NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Lifecycle Cost and GHG Implications of a Hydrogen Energy Storage Scenario

National Hydrogen Association Conference & Expo

Darlene M Steward

National Renewable Energy Laboratory

May 3-6, 2010

Long Beach, CA

NREL/PR-560-48198

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

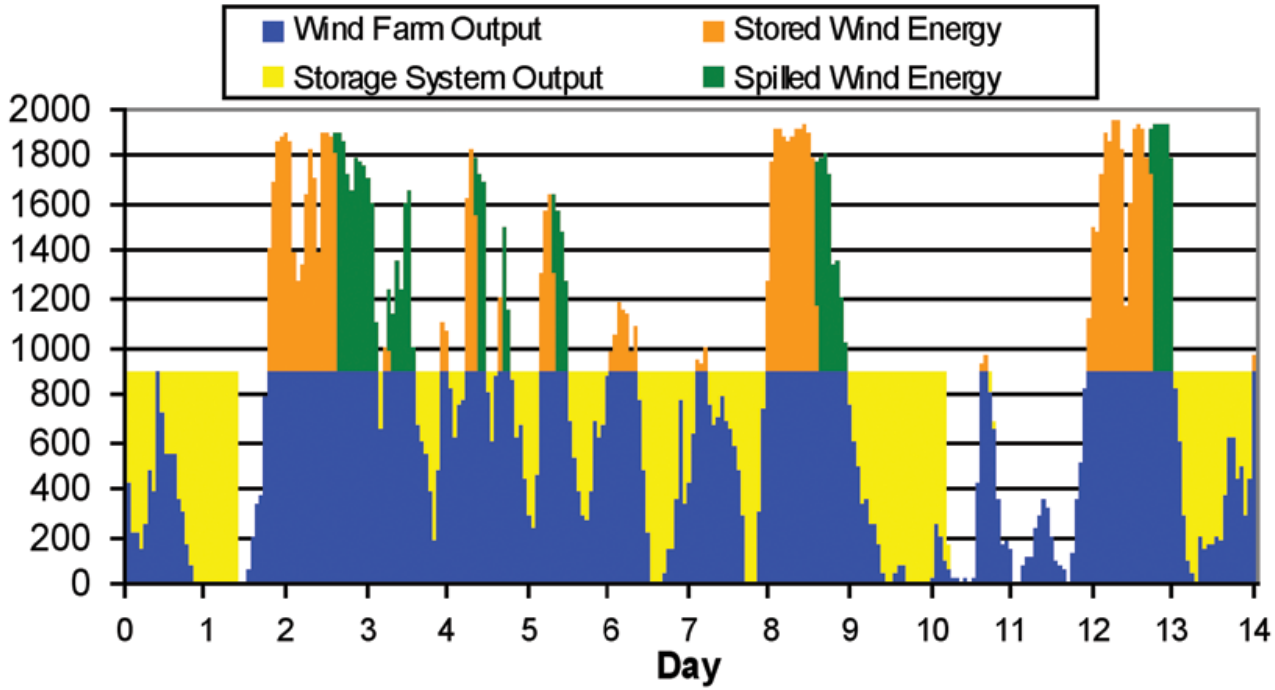
NREL is a national laboratory of the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, operated by the Alliance for Sustainable Energy, LLC.

Acknowledgements

- This work has been funded by the DOE Office of Energy Efficiency and Renewable Energy through a contract with the National Renewable Energy Laboratory

Energy Storage & Greenhouse Gases

+	-
Additional energy from the windfarm can be captured for later use	Efficiency losses incurred by routing wind energy through the storage system reduce the greenhouse gas benefit of wind



Source: Denholm, Paul. (October 2006). "Creating Baseload Wind Power Systems Using Advanced Compressed Air Energy Storage Concepts." Poster presented at the University of Colorado Energy Initiative/NREL Symposium. http://www.nrel.gov/docs/fy07osti/40674.pdf

A Realistic Case Study was used to Explore Cost and GHG Implications for a Hydrogen Energy Storage System

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

Outline

Study Framework

- Choose a specific realistic wind farm location
- Develop a “base case” without storage for comparison
- Develop storage scenarios

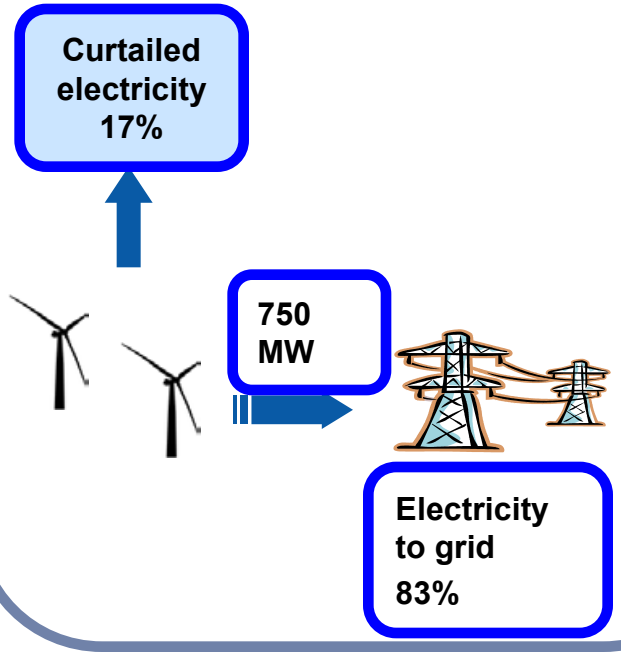
Preliminary Study Results

- Lifecycle cost analysis
- GHG emissions credit

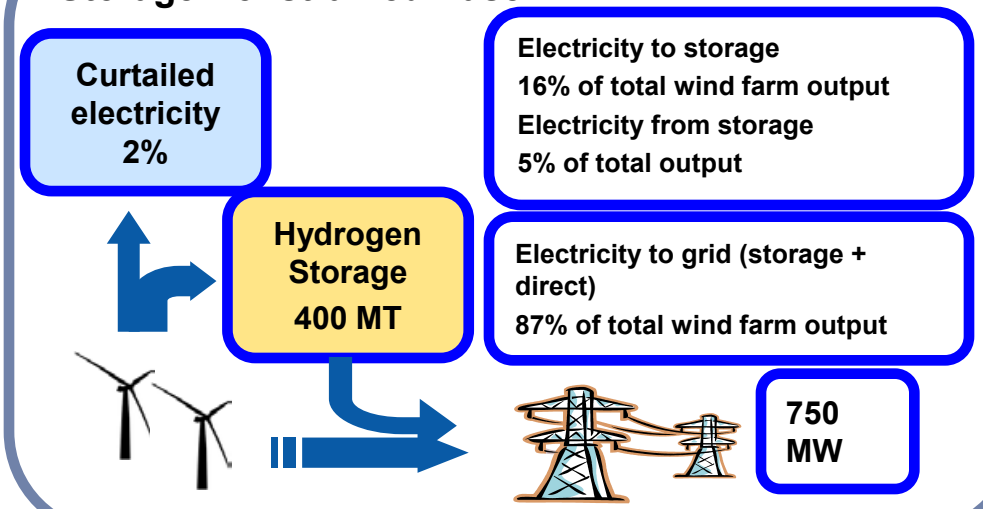
Study Framework - Add Hydrogen Storage to a Base Case Without Storage

Analysis of the base case provides LCOE and avoided emissions for comparison

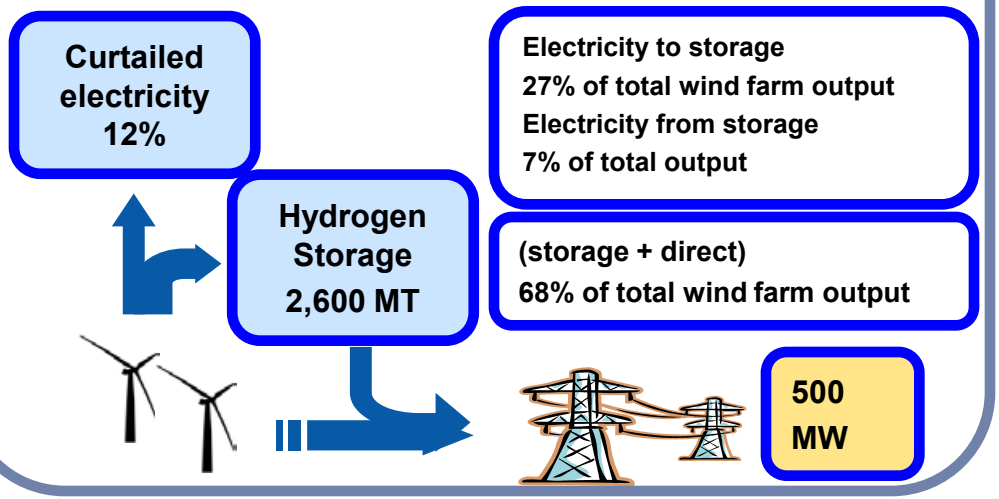
Base Case (without storage)



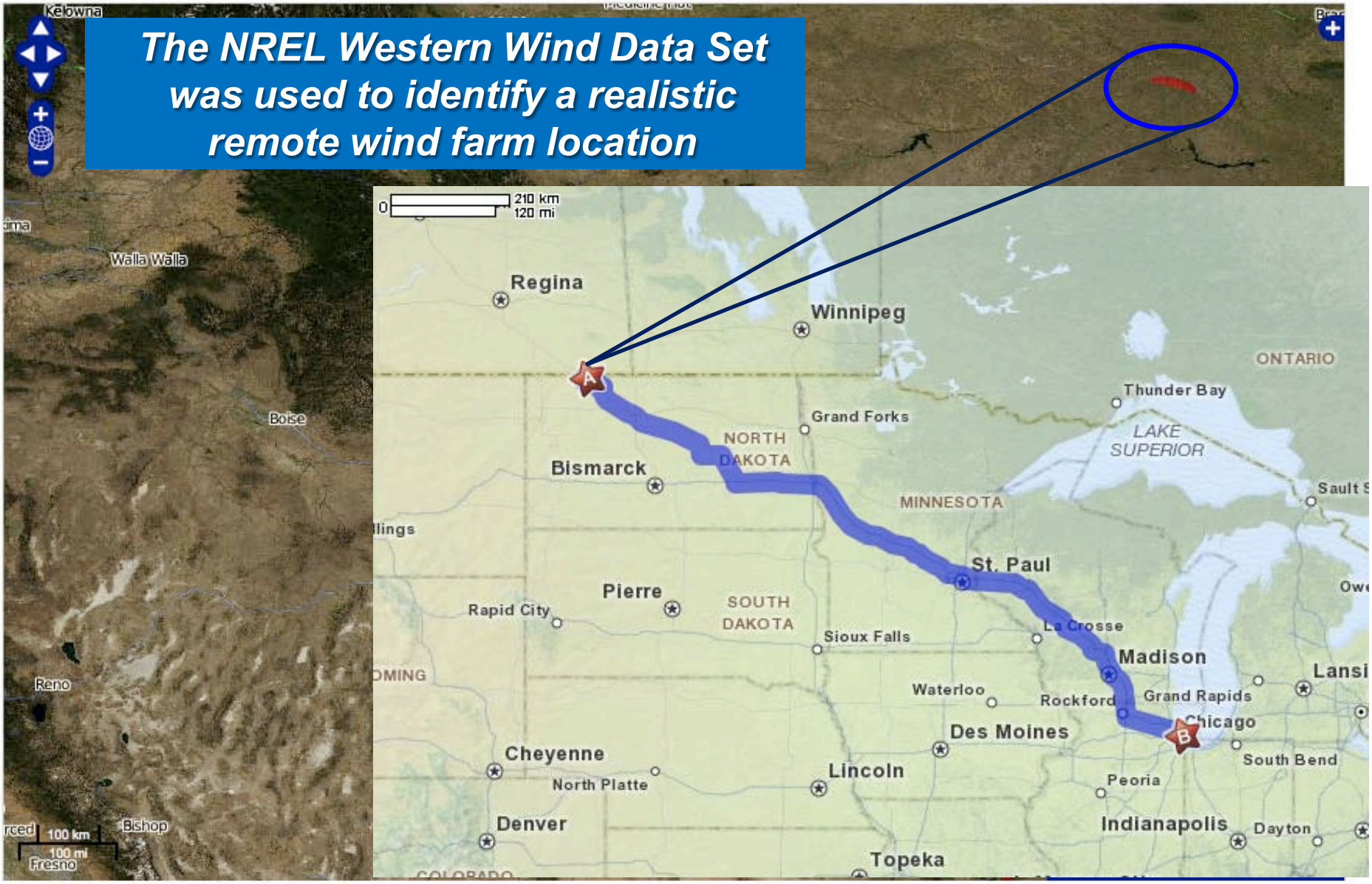
Storage Constrained Case



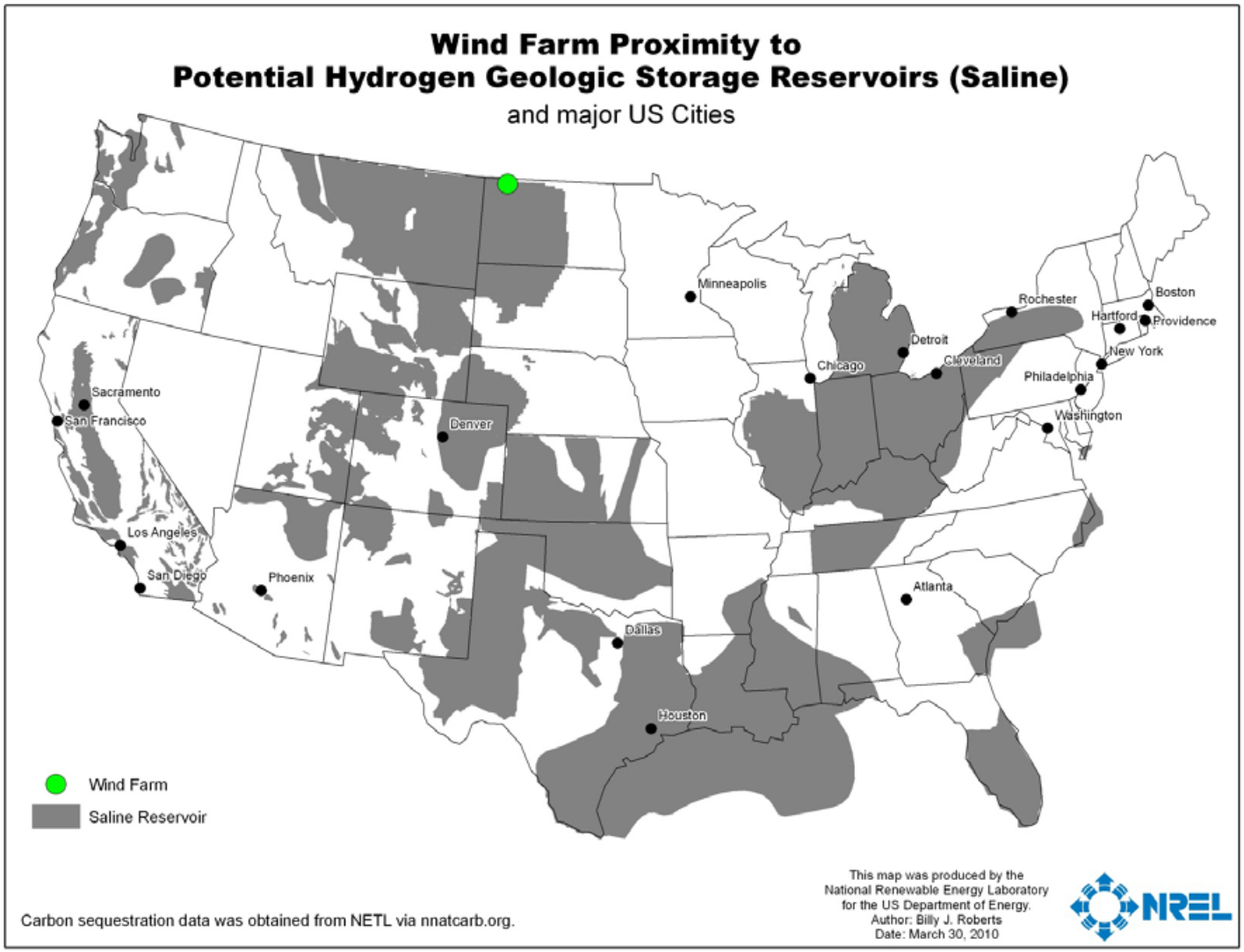
Transmission Constrained Case



Wind Farm Location

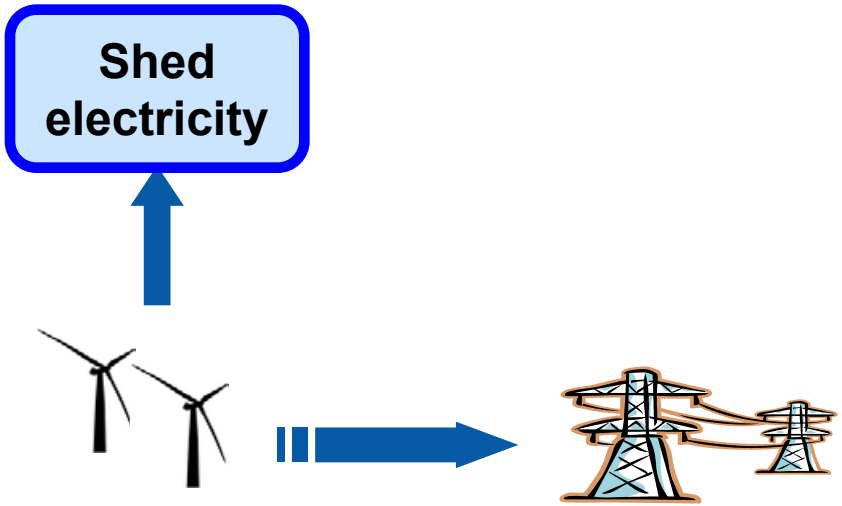


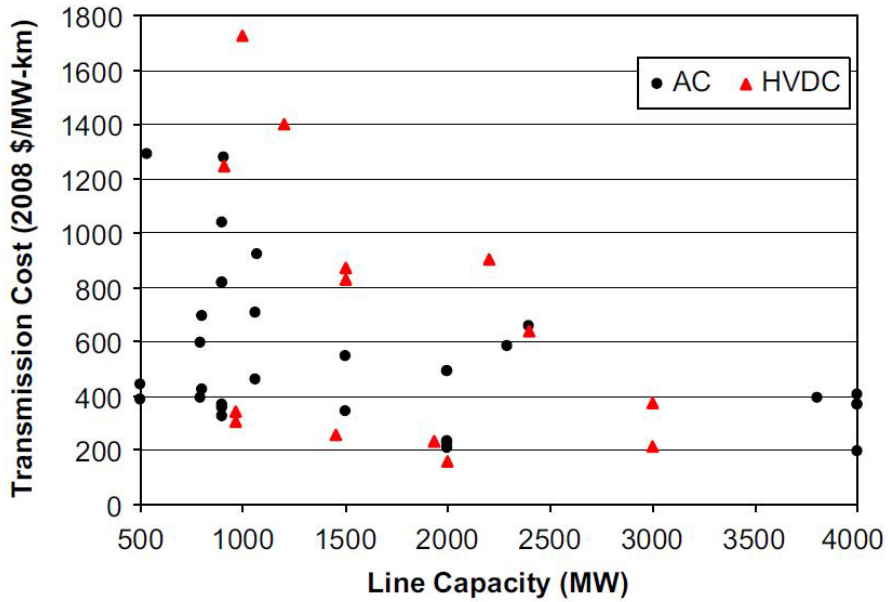
Hydrogen Storage System – Geologic Storage Accessibility



The wind farm sits above a saline reservoir. Therefore, transport of the hydrogen to the storage site is assumed to be negligible.

Configure a Base Case Without Storage



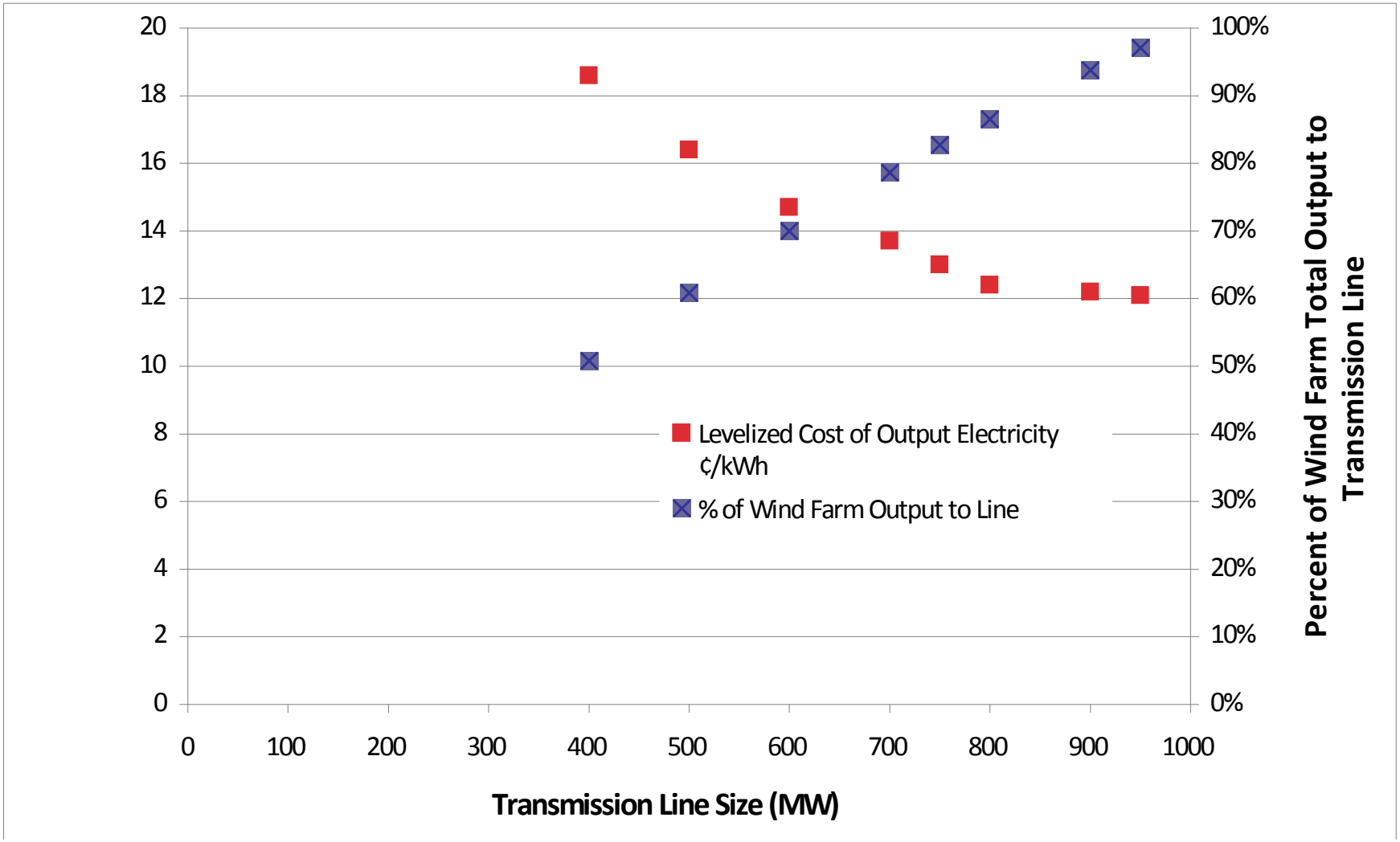


*Source: P. Denholm, R. Sioshansi, Energy Policy 37 (2009) 3149-3158

Base Case Configuration

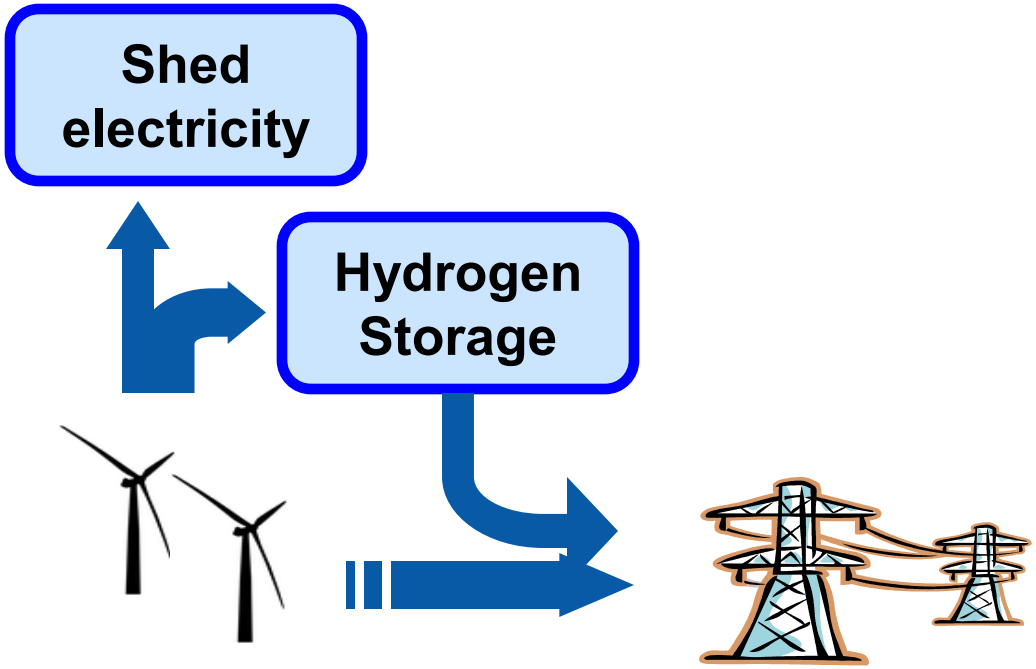
- 1,000 MW nameplate wind farm capacity (~50% capacity factor)
- Power from the wind farm is routed to the transmission line up to the maximum capacity of the line (MW)
- Power from the wind farm will be curtailed (shed) if it exceeds the maximum capacity of the transmission line
- Transmission line is 750 MW maximum capacity (~ 1.5x wind farm average output)

Base Case (wind farm without storage) – Effect of Transmission Line Size & Cost



- The benefit of increasing the transmission line size decreases as the transmission line size approaches 100% of the nameplate capacity of the wind farm (1,000 MW)

Primary Study Assumptions



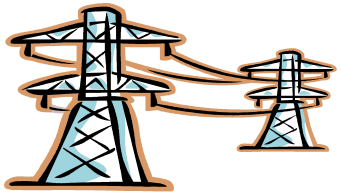
Major Assumptions

- Electrolyzer and PEM fuel cell performance and cost values derived from mid-cost case of lifecycle cost analysis
- Hydrogen storage in geologic storage
- The storage system is located at the wind farm & all electricity charged to the storage system is derived from the wind farm
- A dedicated transmission line carries electricity from the wind farm/storage system to the grid near demand centers.
- Power from the wind farm will be curtailed (shed) if:
  - It exceeds the maximum charging rate of the storage system + maximum capacity of the transmission line
  - The storage system is full

Preliminary Results for the Base Case

Shed electricity

Curtailed electricity
17.3% of total wind farm output



Electricity to grid
82.7% of total wind farm output

Nearly 20% of the wind farm output is lost even with a transmission line capacity of 1.5X average output

Preliminary Results for the Storage Constrained Case

Almost all of the wind output is captured

Configuration

- Hydrogen storage capacity is 400 MT hydrogen (~ 1 day)
- Transmission line is 750 MW maximum capacity (~ 1.5x wind farm average output)

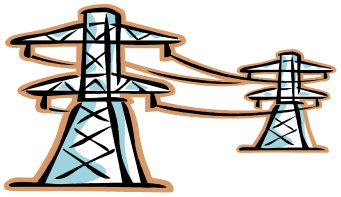
	Installed Cost ($/kW)	LHV Efficiency
Electrolyzer (200 MW)	$450	53
Fuel Cell (200 MW)	$800	53

Curtailed electricity
2% of total wind farm output

Shed electricity

Hydrogen Storage

Electricity to storage
16% of total wind farm output
Electricity from storage
5% of total output



Electricity to grid (storage + direct)
87% of total wind farm output

Preliminary Results for the Transmission Constrained Case

Larger storage system does not fully compensate for smaller transmission line

Curtailed electricity
11.7% of total wind farm output

Shed electricity

Hydrogen Storage

Electricity to storage
27.5% of total wind farm output
Electricity from storage
7.4% of total output

Electricity to grid (storage + direct)
68.2% of total wind farm output

Configuration

- Hydrogen storage capacity is 2,600 MT hydrogen (~ 1 week)
- Transmission line is 500 MW maximum capacity (~ 1.0x wind farm average output)

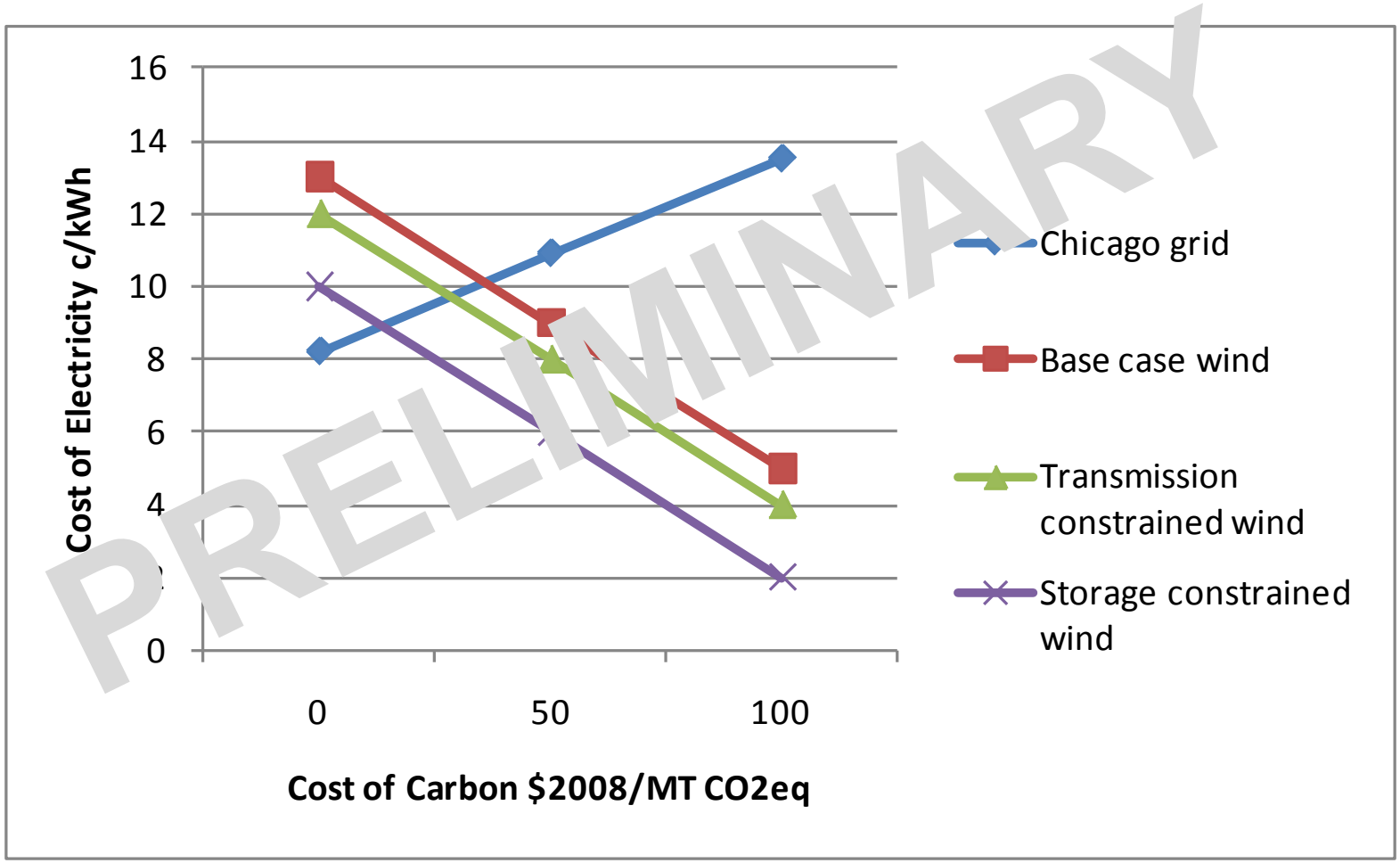
Summary of Preliminary Results

Storage reduces the amount of electricity that must be curtailed and reduces the LCOE

	Base Case	Storage Constrained	Transmission Constrained
	(% of Total Wind Farm Output)		
Electricity Direct from Wind Farm to Transmission Line	82.7	82.7	60.8
Electricity from Storage	N/A	4.5	7.4
Electricity Shed	17.3	1.9	11.7
Net Electricity to Transmission Line	82.7	87.2	68.2
	(% of Total Transmission Line Capacity)		
Transmission Line Utilization	56.0	59.0	69.0
	(LCOE ¢/kWh)		
Without cost of carbon	13	10	12
@ cost of carbon $50/MT CO2eq	9	6	8
@ cost of carbon $100/MT CO2eq	5	2	4

Effect of a Cost of Carbon on the Competitiveness of Wind & Hydrogen Storage System

Credit for avoided emissions reduces LCOE for wind electricity below grid price



Cost comparison for Chicago Grid Electricity v Wind Electricity for Various Storage Configurations

Proposed Future Work

- Develop a methodology for optimizing the size of the storage system components and transmission to minimize costs for an isolated wind farm or solar installation
- Perform an analysis for an isolated solar installation
- Compare greenhouse gas emissions/carbon tax implications for hydrogen storage and compressed air energy storage.

Thank You

Darlene Steward

Darlene.steward@nrel.gov