Cost and GHG Implications of Hydrogen for Energy Storage

2011 Hydrogen Program Annual Merit Review and Peer Evaluation Meeting

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Project ID # AN006

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Overview

Timeline

- Start: October 2008
- End: September 2011
  (expected to continue in FY12)
- Complete: 60% (FY2011 work)

Barriers

•Stove-piped/Siloed Analytical Capability [4.5.B]

•Suite of Models and Tools [4.5.D]

•Unplanned Studies and Analysis [4.5.E]

Budget

- Total Project Funding: $340k
  - 100% DOE-funded
- FY2010: $40k
- FY2011: $150k

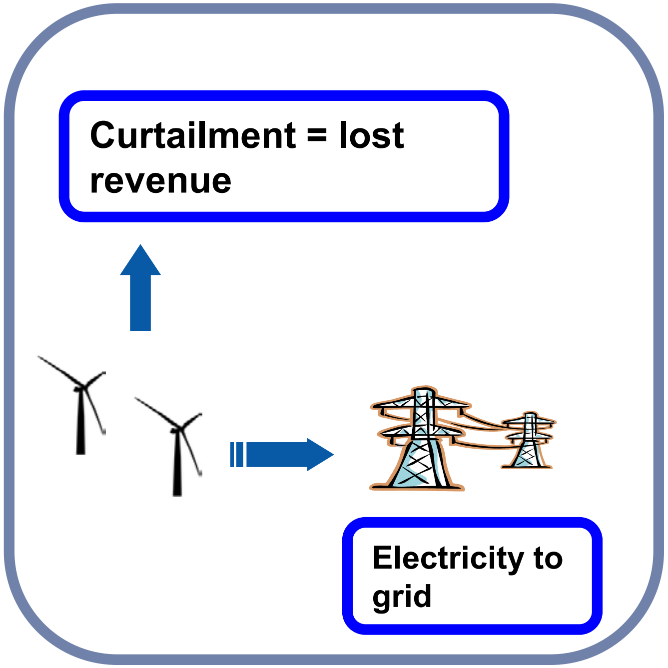
Partners

•NREL Strategic Energy Analysis Center analysts

•Pacific Northwest Laboratory

•Xcel Energy (Utility)

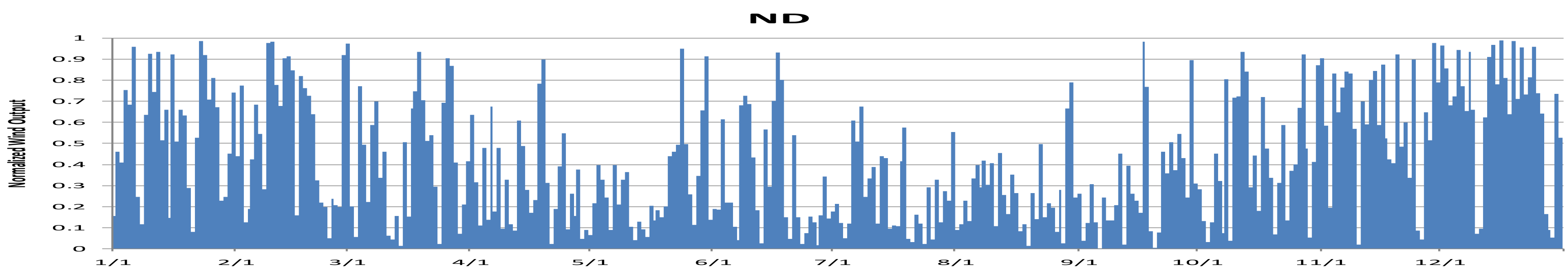
Relevance: Increasing Renewable Electricity Production Provides an Opportunity for Hydrogen



Energy storage is needed to make variable renewable resources dispatchable

A load is needed to “soak up” excess electricity generation

Hydrogen could play dual role as a storage medium for electricity and as a fuel for vehicles.



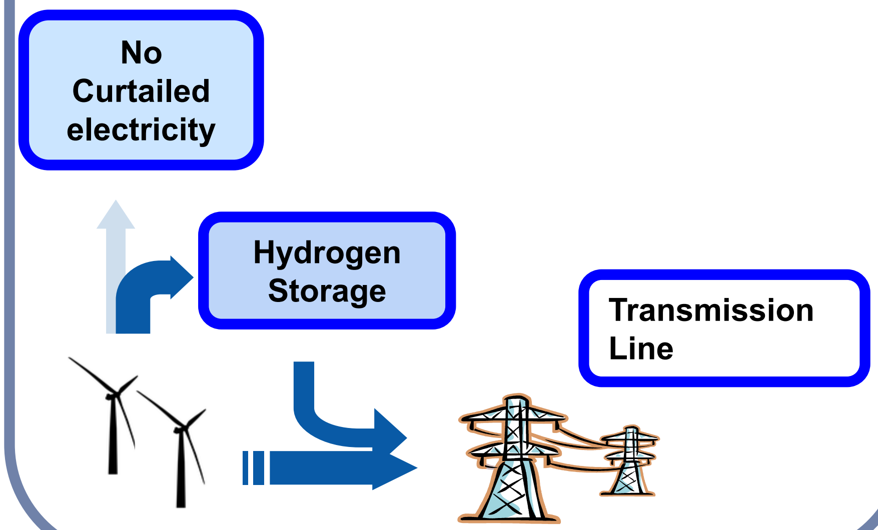
Near-term hydrogen production from renewables could be made more economical if hydrogen provides other services

Relevance: Lifecycle Cost Analysis Used to Evaluate Hydrogen Energy Storage and Hydrogen For Vehicles

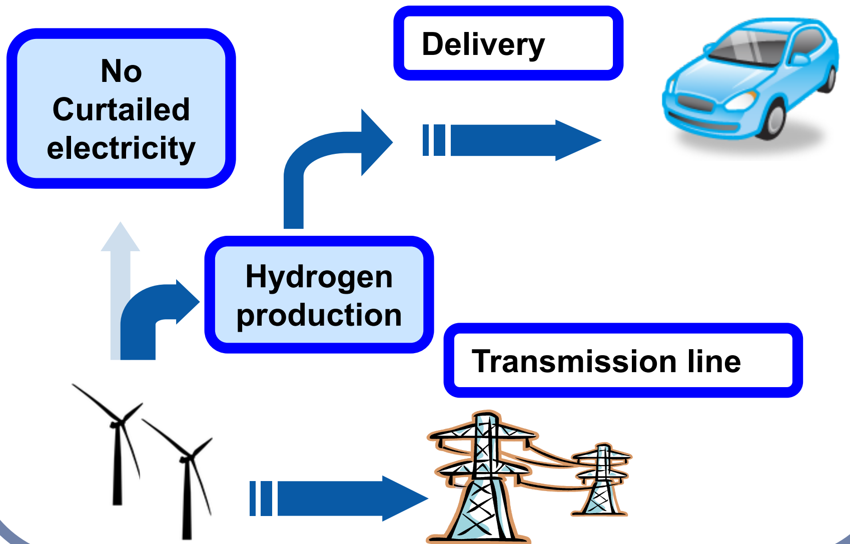
Objective

Use analysis of scenarios for renewable electricity generation coupled with hydrogen systems to find opportunities for cost savings and other benefits of hydrogen energy storage and renewable hydrogen for vehicles

Hydrogen for Energy Storage Case



Hydrogen for Vehicles Case



Relevance: Impact on Barriers

Barrier	*Impact*
Stove-piped/Siloed Analytical Capability [4.5.B]	• Competing hydrogen energy storage against other alternatives in a lifecycle cost analysis provides context for results • Analysis of production of excess hydrogen for vehicles integrates transportation and electricity sectors
Suite of Models and Tools [4.5.D]	• Fuel Cell Power model modified to evaluate storage integrates hourly energy analysis capability with H2A economic analysis capabilities • Results from storage studies can be evaluated geographically in the SERA model
Unplanned Studies and Analysis [4.5.E]	• Analysis integrating renewable resources (wind and solar) in specific locations with hydrogen storage

Approach: Milestones and Deliverables

Milestone/ Deliverable	***Title***	***Date***	***Status***
Milestone	Complete literature review for new storage systems and cost projections	April 2011	In Progress
Milestone	Provide update on preliminary results	June 2011	In Progress
Deliverable	Quarterly Reports	1/11, 4/11, 7/11, 10/11	In Progress
Deliverable	Internal draft for DOE review: technical report on hydrogen and competing storage technology case studies	July 2011	In Progress

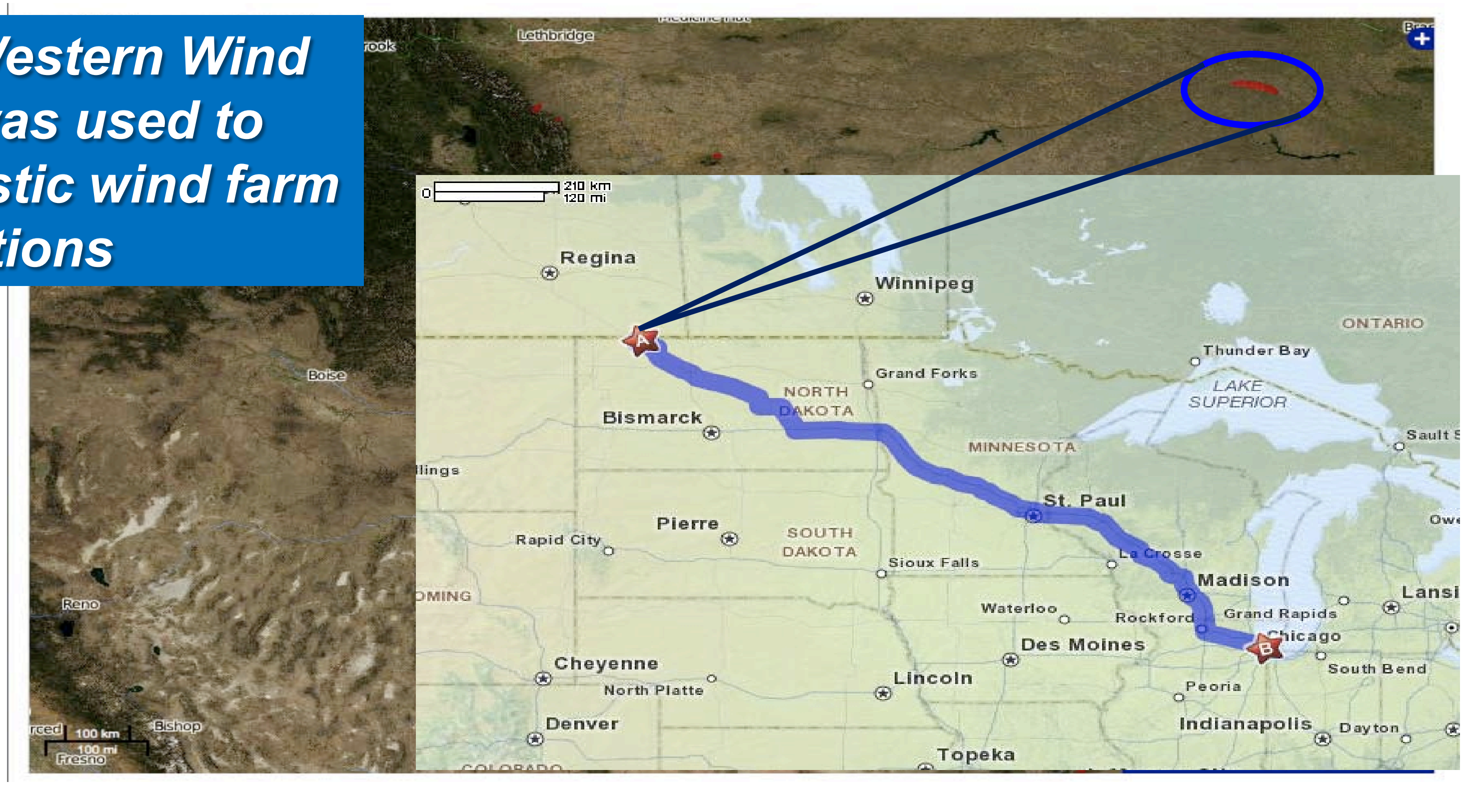
Approach: Realistic Case Studies used to Explore Cost for Hydrogen Energy Storage Systems and Hydrogen for Vehicles

Objective

Explore the cost and GHG emissions impacts of interaction of hydrogen storage and variable renewable resources

– Specific locations and wind profiles
– Hourly energy analysis to capture detail

The NREL Western Wind Data Set was used to identify realistic wind farm locations

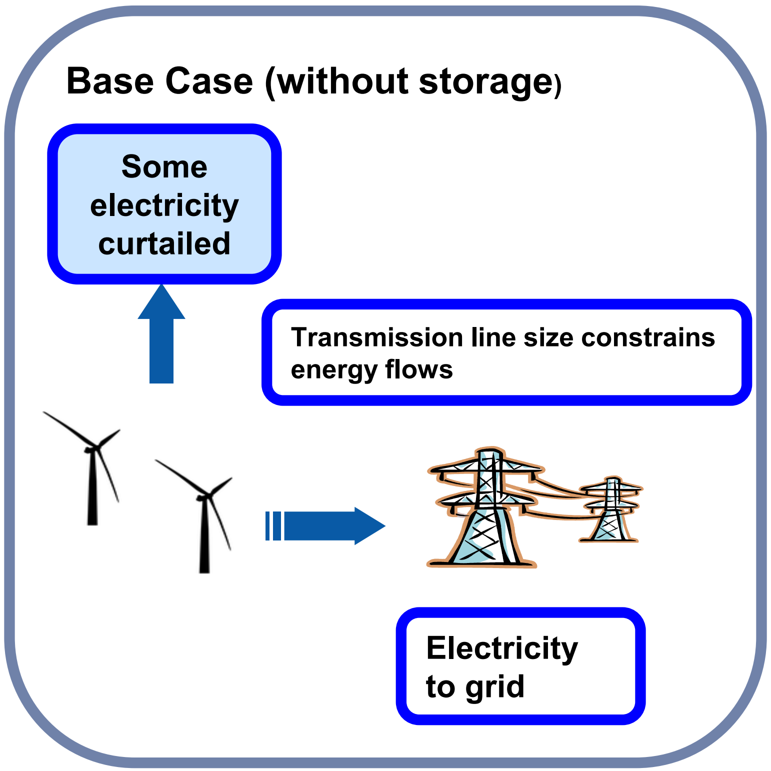


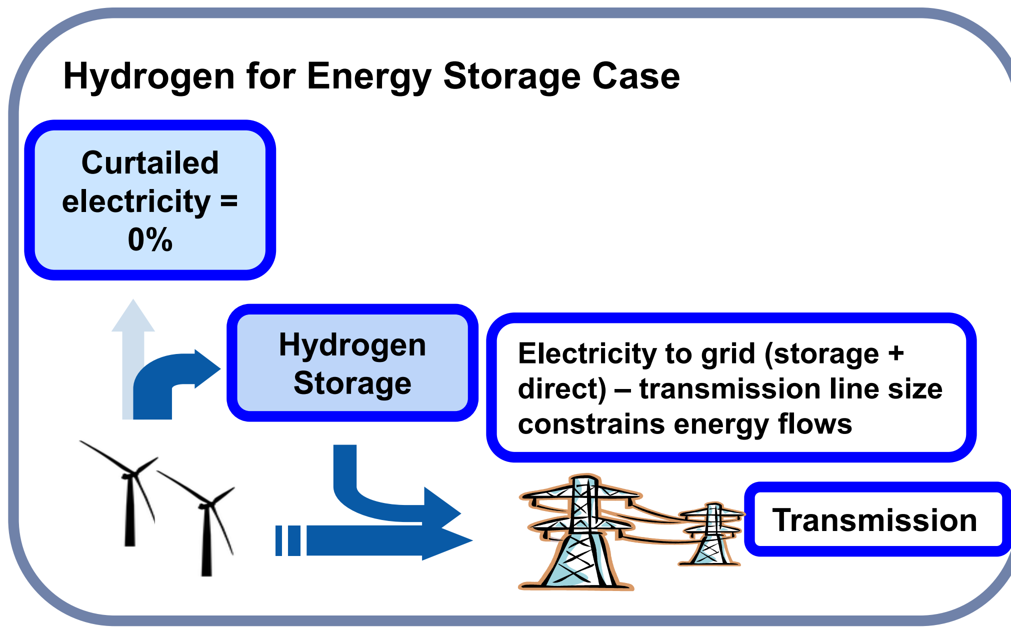
Approach: Economic Analysis Strategy – Energy Storage

- Calculate the levelized, profited cost of the delivered electricity from the wind farm/storage system
- Focus = load leveling and transmission line utilization

Include All Costs

- Cost for transmission line
- Cost of transmission losses





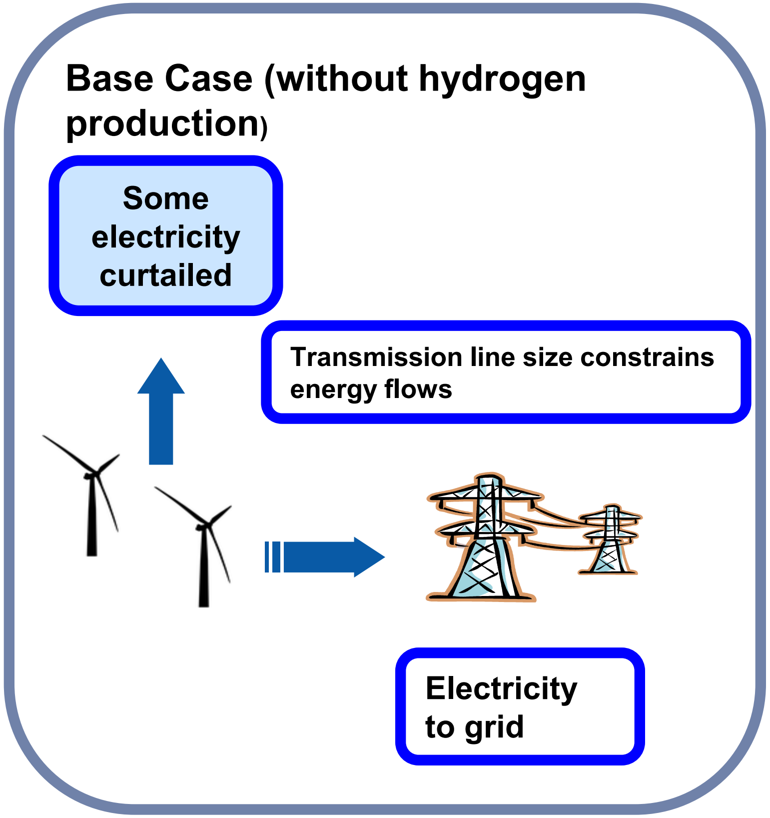
Do the advantages of dispatchability and lower transmission line costs outweigh the cost of the storage system?

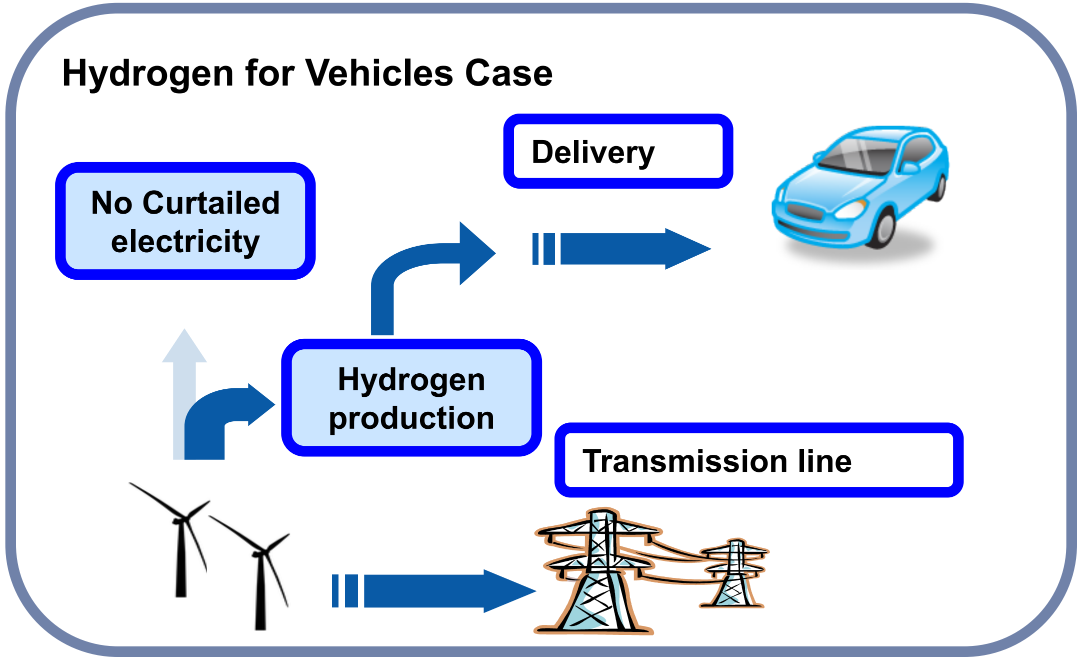
Approach: Economic Analysis Strategy – Hydrogen for Vehicles

Calculate the levelized, profited cost of the delivered electricity from the wind farm; then add hydrogen production

Apportion costs between electricity and hydrogen

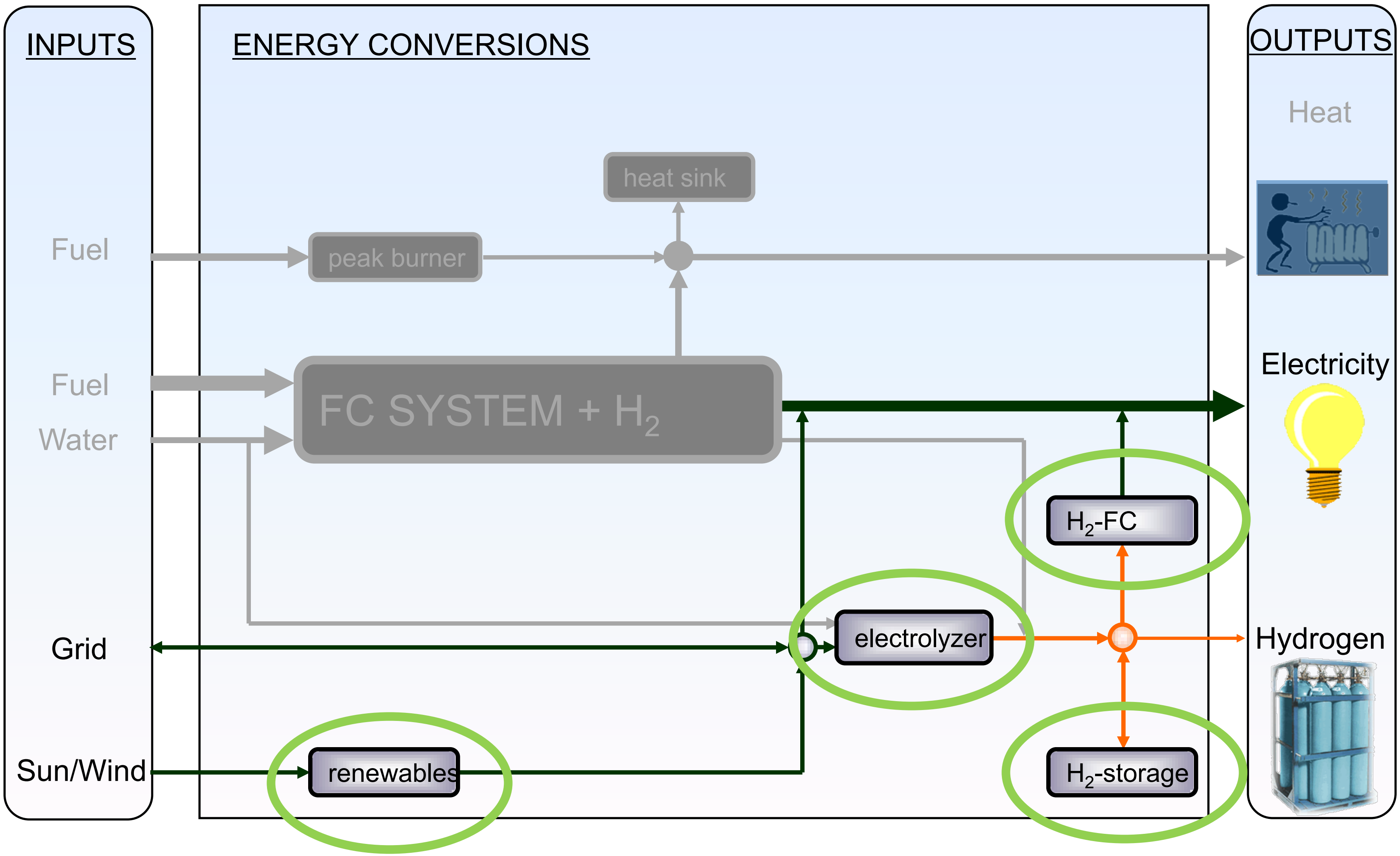
- Only otherwise curtailed wind is "free" for hydrogen production
- Electrolysis is "paid for" by hydrogen revenue





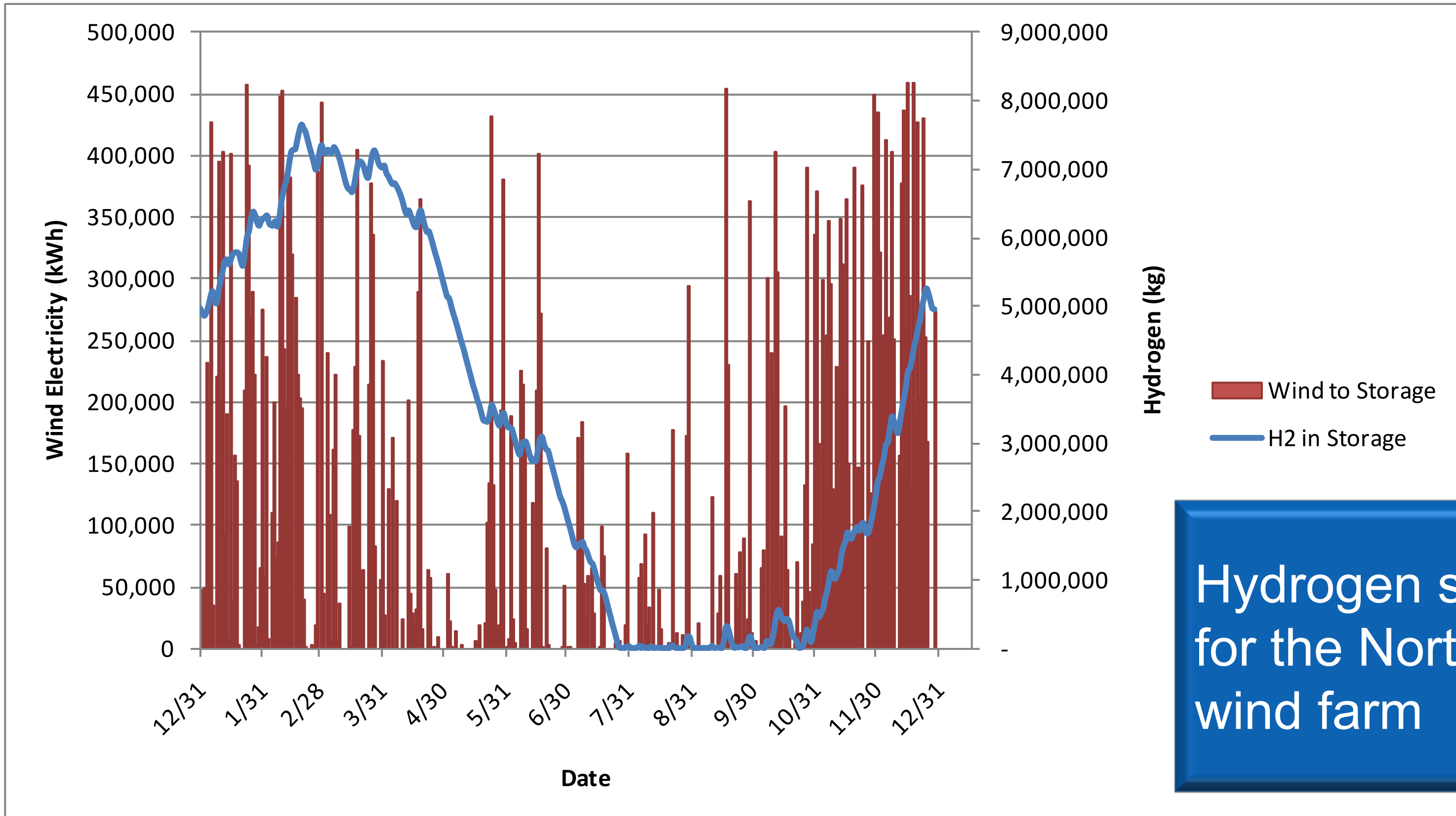
What is the lowest cost mix of electricity and hydrogen?

Approach: The Fuel Cell Power Model was used for Hourly Energy Analysis



Accomplishments: Hourly Model of Hydrogen for Energy Storage

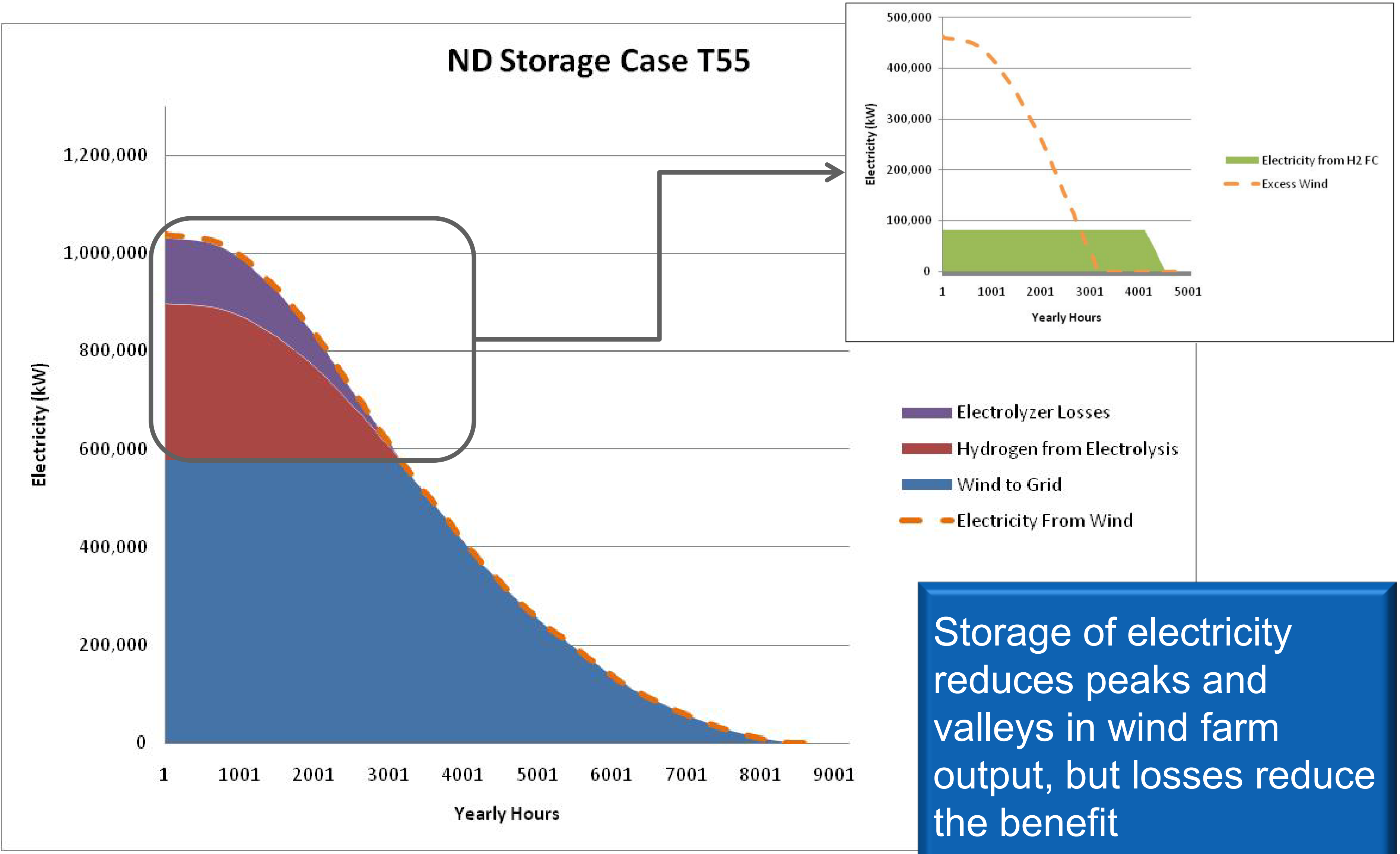
Modified Fuel Cell Power Model was used to calculate the storage needed and optimal equipment sizes for each wind farm.



Hydrogen storage profile for the North Dakota wind farm

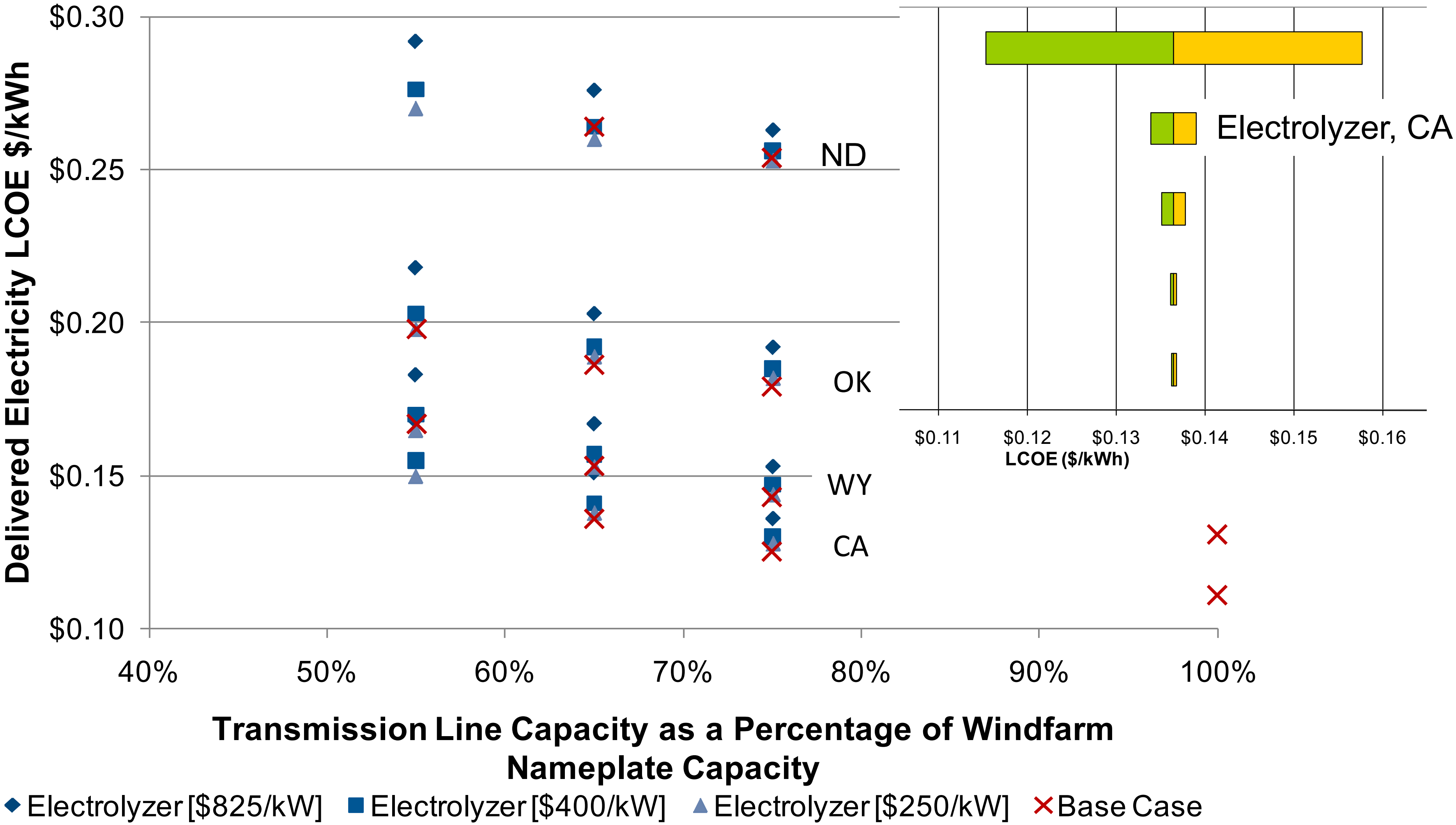
Hydrogen storage capacity needed varies seasonally and between wind farms

Accomplishments: Storage System Output is the Economic Metric for Comparison to the Baseline



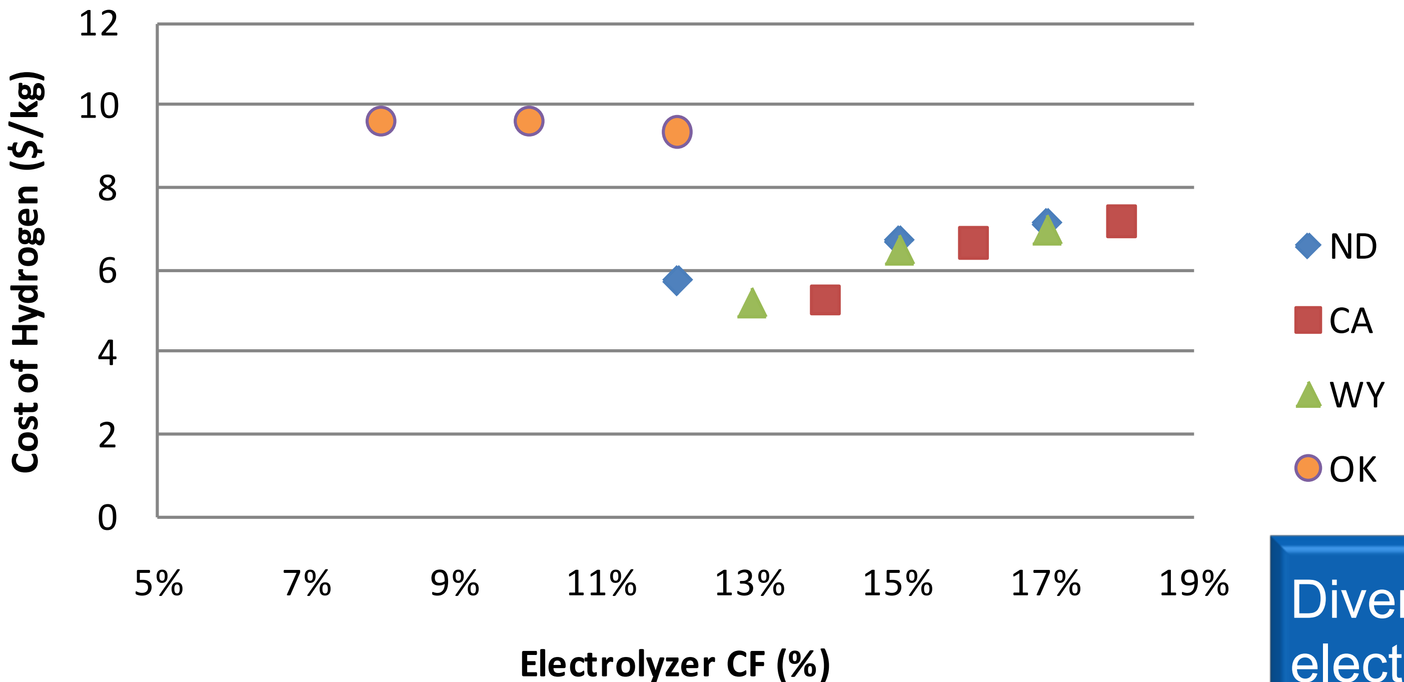
Storage of electricity reduces peaks and valleys in wind farm output, but losses reduce the benefit

Accomplishments: Storage System Sensitivity to Electrolyzer Costs



Electrolyzer costs must decrease for hydrogen energy storage to be less expensive than curtailing excess wind

Accomplishments: Dispatchable Demand – Economic Analysis of Hydrogen for Vehicles

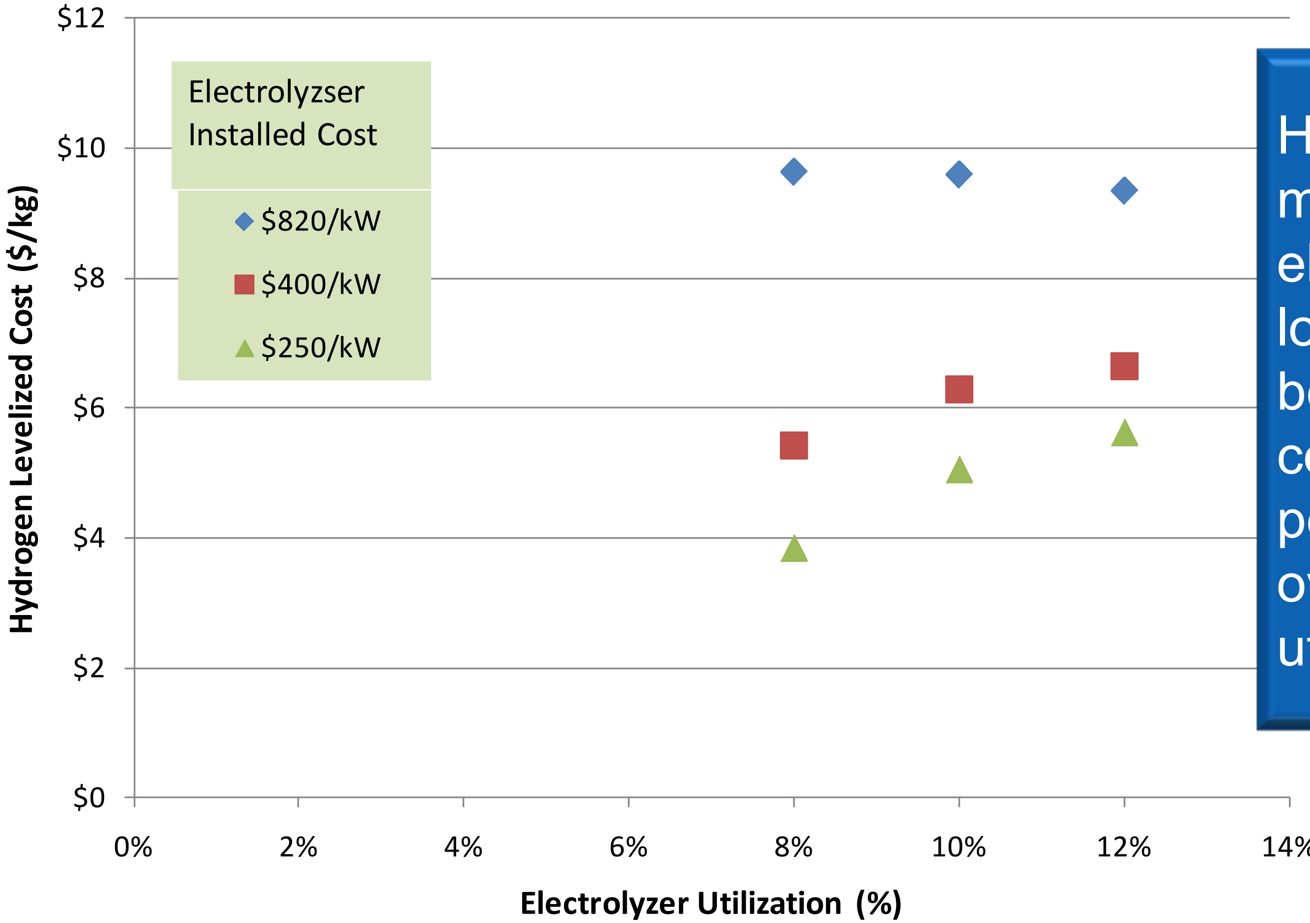


Wind Farm	Cost of Electricity to Electrolyzer T75 ($/kWh)	Electricity to electrolyzer at T65 (% at no cost)	Cost of Electricity to Electrolyzer T65 ($/kWh)	Electricity to electrolyzer at T55 (% at no cost)	Cost of Electricity to the Electrolyzer T55 ($/kWh)
OK	$ -	56%	$ 0.079	36%	$ 0.115
ND	$ -	59%	$ 0.103	40%	$ 0.152
CA	$ -	61%	$ 0.049	43%	$ 0.072
WY	$ -	60%	$ 0.057	41%	$ 0.084

Diverting more electricity to the electrolyzer increases the electrolyzer capacity factor but also increases the cost of the electricity

What is the optimal balance between hydrogen and electricity?

Accomplishments: Hydrogen for Vehicles Sensitivity to Electrolyzer Cost



Hydrogen cost is more sensitive to electrolyzer cost at low utilization because electricity cost is a smaller percentage of overall cost at low utilization

Proposed Future Work

- Perform an analysis for an isolated solar installation
- Compare greenhouse gas emissions/carbon tax implications for hydrogen storage and compressed air energy storage.
- Obtain better cost estimates for geologic storage
- Sensitivity analyses for fuel cell and electrolyzer efficiency
- Add delivery of hydrogen for vehicles
  - Look at rail and pipeline delivery of hydrogen

Summary

Relevance	• Hydrogen could bridge power and transportation sectors • Hydrogen storage could provide an advantage for large scale isolated renewables • Use of hydrogen for storage or dispatchable load could stimulate the market for lower cost electrolyzers
Approach	• Analysis of hydrogen storage for realistic case studies for wind farms of various sizes, classes and proximity to demand centers. • Hourly analysis of energy flows
Accomplishments	• Hydrogen storage could reduce the amount of electricity that must be curtailed and reduce the LCOE for wind farms. • Hydrogen can be produced from curtailed wind, but electrolyzer costs must come down for this option to be economical
Collaborations and Reviewers	• Xcel Energy • NREL Strategic Energy Analysis team
Proposed Future Work	• More detailed analysis of geologic storage and above-ground storage options • Analysis of solar installations • Analysis of hydrogen delivery costs • Analysis of GHG implications (see CAES supplementary slide)