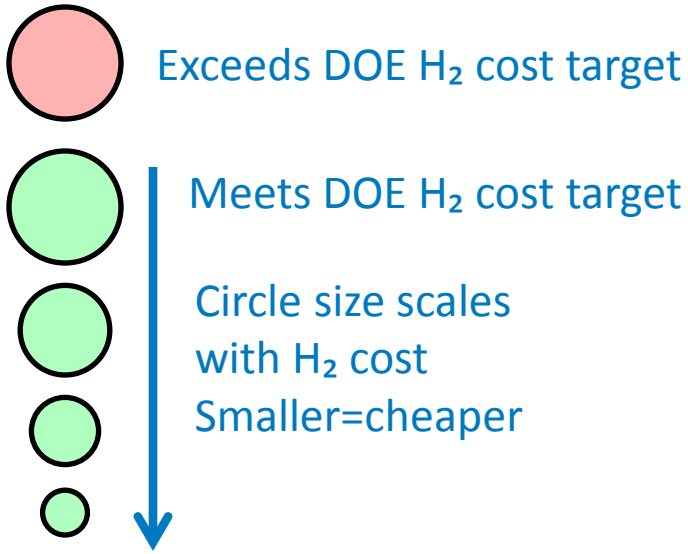


Results explorer

- **NREL created an interactive website to allow exploration of the results**

http://www.nrel.gov/hydrogen/production_cost_analysis.html

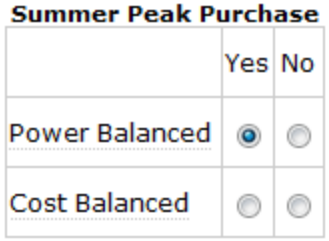




Wind2H2 Analysis Accomplishments

Users can:

- **Explore the effects of the four different balance scenarios**



- **Compare site hydrogen costs to DOE targets**

- **Compare the effects of the PTC/ITC and Treasury Grant on hydrogen costs**

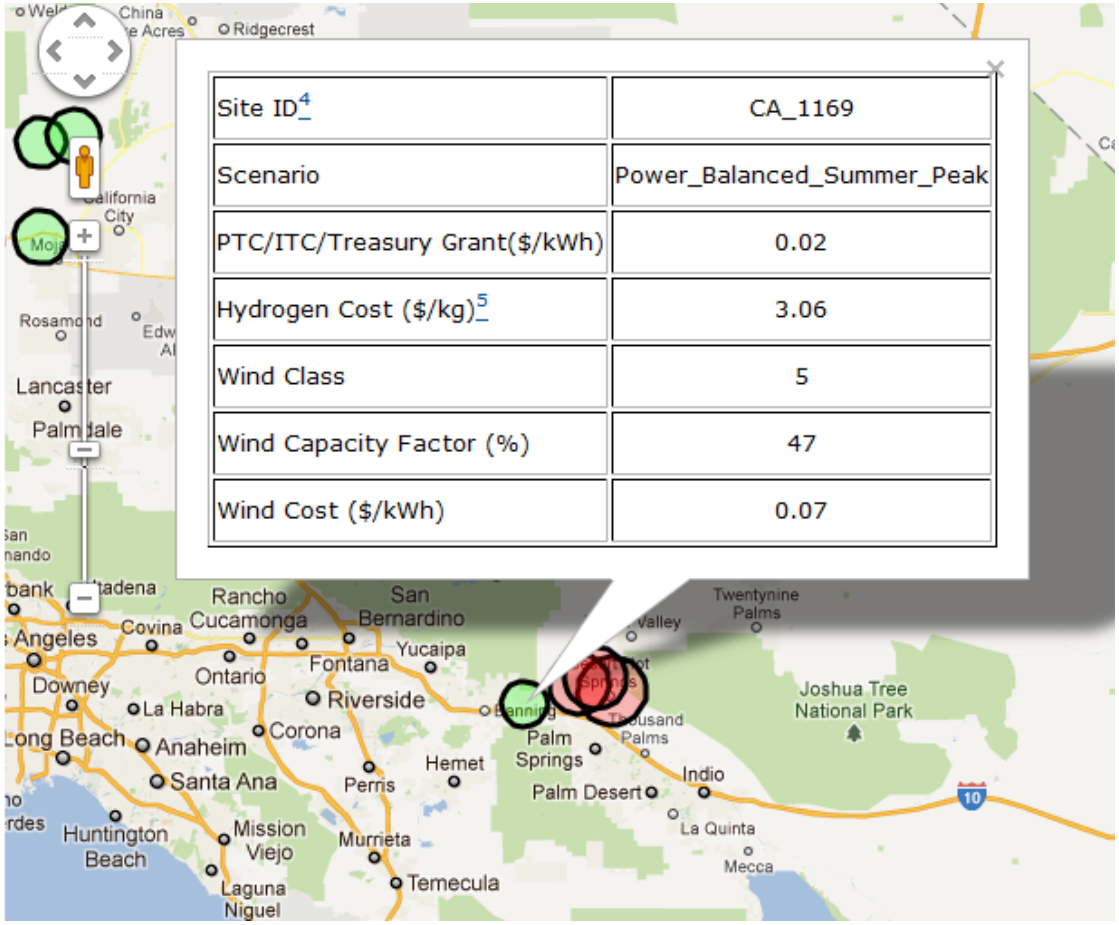
- **Add compression, storage, and dispensing (CSD) costs**

- **And see results updated immediately…**

Wind2H2 Analysis Accomplishments

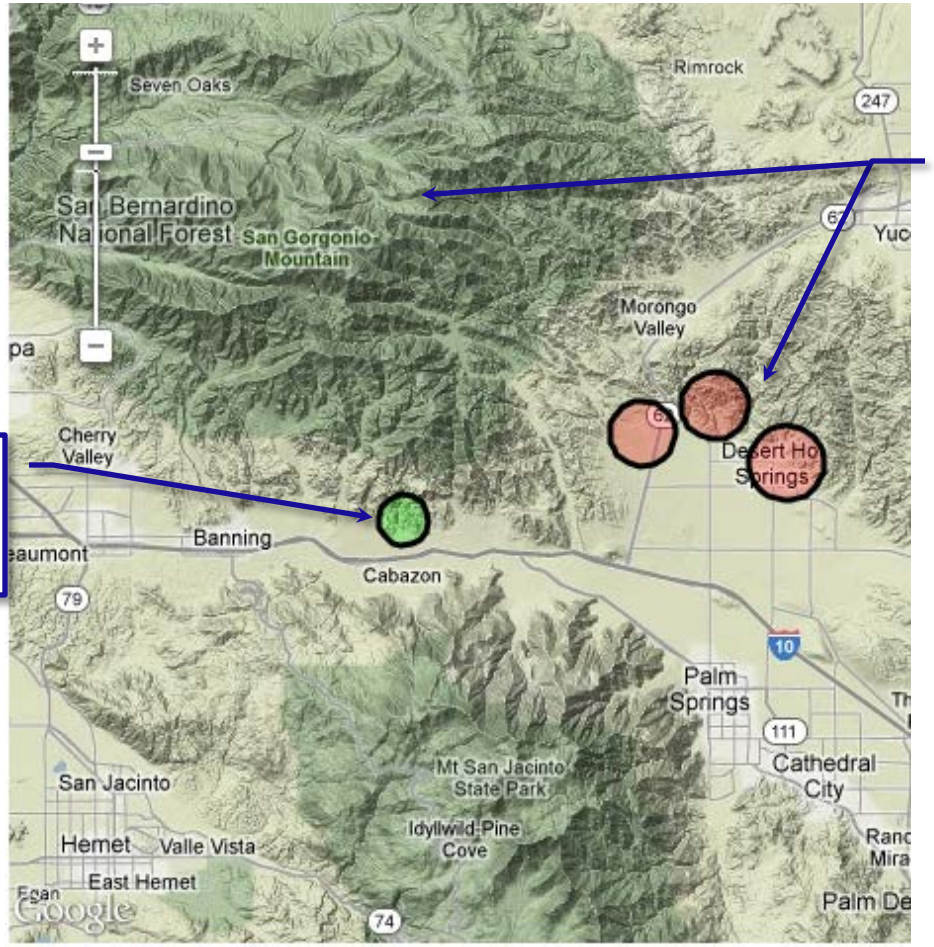
Results are updated instantaneously

Mouse hover will display: The site ID from the NREL Eastern & Western Wind Datasets, balance scenario, the status of the PTC/ITC, hydrogen cost, wind class, wind capacity factor, wind electricity cost



Wind2H2 Analysis Accomplishments

Users can see the effects of local topography on the viability of a site



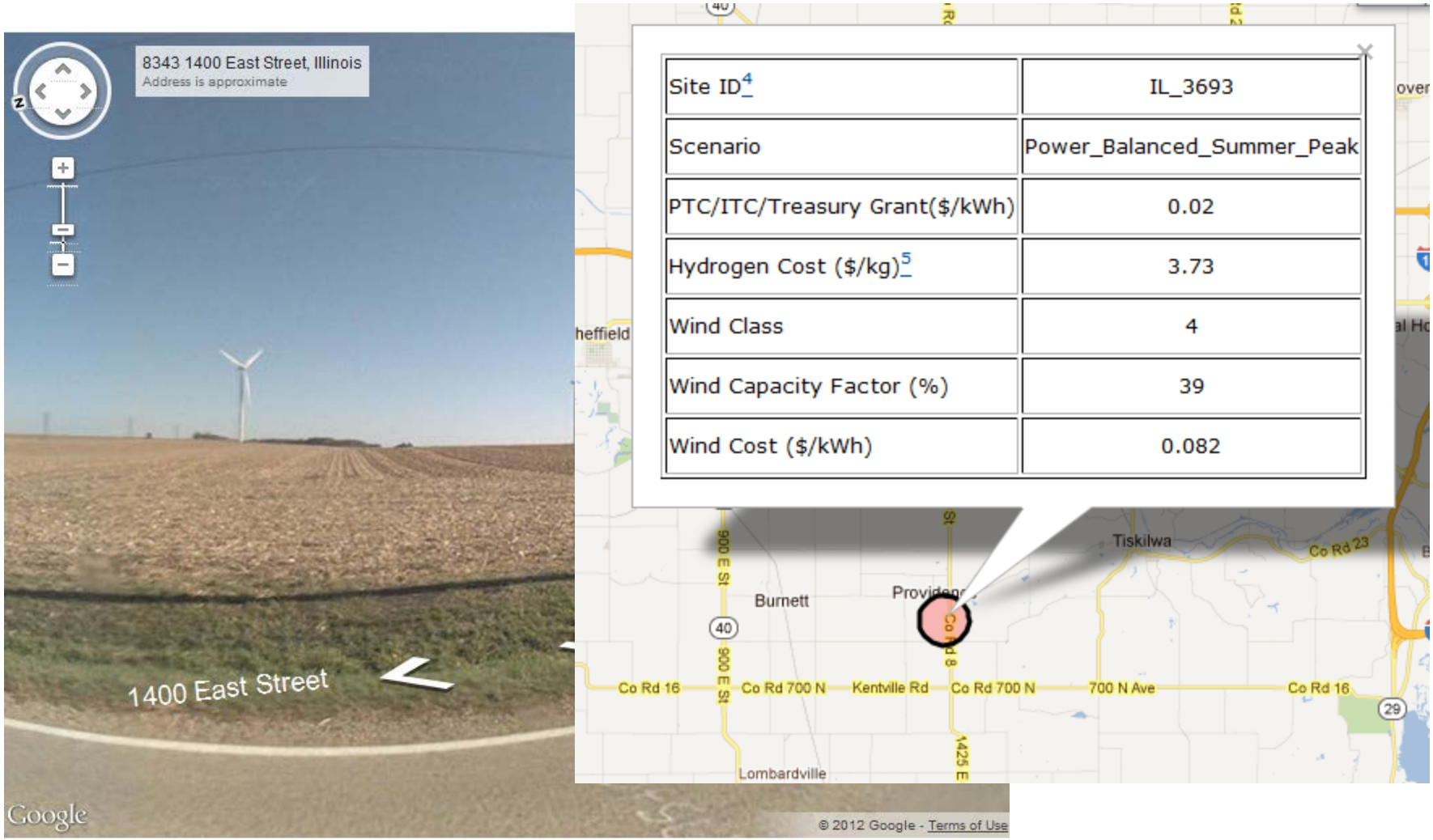
Site meets DOE target

Nearby mountains degrade the wind resource making these sites less viable. Despite being in the same electricity market, hydrogen cost is increased from $3/kg to more than $4.5/kg

Wind2H2 Analysis Accomplishments

Users can see the street view of many sites

Site IL_3693 is already a developed wind site southwest of Chicago



Collaborations with Industry

- **Information, technical support, and equipment for overall project from:**
  - DOE Fuel Cell Technologies Office
  - Xcel Energy
  - Giner Electrochemical Systems
  - Avalence
  - Proton Onsite

Wind2H2 Analysis Summary

- **The effect of the PTC/ITC/Treasury Grant on the cost of hydrogen is significant. $0.02/kWh = ~$1/kg drop in H_2 cost. Including these effects, the cost of hydrogen drops into the range of $2.76–$4.79/kg.**
- Wind classes 3-6 can produce hydrogen in the range of $3.74–$5.86/kg, unsubsidized by wind or renewable fuel tax credits.
- This does not yet meet DOE centralized or distributed production targets.
- Site viability is very dependent on the quality of the local wind resource.
- Further reductions in the cost of wind electricity and electrolyzer capital are needed to make this type of plant widely applicable.

References

1. Saur, G. and T. Ramsden. *Wind Electrolysis: Hydrogen Cost Optimization*. NREL/TP-5600-50408. Golden, CO:NREL, 2011.
2. EIA, U.S. *Short Term Energy Outlook (August 9, 2011)*. 2011 [cited 2011 August 15]; Available from: http://www.eia.gov/emeu/steo/pub/cf_tables/steotables.cfm?tableNumber=5.
3. *DOE Hydrogen Program: DOE H2A Production Analysis*. 2008 August 23, 2011]; Available from: http://www.hydrogen.energy.gov/h2a_production.html.
4. Wiser, R. and M. Bolinger. *2010 Wind Technologies Market Report*. DOE/GO-102011-3322. 2011.
5. Genovese, J., et al. *Current (2009) State-of-the-Art Hydrogen Production Cost Estimate Using Water Electrolysis: Independent Review*. Golden, CO:NREL, 2009.
6. Ramsden, T., *Current (2008) Hydrogen Production from Central Grid Electrolysis v 2.0.1*, U. DOE, Editor. 2008.
7. *DOE Hydrogen Program: DOE H2A Analysis*. 2008 March 11, 2008]; Available from: http://www.hydrogen.energy.gov/h2a_analysis.html.
8. *NREL: Wind Integration Datasets - Eastern Wind Dataset*. [cited 2011 August 1]; Available from: http://www.nrel.gov/wind/integrationdatasets/eastern/methodology.html.
9. *NREL: Wind Integration Datasets - Western Wind Dataset*. [cited 2010 July 15]; Available from: http://www.nrel.gov/wind/integrationdatasets/western/methodology.html.

Contact Information

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