



# Wind Electrolysis – Hydrogen Cost Optimization



**Fuel Cell & Hydrogen  
Energy Conference**

**Washington, DC**

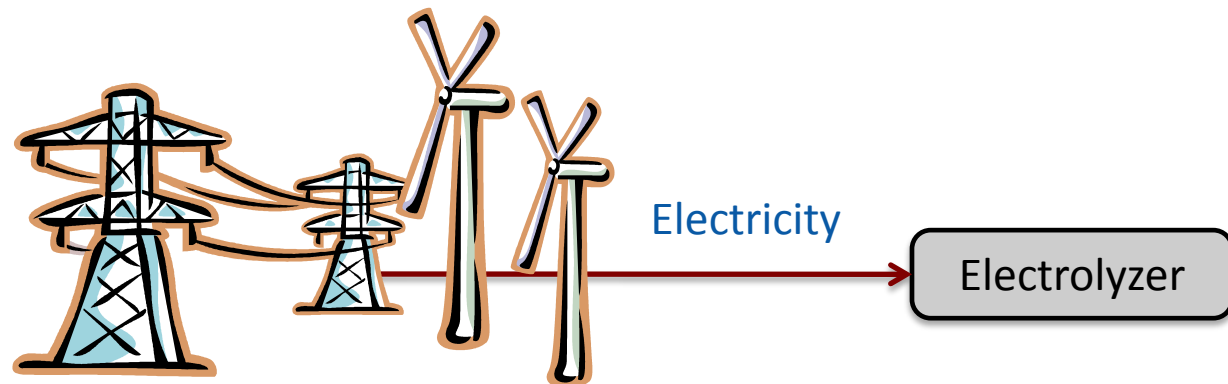
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# Project Background

- U.S. Department of Energy (DOE) and Xcel Energy's Wind-to-Hydrogen Project at NREL, part of the Renewable Electrolysis task
- Examination of a grid-tied, co-located wind electrolysis hydrogen production facility
- 4 scenarios optimize wind farm size vs electrolyzer requirements using hour-by-hour modeling



# Key Parameters - System

## 8,760 hourly analysis based upon NREL's H2A Production and Fuel Cell Power models

- Using hourly electricity market pricing and hourly wind data

## Hydrogen production facility

- 50,000 kg H<sub>2</sub>/day nominal

## 4 grid-connected wind electrolysis scenarios

- Grid supplements wind to power electrolyzers

### 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)
- \$50.1M 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

	Low Cost	Current Cost
Installed wind turbine	\$1,148/kW	\$1,964/kW
O&M (incl replacement)	\$0.012/kWh	\$0.0074/kWh
Fixed charge rate	12.1%	12.1%

# Key Parameters - Infrastructure

## Grid Electricity Pricing

- 6 tiered structure; 3 summer, 3 winter
- \$0.039/kWh to \$0.099/kWh
- “hotter” hours = higher price

Summer rates definitions

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Sunday	6	6	6	6	6	6	6	6	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	6
Monday	6	6	6	6	6	6	6	6	5	5	5	5	5	4	4	4	4	4	4	5	5	5	5	6
Tuesday	6	6	6	6	6	6	6	6	5	5	5	5	5	4	4	4	4	4	4	5	5	5	5	6
Wednesday	6	6	6	6	6	6	6	6	5	5	5	5	5	4	4	4	4	4	4	5	5	5	5	6
Thursday	6	6	6	6	6	6	6	6	5	5	5	5	5	4	4	4	4	4	4	5	5	5	5	6
Friday	6	6	6	6	6	6	6	6	5	5	5	5	5	4	4	4	4	4	4	5	5	5	5	6
Saturday	6	6	6	6	6	6	6	6	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	6

Hour

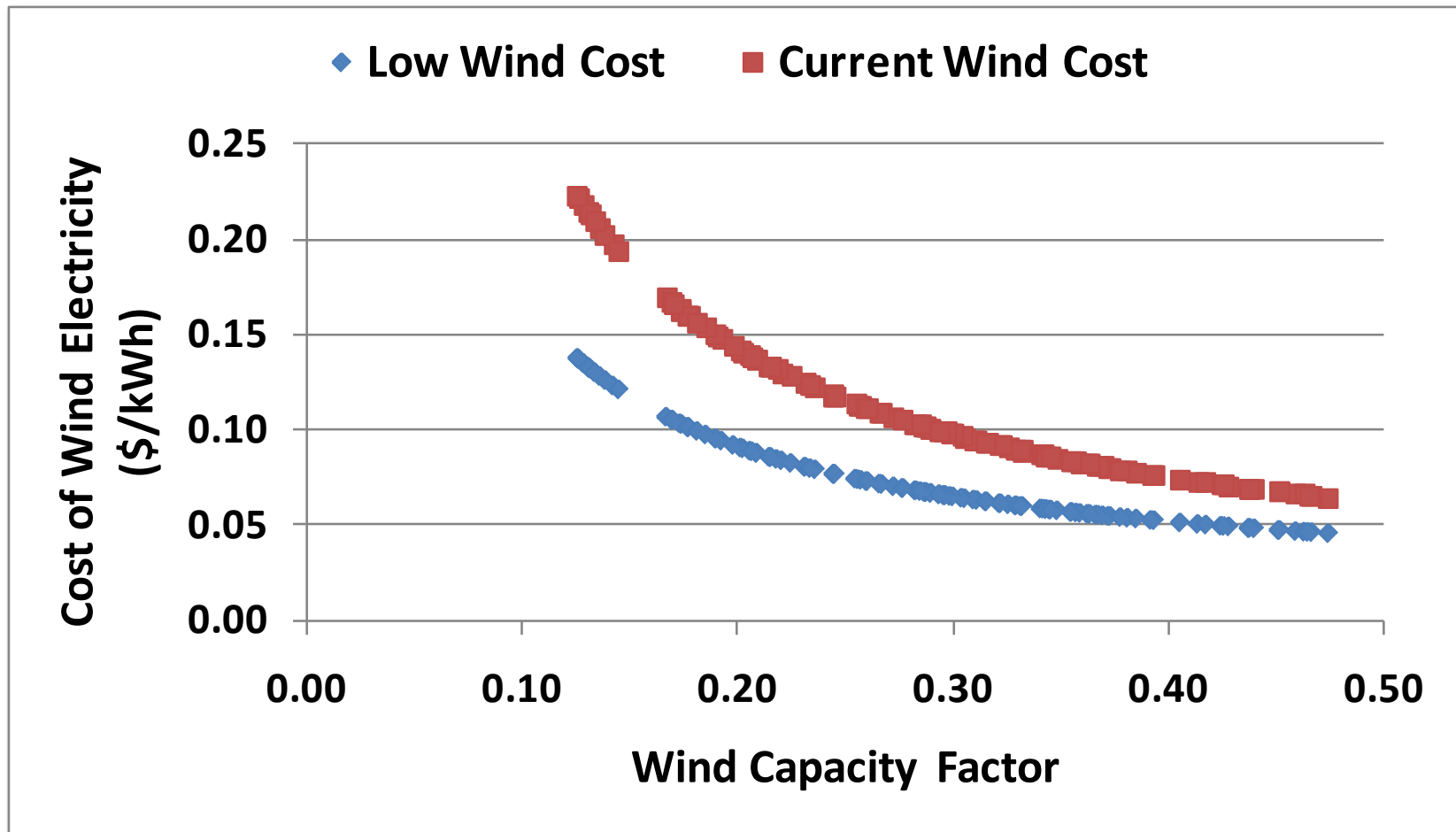
Winter rates definitions

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Sunday	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	1	1	1	1	2	2	2
Monday	3	3	3	3	3	2	2	2	2	2	1	1	1	2	2	2	2	2	1	1	1	2	2	3
Tuesday	3	3	3	3	3	2	2	2	2	2	1	1	1	2	2	2	2	2	1	1	1	2	2	3
Wednesday	3	3	3	3	3	2	2	2	2	2	1	1	1	2	2	2	2	2	1	1	1	2	2	3
Thursday	3	3	3	3	3	2	2	2	2	2	1	1	1	2	2	2	2	2	1	1	1	2	2	3
Friday	3	3	3	3	3	2	2	2	2	2	1	1	1	2	2	2	2	2	1	1	1	2	2	3
Saturday	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	1	1	1	1	2	2	2

# Key Parameters - Infrastructure

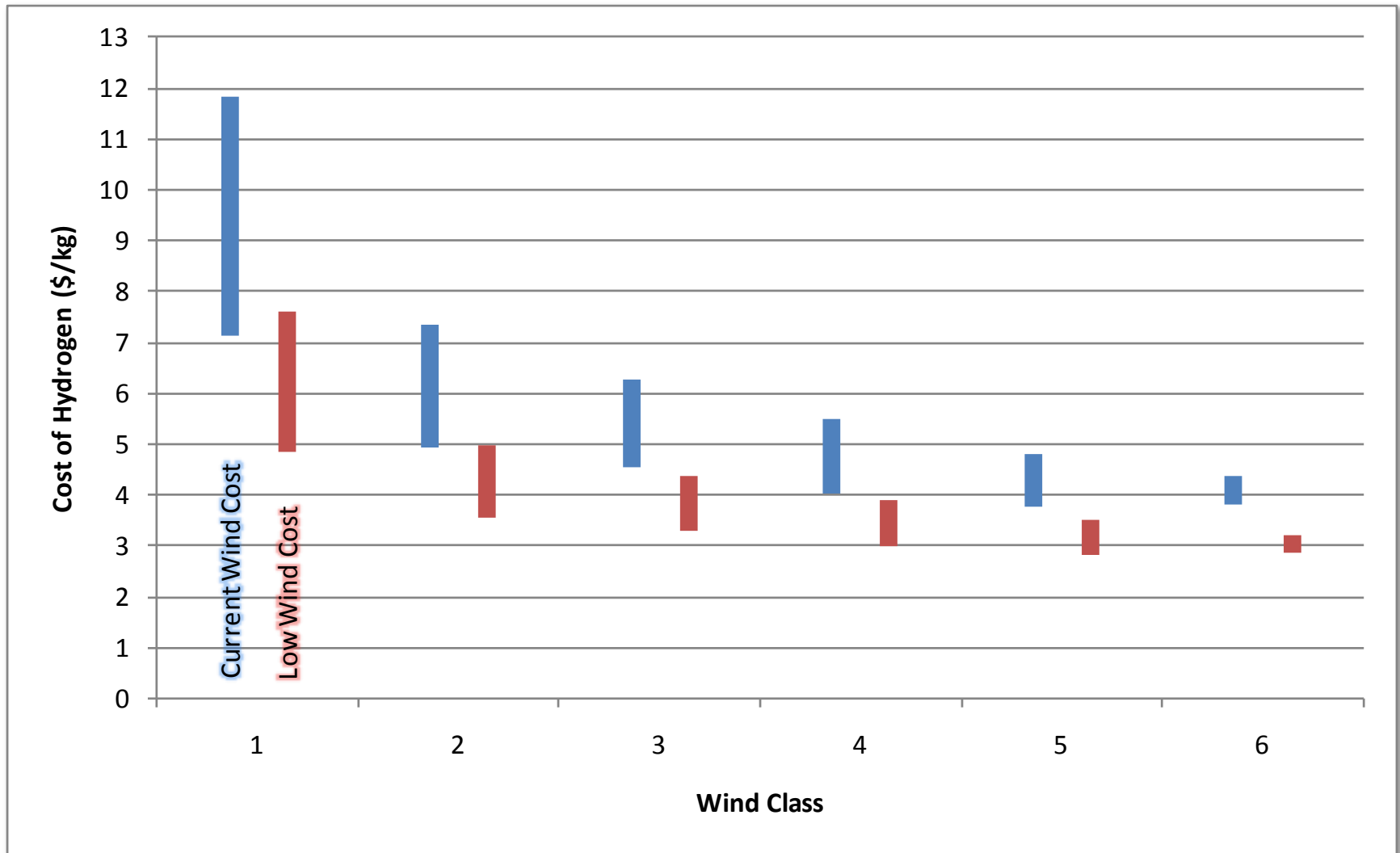
## Wind Profiles

- NREL's Western Wind data set
- 136 sites in California, class 1 to class 6



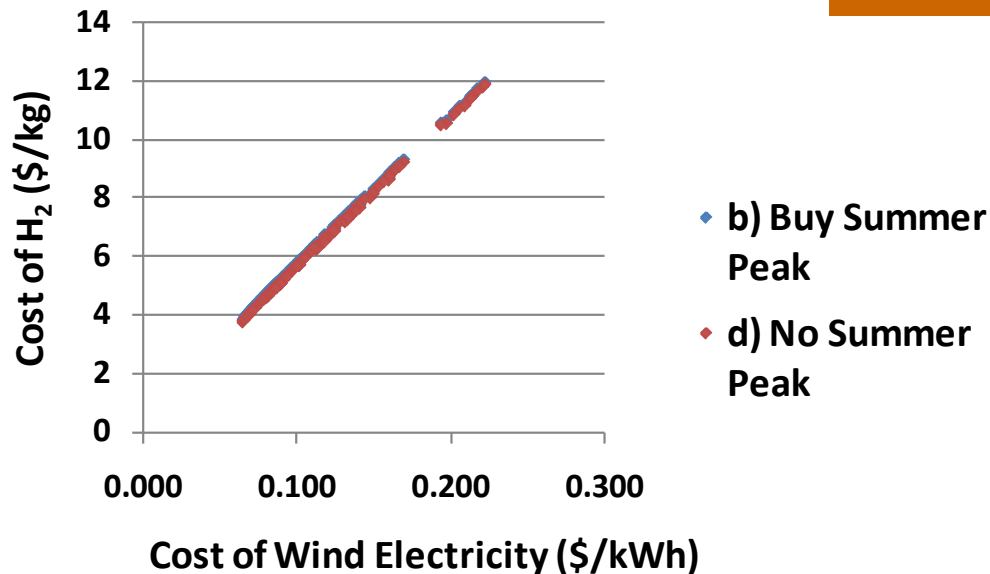
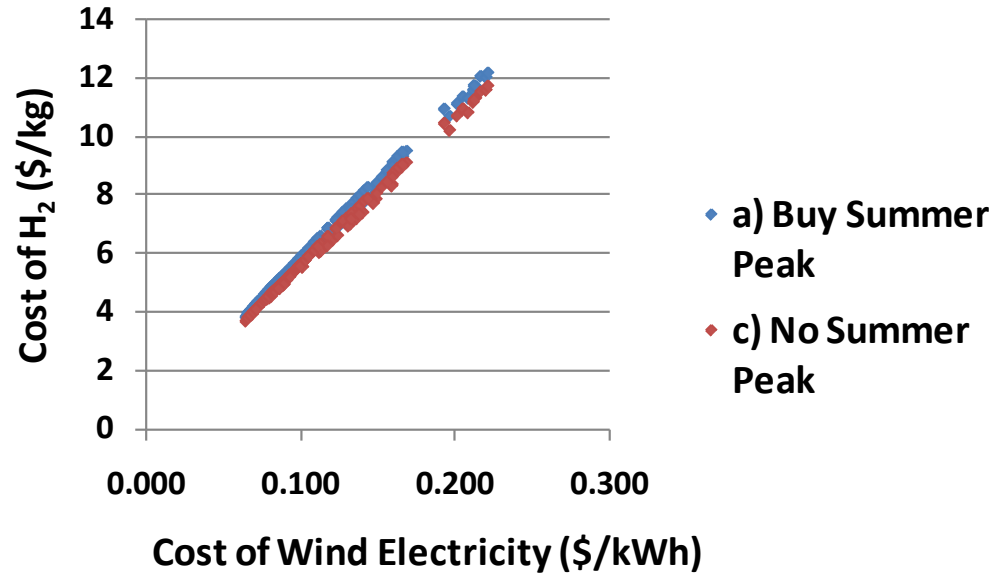
# Results - Comparison

## Power Balanced Scenario – range of costs



# Results – Current Wind Costs

## Cost Balanced Scenarios



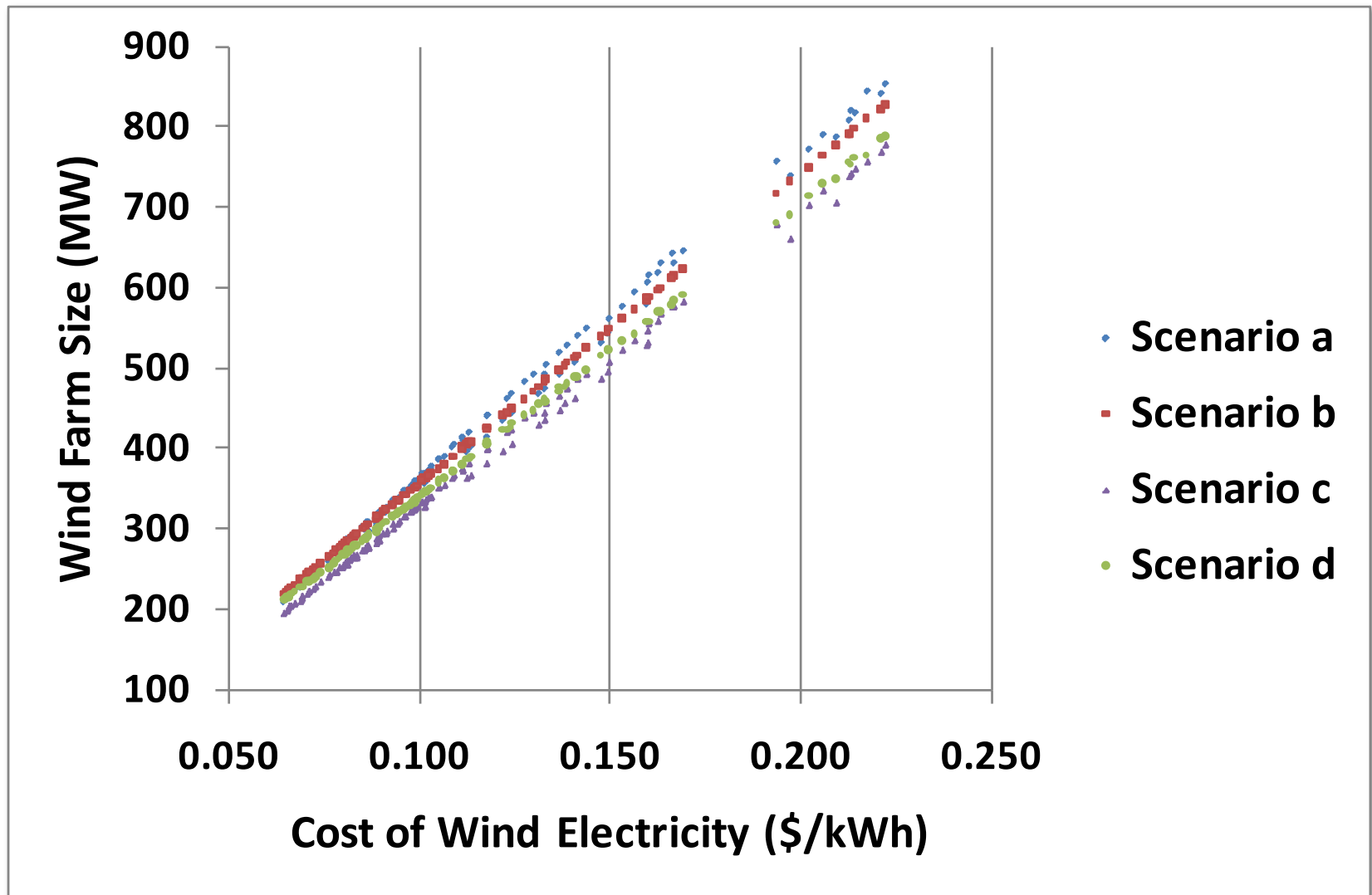
## Power Balanced Scenarios





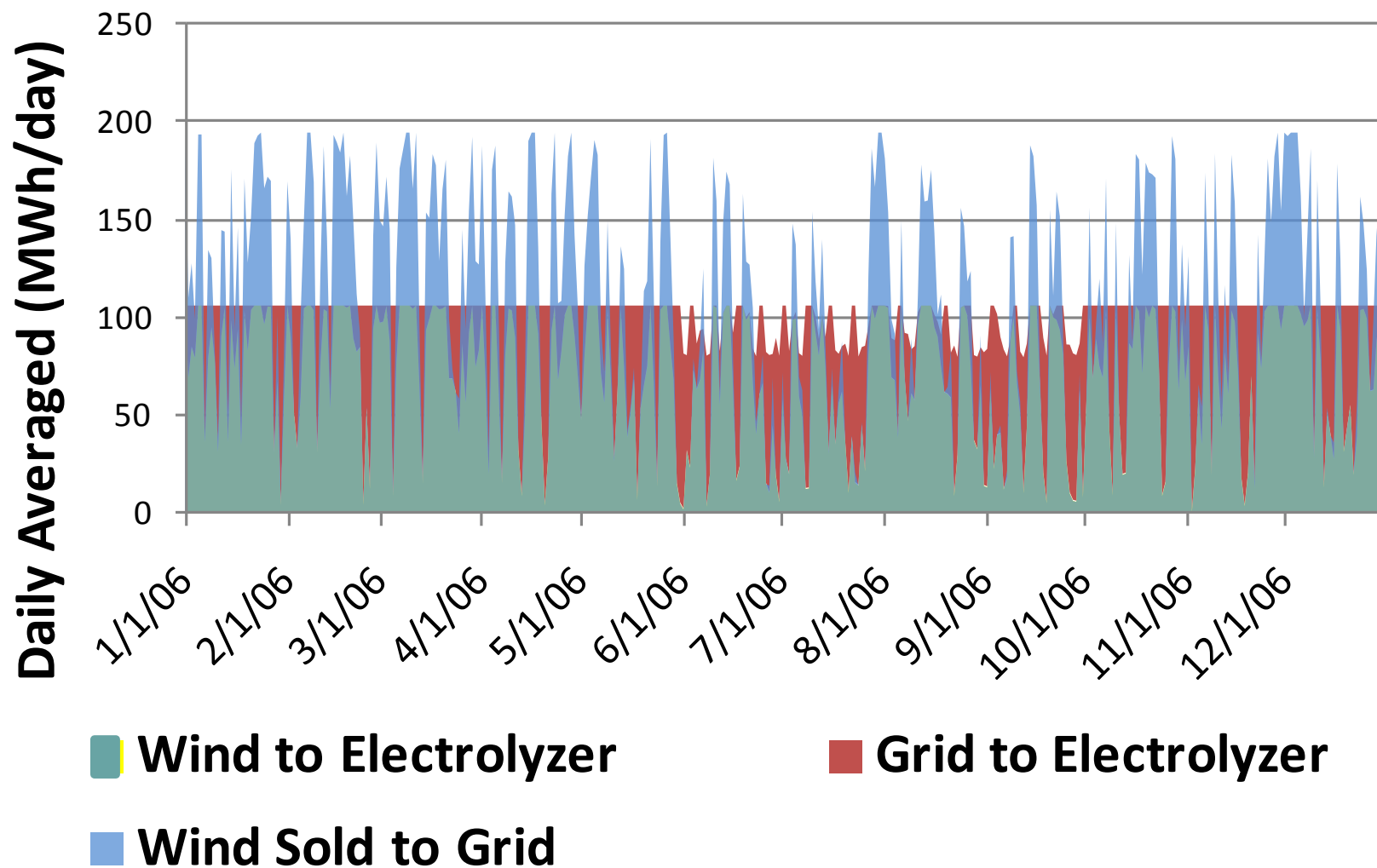
# Results – Scenario Details

## Wind Farm Sizes to Produce 50,000 kg/day H<sub>2</sub>



# Results – Case Example

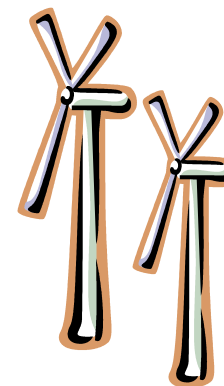
## Averaged Yearly Profile



# Results – Case Example

## Wind Site Details

- **Class 5 wind site with capacity factor 47%**
- **Average wind speed at 100 m 8.5 m/s**
- **Produces electricity for \$0.064/kWh**

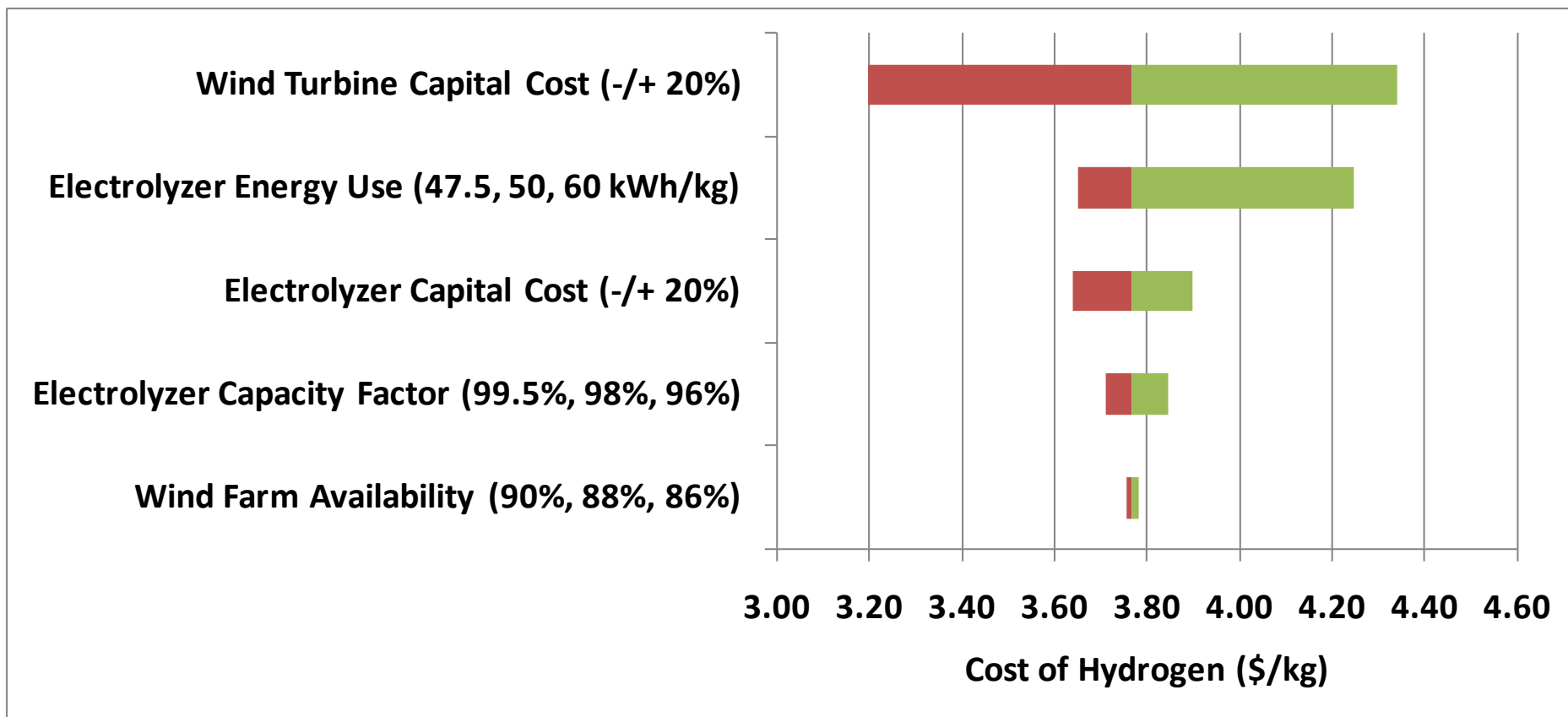


Scenario	Wind Farm Size (MW)	# 3-MW Turbines	Grid Utilization (%)	Unmet H2 Production (kg/yr)	Cost of H2 (\$/kg)
(a) Cost-Balanced—Buy Summer Peak	210	70	94	0	3.80
(b) Power-Balanced—Buy Summer Peak	219	73	102	0	3.82
(c) Cost-Balanced— No Summer Peak	195	65	100	622,000	3.72
(d) Power-Balanced—No Summer Peak	213	71	120	602,000	3.77

# Results – Case Sensitivity

## Sensitivity for power balanced case

- Baseline optimization and sizing held constant
- Other scenarios show similar ranges



# Acknowledgements

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