



ASAP
(American Solar Action Plan)

West Texas PV-Wind Electrolytic Hydrogen System

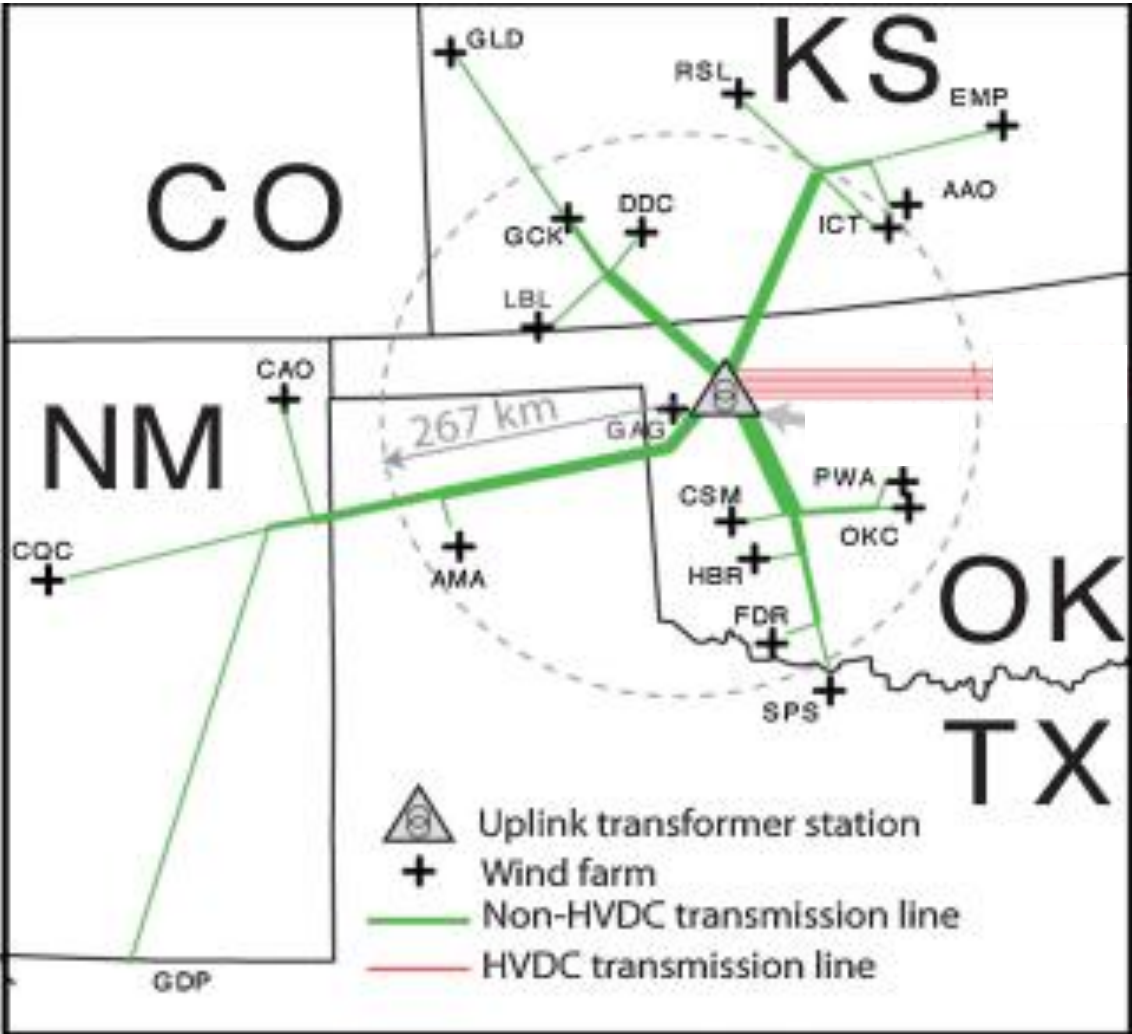
September 2024
James Mason, Ph.D.

ASAP

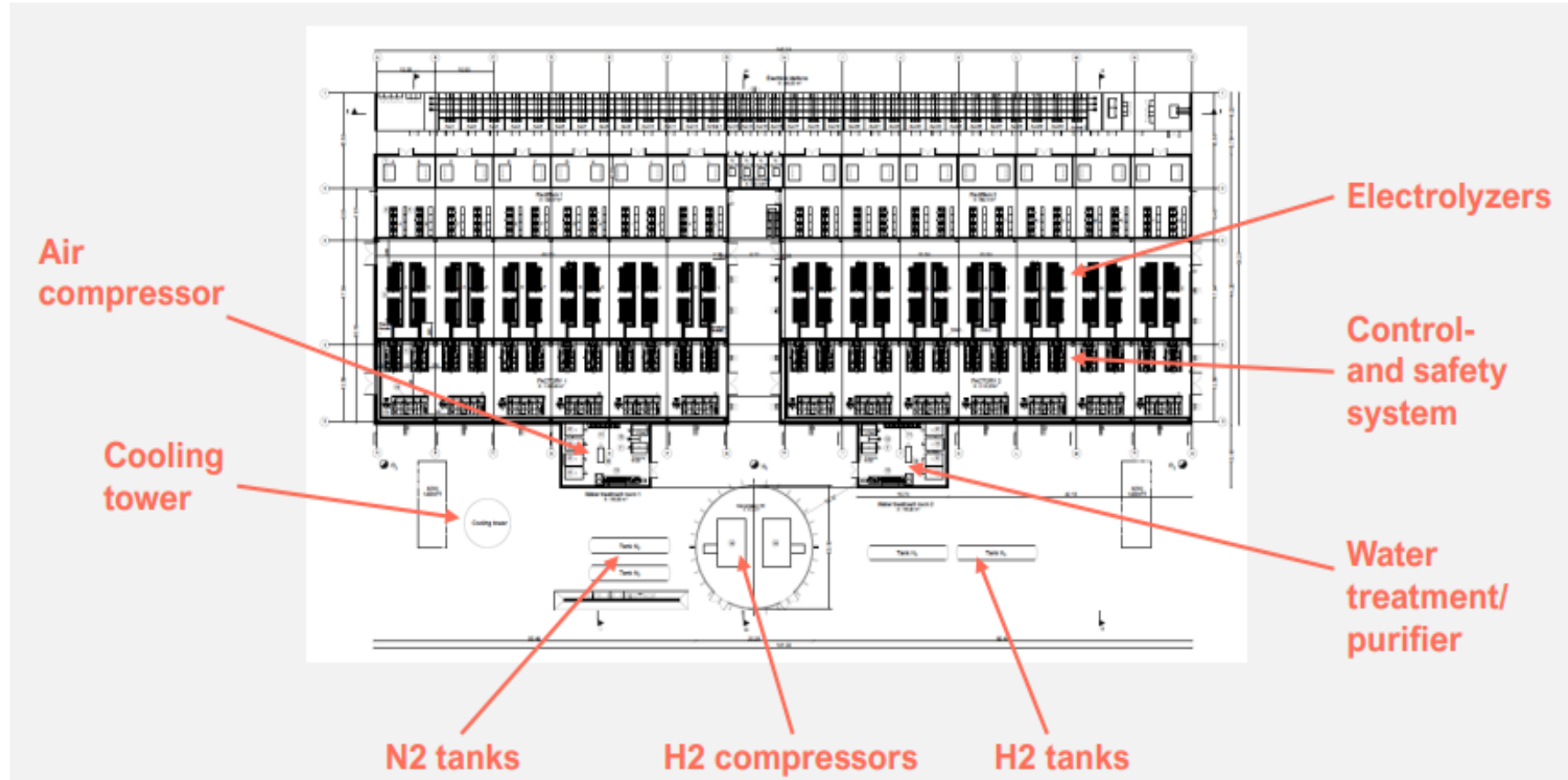
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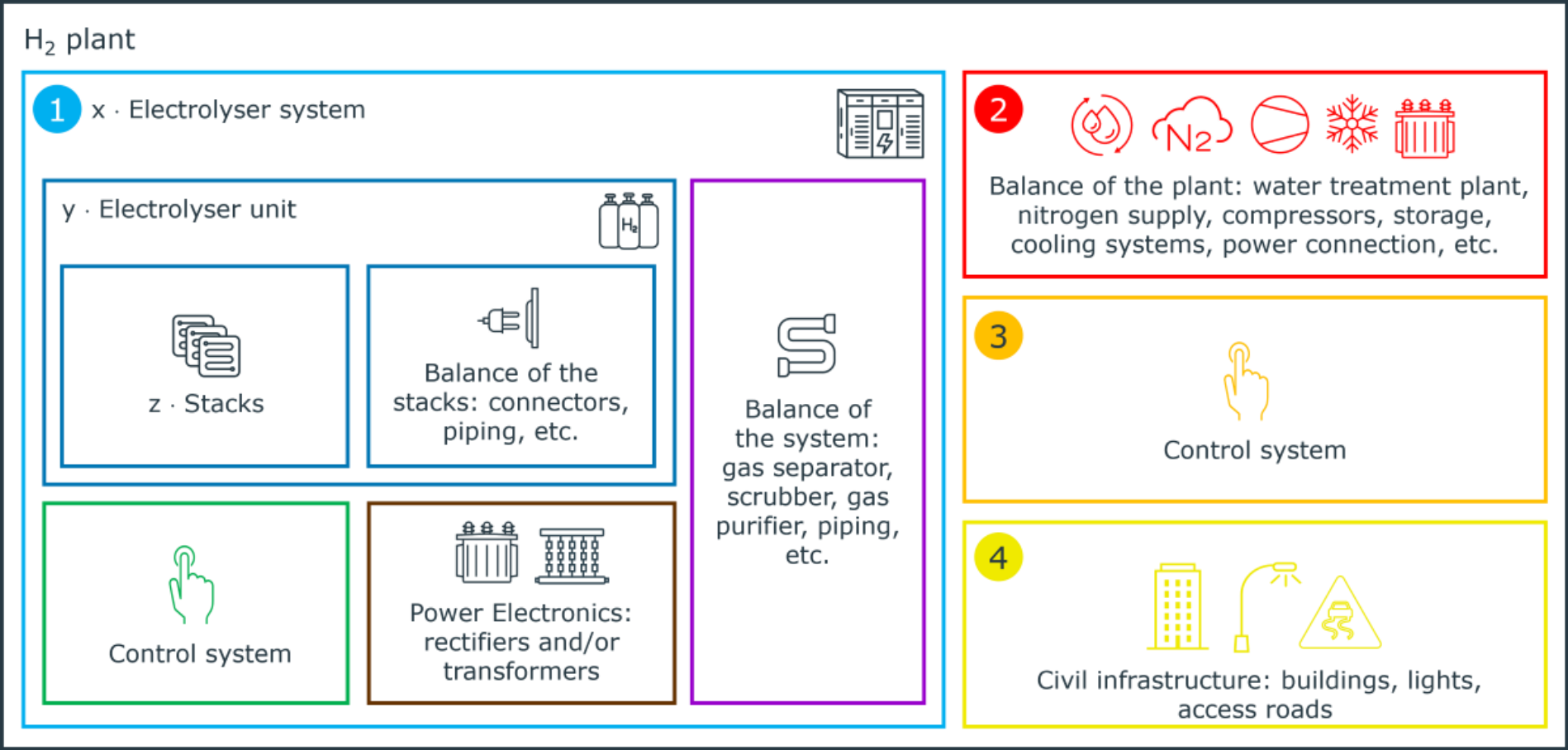
Premier PV-Wind Electrolytic Hydrogen Production Hub



Hydrogen Electrolysis Plant



Components of a Hydrogen Electrolysis Plant



Components of a PV/Wind Electrolytic Hydrogen Plant



<u>Electrolysis Plant Components</u>	<u>Cost</u>	<u>Electricity Consumption (kWh/kg H₂)</u>	<u>Lifetime (Yrs)</u>
2025 – Electrolysers (\$/kW _{dc-in})	\$450	43 Stack / 13 BOP / 55.60 System	50
2030 – Electrolysers (\$/kW _{dc-in})	\$405	41 Stack / 9 BOP / 50.04 System	50
dc-dc Transformers and Rectifiers			
Electricity Control Panels and Wiring			
Control and Safety System			
Air Compressor			
Hydrogen Compressor			
Cooling Tower			
Nitrogen Storage			
Hydrogen Storage			
Water Treatment/Purifier			
Lye Storage and Water Mixing Units			
Water/Lye Pumps			
Electrolyser Buildings			
Administration Building			
Grounds Parking and Landscaping			
PV and Wind Farms (\$/kW)	\$900 PV – \$1,200 W		50 PV – 25 W

PV-Wind Electrolytic Hydrogen System Capacity

Scaled for 100,000 tpa of Delivered Hydrogen

Effect of Electrolysis Plant Efficiency – 55.6 Avg kWh/kg H2; 50.04 Avg kWh/kg H2



	Electrolyser Capacity (MW)	PV Capacity (MW)	Wind Capacity (MW)	Hydrogen (Mtpa)
<u>55.6 kWh/kg</u>				
Wind	1,700	0	2,200	1.0
PV-Wind	1,200	1,500	1,500	1.0
PV	1,900	3,300	0	1.0
<u>50.04 kWh/kg</u>				
Wind	1,400	0	2,200	1.0
PV-Wind	1,100	1,300	1,300	1.0
PV	1,700	3,000	0	1.0

CAPEX Wind and PV Electrolytic Hydrogen System

Scaled for 100,000 tpa of Delivered Hydrogen with a 50-Year Operating Life

2025: Electrolysers \$450/kW_{dc-in} Wind Farm \$1,200/kW_{dc-out} PV Plant \$900/kW_{dc-out}
 2030: Electrolysers \$405/kW_{dc-in} Wind Farm \$1,200/kW_{dc-out} PV Plant \$900/kW_{dc-out}
 600 Mile Pipeline – \$2,000,000/mile (10% Allocation); Two Salt Storage Caverns – \$100,000,000
 Six Heavy Freight Truck Fueling Stations – \$90,000,000



2025						
	Electrolysis Plant	PV Plant	Wind Farm 1st Gen	Wind Farm 2nd Gen (40%)	Downstream Components	Total CAPEX
Wind	\$765,000,000	\$0	\$2,640,000,000	\$1,056,000,000	\$373,600,000	\$4,834,600,000
PV-Wind	\$540,000,000	\$1,350,000,000	\$1,800,000,000	\$720,000,000	\$373,600,000	\$4,783,600,000
PV	\$855,000,000	\$2,970,000,000	\$0	\$0	\$373,600,000	\$4,198,600,000
2030						
Wind	\$630,000,000	\$0	\$2,640,000,000	\$1,056,000,000	\$373,600,000	\$4,699,600,000
PV-Wind	\$495,000,000	\$1,170,000,000	\$1,560,000,000	\$624,000,000	\$373,600,000	\$4,222,600,000
PV	\$765,000,000	\$2,700,000,000	\$0	\$0	\$373,600,000	\$3,838,600,000

Financial Assumptions for Hydrogen Cost Estimates

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Discount Rate - Weighted Average Cost of Capital

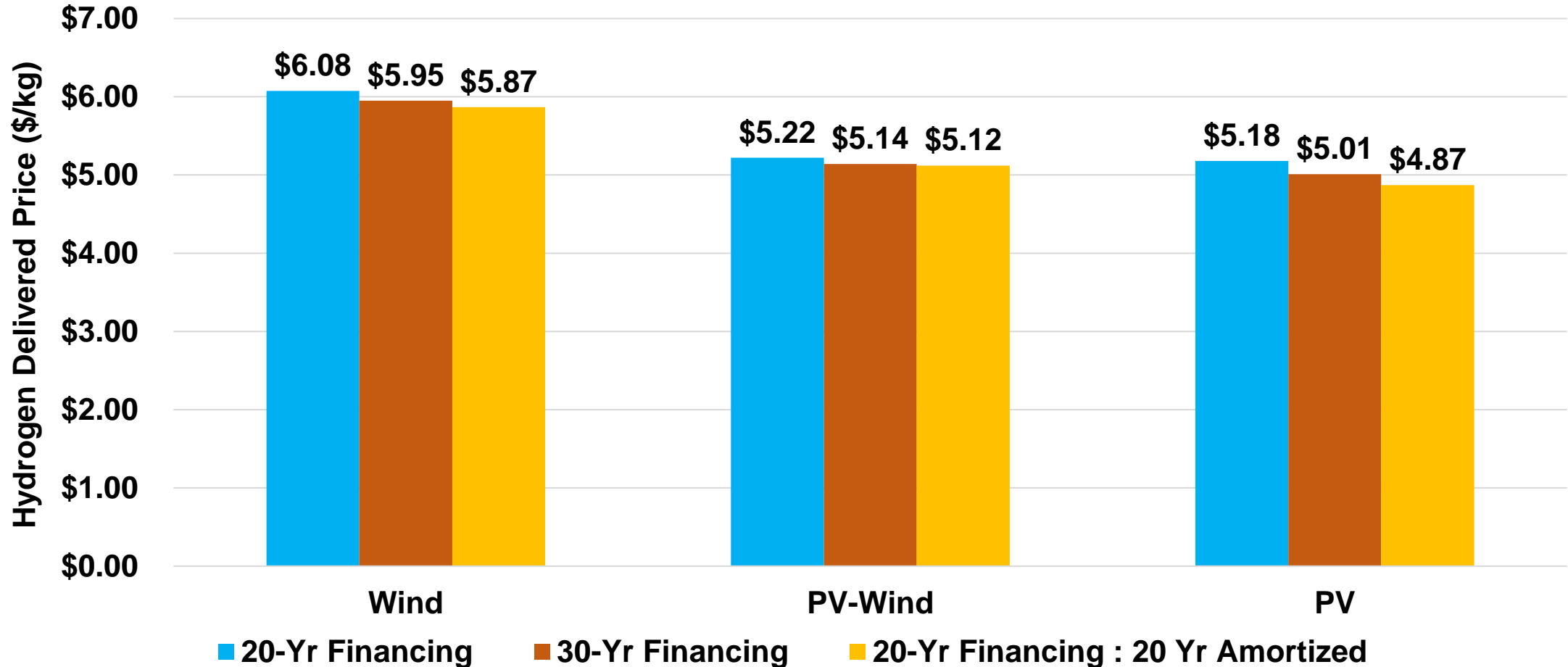
Discount Rate	10.4%
Annual Inflation	3.0%
Capital Recovery Period	20 Years
<u>Capital Structure</u>	
% Equity Capital	5.0%
% Debt Capital	95.0%
<u>Cost of Capital</u>	
Cost of Equity Capital	12.0%
Cost of Debt Capital	9.0%
Federal/State Income Tax Rate (Federal = 21%, Texas State Franchise Tax = 0.75%)	21.75%
CAPEX Depreciation	MACRS 20-yr
Electrolysis Plant Operation (% of Year)	95.0%

West Texas PV-Wind Electrolytic Hydrogen Delivered Price Estimates

Effect of Project Financing – 20 Years; 30 Years; 20 Years + 20 Years Amortization

2025: Electrolysis Plant – \$450/kW; 55.6 kWh/kg (1%/a Degradation)

Electricity Cost: PV \$0.035/kWh; Wind \$0.050/kWh; Wt. Avg. PV-Wind \$0.0435/kWh



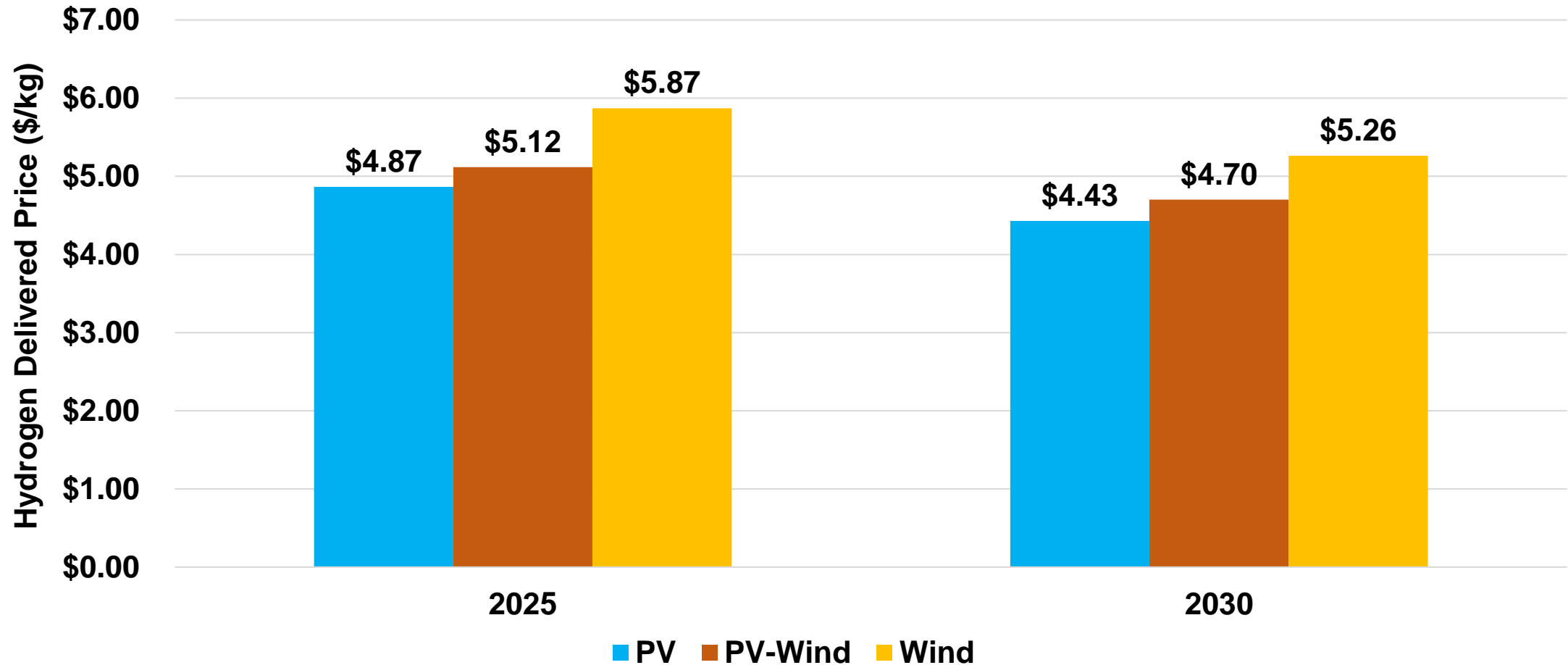
West Texas PV-Wind Electrolytic Hydrogen Delivered Price Estimates

Project Financing – 20 Years; Project Amortization – 20 Years

2025: Electrolysis Plant – \$450/kW; 55.6 kWh/kg (1%/a Degradation)

2030: Electrolysis Plant – \$405/kW; 50.04 kWh/kg (1%/a Degradation)

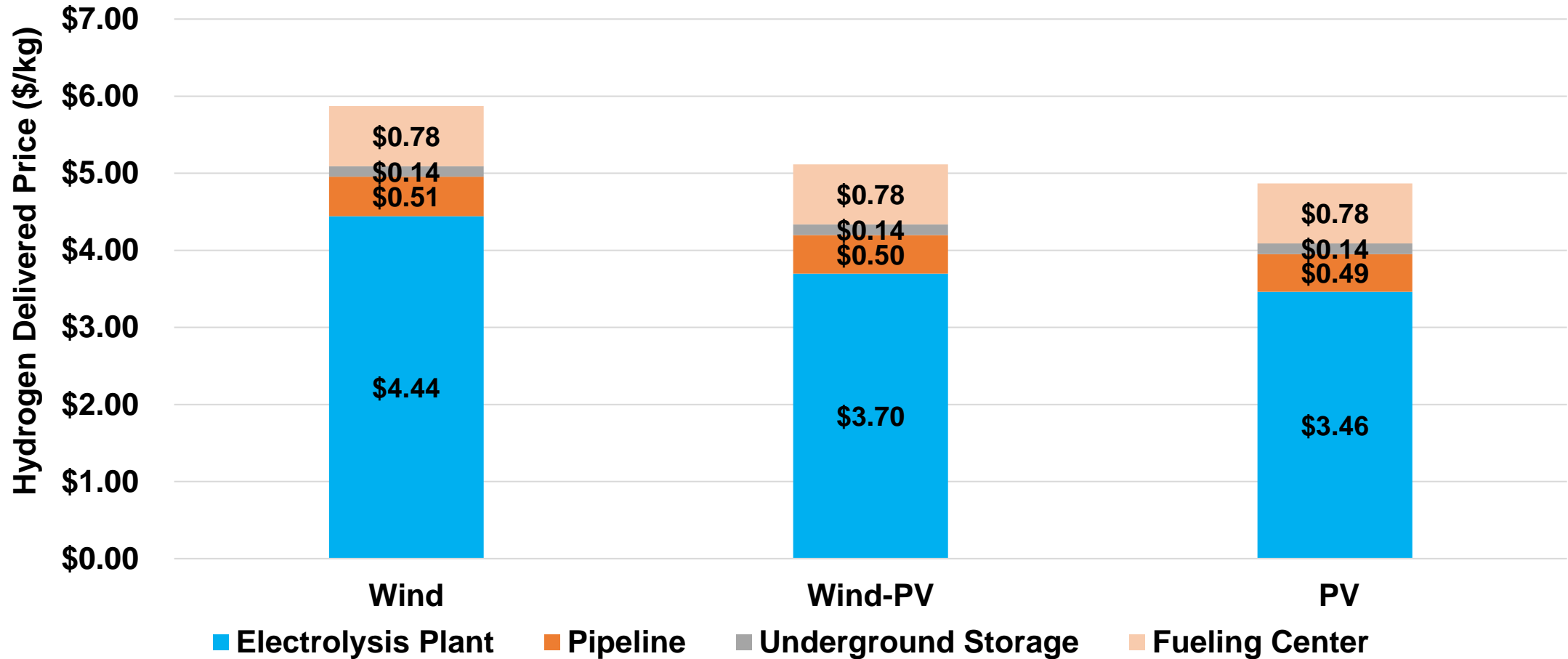
Electricity Cost: PV \$0.035/kWh; Wind \$0.050/kWh; Wt. Avg. PV-Wind \$0.0435/kWh



West Texas PV-Wind Electrolytic Hydrogen System

Baseline Electrolysis Plant – \$450/kW, 55.6 kWh/kg (1%/a Degradation)

Electricity Cost: Wind \$0.050/kWh; PV \$0.035/kWh; Wt. Avg. Wind-PV \$0.0435/kWh

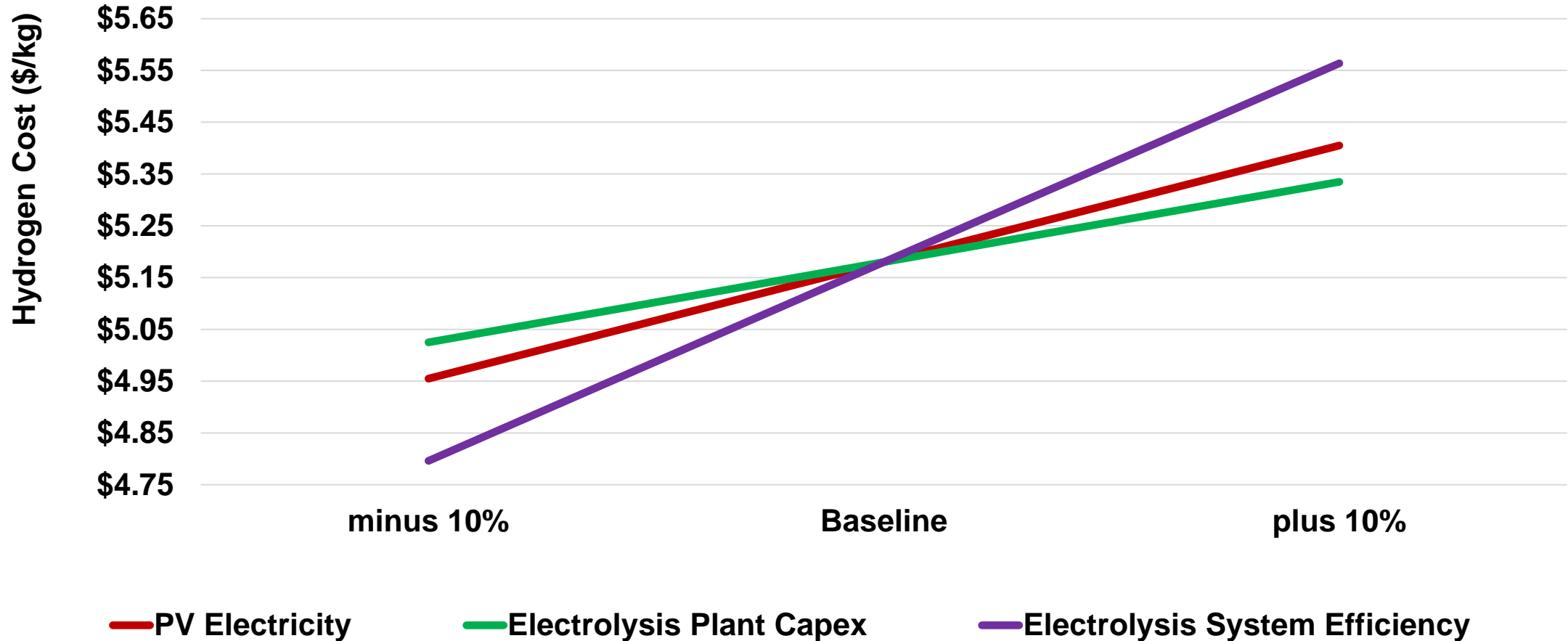


Sensitivity Analysis of PV Electrolytic Hydrogen Production Cost

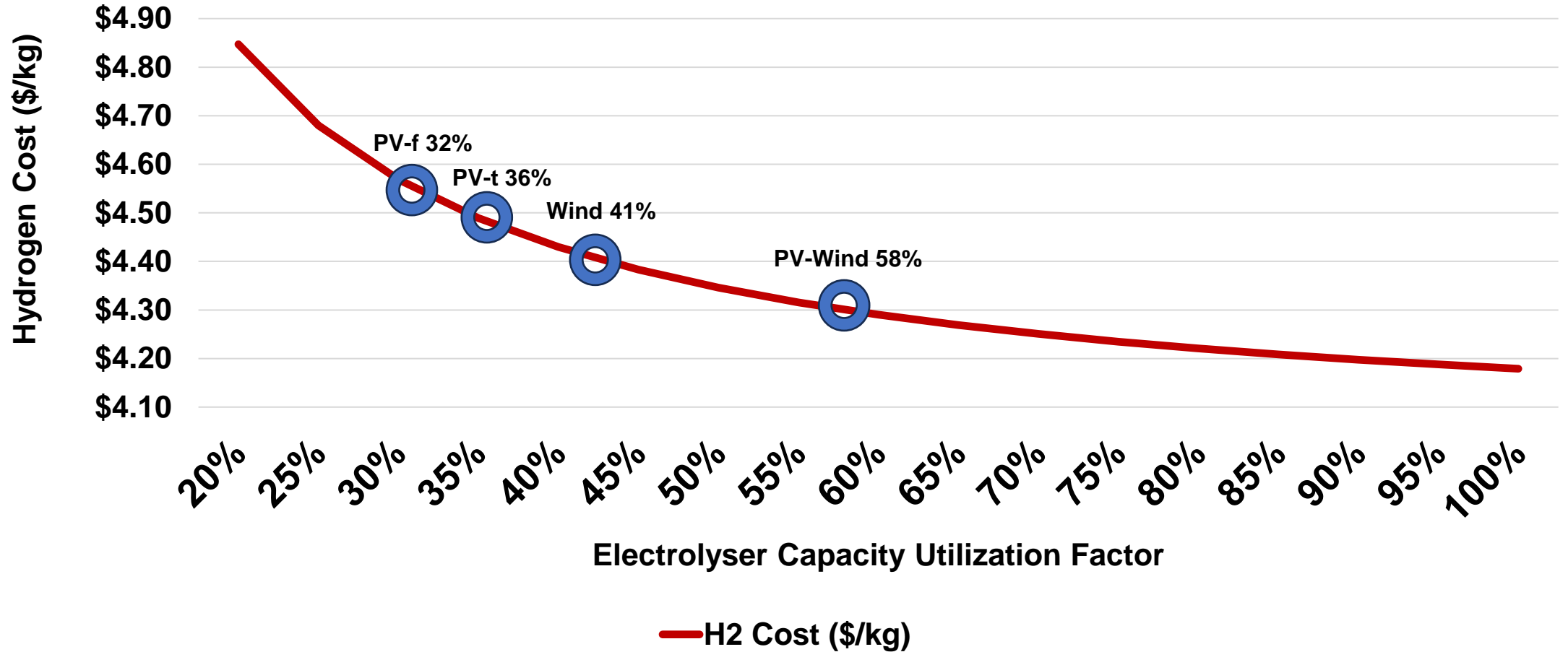
+/- 10% Component Change

Electrolysis Plant Capex \$405/kW-\$500/kW; PV Electricity Cost \$0.0315-\$0.0385

Electrolyser System Efficiency 50.04 kWh/kg-61.16 kWh/kg

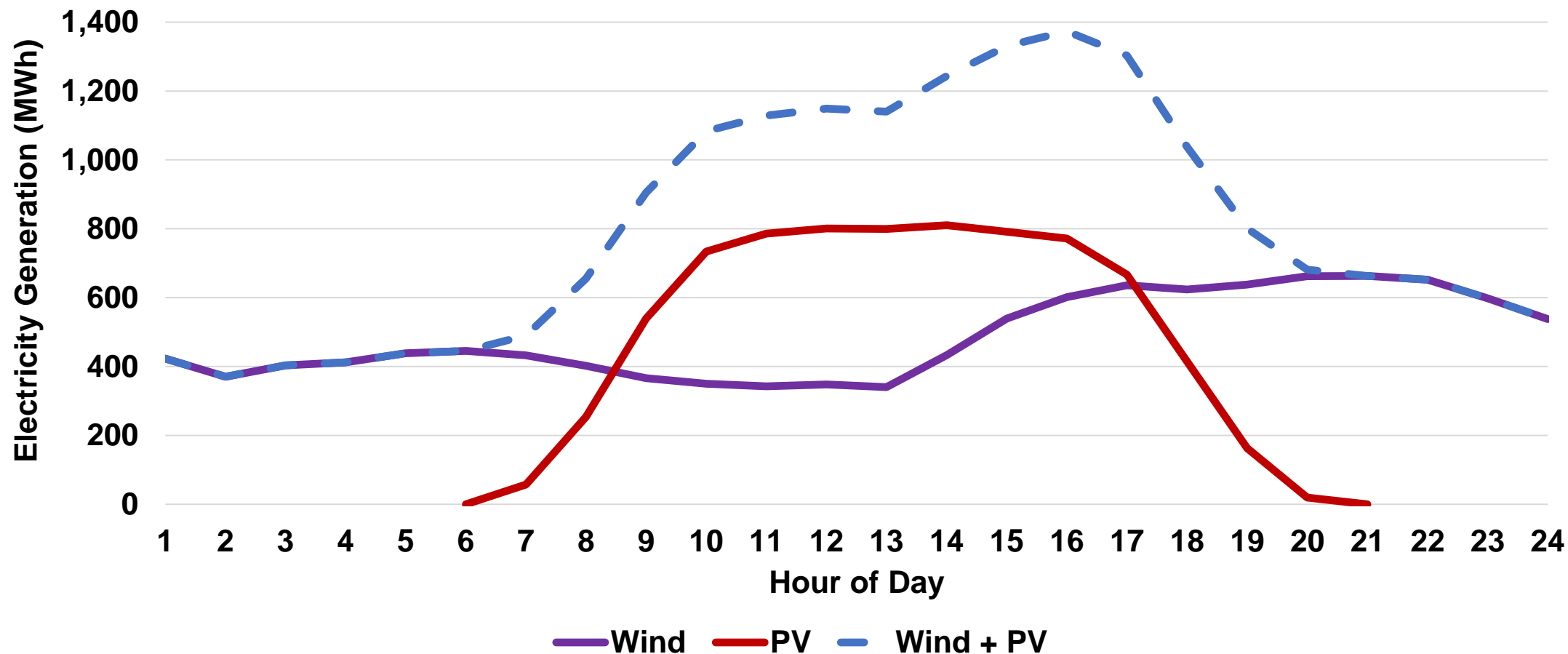


Sensitivity of Hydrogen Cost to Electrolyser Capacity Factor



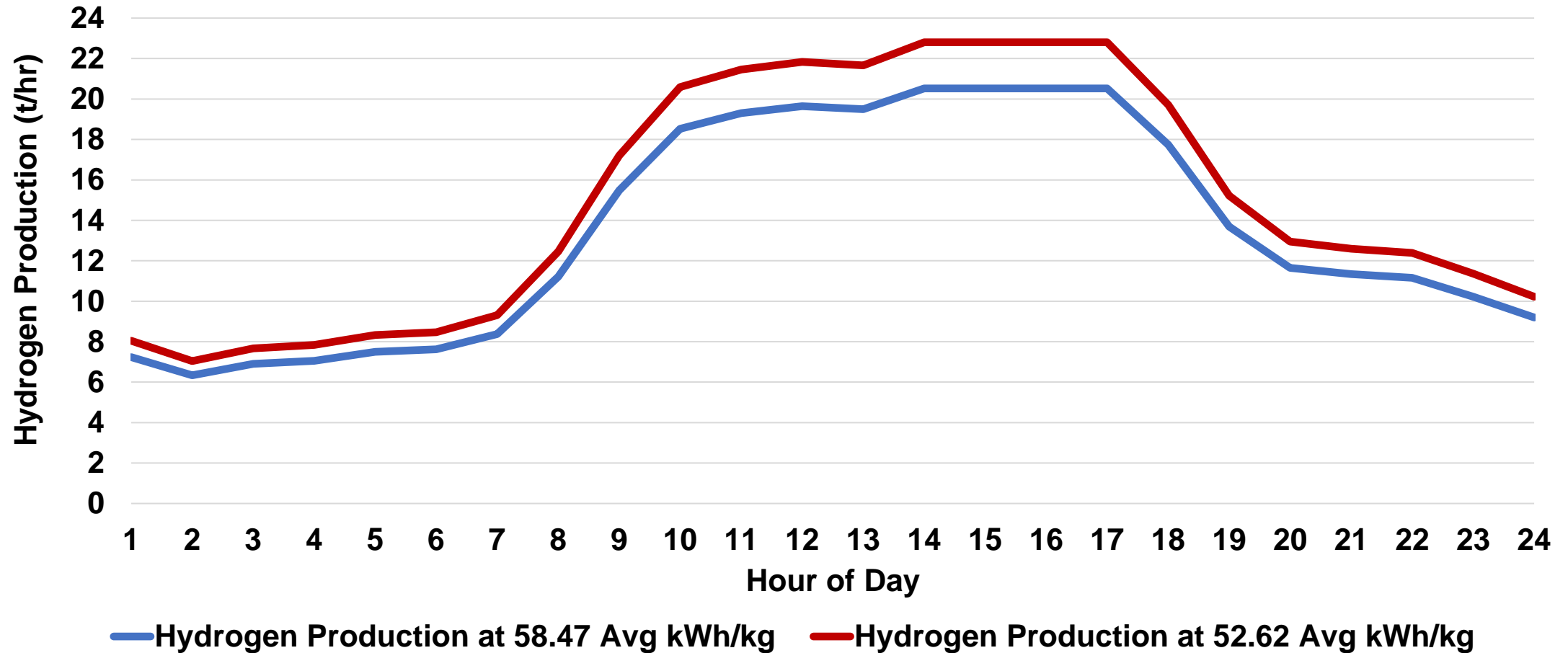
Wind and PV Electricity Generation

Daily Average for 1.5 GW PV and 1.5 GW Wind with PV and Wind Additions to Offset Degradation



Wind-PV Daily Average Hydrogen Production

Scaled to Deliver 100,000 tpa Hydrogen
1.2 GW Electrolysis Plant; 1.5 GW Wind Farm; 1.5 GW PV Plant



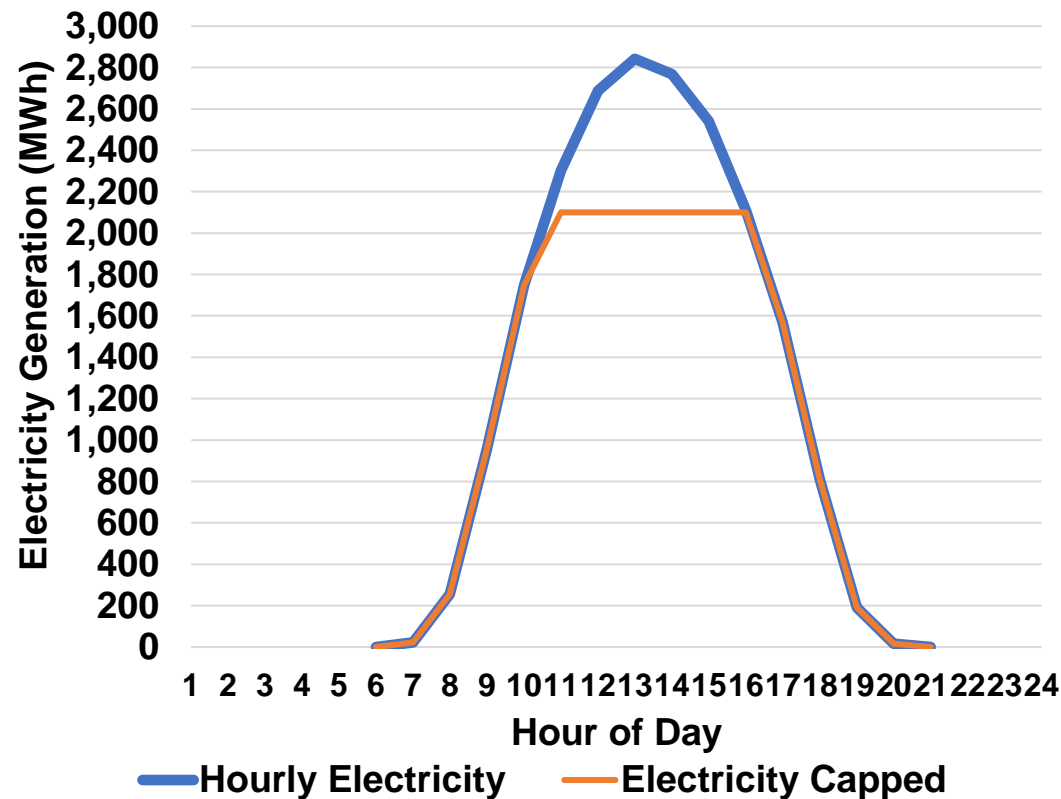
PV Electricity Generation – Fixed Mount and Single-Axis Tracking

Which Produces Lowest Cost Electrolytic Hydrogen?

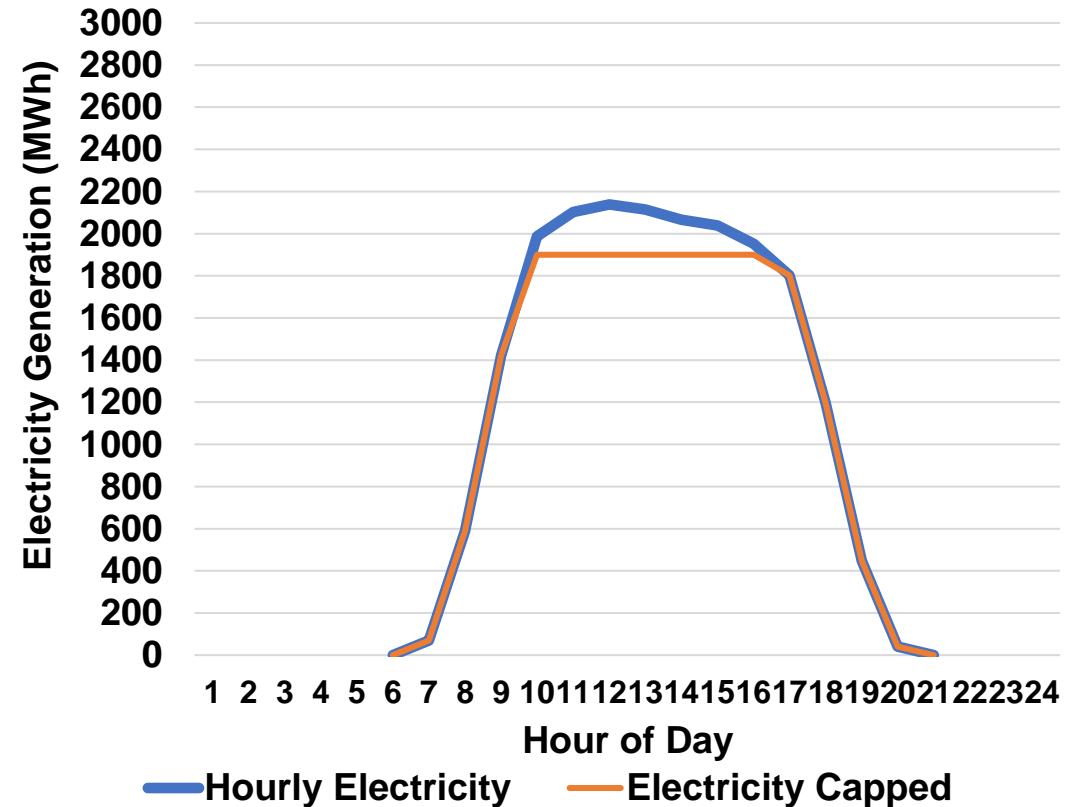


100,000 tpa Hydrogen Production with Annual PV Additions to Offset Degradation

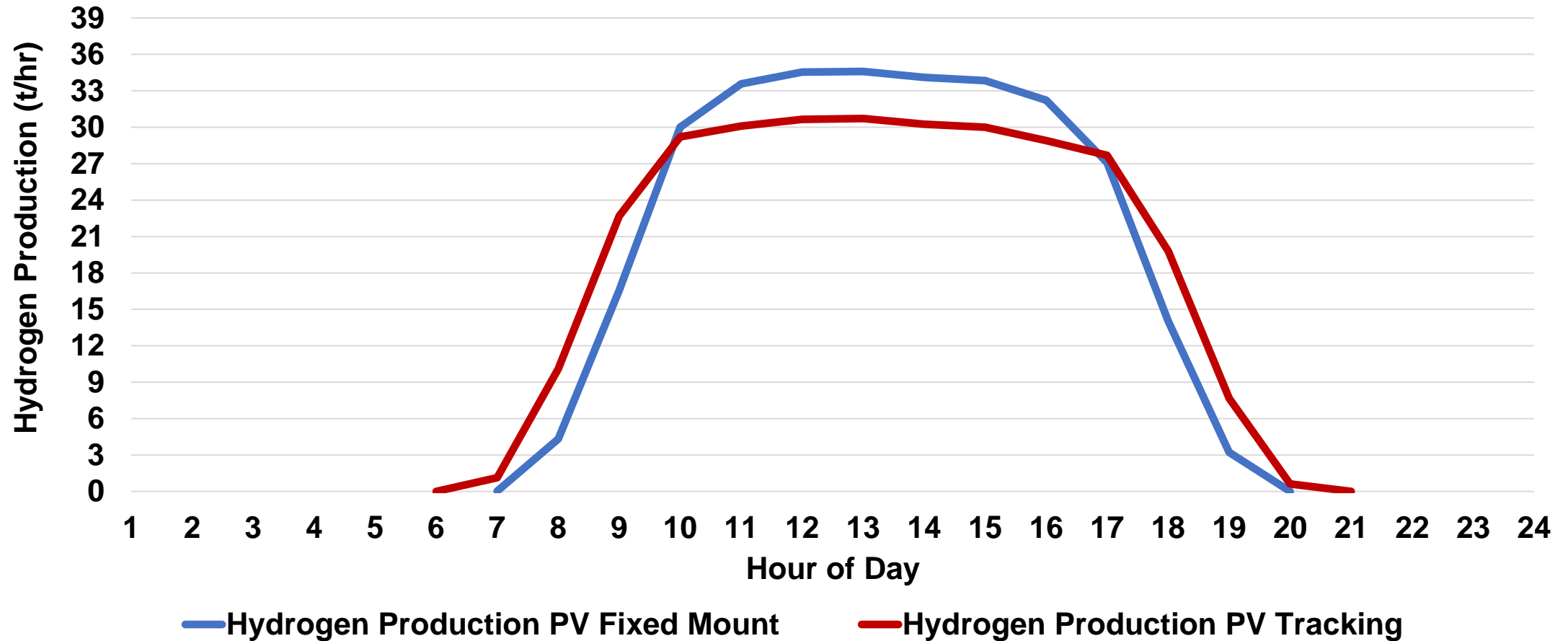
PV Fixed Mount



PV with Single-Axis Tracking



Daily Average PV Hydrogen Production Scaled to Deliver 100,000 tpa Hydrogen



Electrolytic Hydrogen System Assumptions

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Electrolysis Plant Operation (% of Year)	95%
Electrolyser Annual Degradation Rate (%/a)	1.0%
System Fugitive Hydrogen Loss Rate (%/a)	3.0%
Compressors Powered by Grid Electricity (Grid Electricity Cost)	\$0.09/kWh
Pipeline Compressor Stations (Miles between Stations)	50
Underground Salt Storage 2 45-Mcf Sites (tonnes Working Gas H2 Storage at 1,700 psi)	16,000
Annual Hydrogen Storage Cycle (tonnes)	6,000-11,000
FC Class 8 Trucks Servicing San Antonio/Austin/Corpus Christi/Houston Freight Routes	14,400
Fueling Center Pumps (# Pumps per Center @ 2 Trucks/Hour for 24 Hours/Day)	50
Fueling Center Truck Capacity per Center (# FC Class 8 Trucks)	2,400

CAPEX PV Electrolysis Plant and Downstream Components

Scaled for 100,000 tpa of Delivered Hydrogen



<u>Capital Costs</u>	<u>Unit Cost</u>	<u>Capex</u>
Electrolyser Plant Total Installed Cost All Components (\$/kW _{dc el-in})	\$500	\$855,000,000
Electrolyser Plant Land, Site Design, and Preparation Costs		\$50,000,000
Pipeline 600 Miles (\$/mile)	\$2,000,000	
Pipeline Portion Allocated to 100,000 tpa H2 Plant	10%	\$120,000,000
16 Pipeline Compressor Stations Total Installed Cost (\$/Station)	\$3,000,000	
Pipeline Compressor Stations Portion Allocated to 100,000 tpa H2 Plant	10%	\$3,600,000
2 Underground 45-Mcf Salt Storage Caverns (\$/Cavern)	\$50,000,000	\$100,000,000
6 Fueling Centers (\$/Station)	\$15,000,000	\$90,000,000
Total Capex		\$1,218,600,000

Annual O&M Expense Estimates

Scaled for 100,000 tpa of Delivered Hydrogen



<u>Expenses</u>	Unit Expense	Total Expense
PV Electricity Electrolysis Expense (\$/kWh)	\$0.035	\$216,230,118
Electrolyser Efficiency (Avg kWh/kg H2 10-Yr Degradation)	58.47	
Electrolyser Degradation (%/annum with Rebuild Year 10)	1.0%	
Electrolysis Plant O&M (PV/Wind % Capex)	2.0%/3.0%	\$20,000,000
Pipeline O&M Expense (% Capex)	2.0%	\$3,200,000
Compression Station O&M Expense 12 Stations (% Capex)	4.0%	\$192,000
Underground Storage O&M Expense (% Capex)	2.0%	\$2,000,000
Filling Station O&M Expense 6 Stations (% Capex)	20.0%	\$18,000,000
Insurance Expense (% Capex)	0.5%	\$4,618,000
Total Expenses with 3% Annual Inflation (20-year Debt)		\$279,000,000->\$347,000,000

Hydrogen Compression Energy Estimates

Grid Electricity Expense \$0.09/kWh

Note: Compressors at Pipeline Entry Use PV Electricity (\$0.035/kWh)

All Other Compression Points Use Grid Electricity (\$0.090/kWh)



Grid Electricity Cost (\$/kWh)	\$0.090				
	Quantity	Pressure (Begin and End)	Energy		Electricity Expense
Electrolysis Plant to Pipeline	103,093 tpa	290-1000 psi	0.770 kWh/kg		\$2,778,351
Compressor Stations (16)	103,093 tpa	700-1000 psi	0.130 kWh/kg		\$19,298,969
Underground Storage (2)	10,000 tpa	900-1700 psi	0.38 kWh/kg		\$342,000
Fueling Centers (6)	100,000 tpa	900-12760 psi	1.757 kWh/kg		\$3,162,600
Total Electricity Expense					\$25,581,920

Hydrogen System Water Consumption and Expense

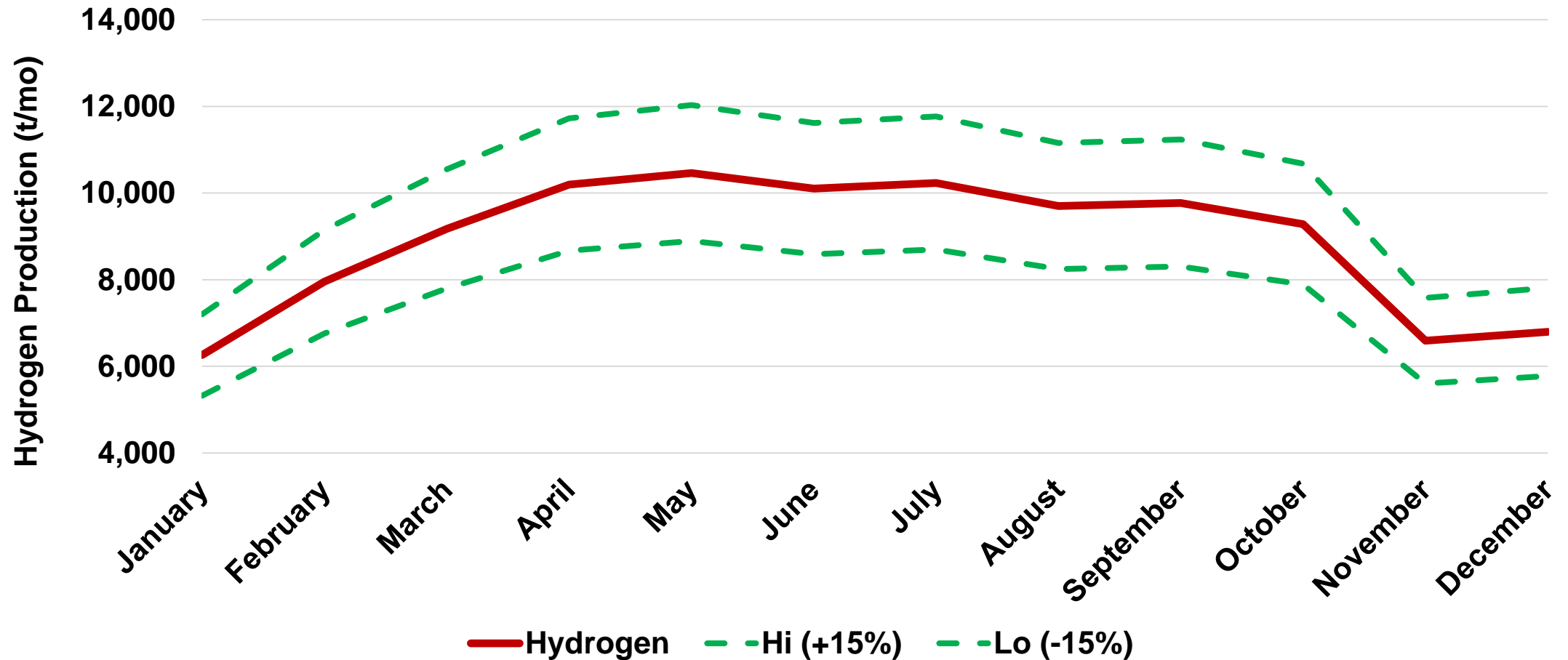
Conservative Water Cost for Gulf Coast Desalination - \$10.00/1000 gallons



Water Cost (\$/gal)	\$0.010	
	Quantity (gal)	Water Expense
Electrolyser Water Expense (11.13 liters water/kg H2)	303,117,004	\$3,031,170
Electrolyser Cooling Water Expense (300 liters water/kg H2)	7,461,433	\$74,614
Pipeline Compressor Cooling Water Expense (50 liters water/kg H2)	16,166,439	\$161,665
Storage Compressor Cooling Water Expense (50 liters water/kg H2)	278,848	\$2,788
Filling Station Compressor Cooling Water Expense (50 liters water/kg H2)	1,492,287	\$14,923
Total Water Consumption and Expense	328,516,011	\$3,285,160

Note: Tampa Bay Water Desalination Plant (25 million gpd) – Cost of Water \$8.56/1000 gallons (2024)

Panhandle Monthly Average Hydrogen Production with High and Low Estimates



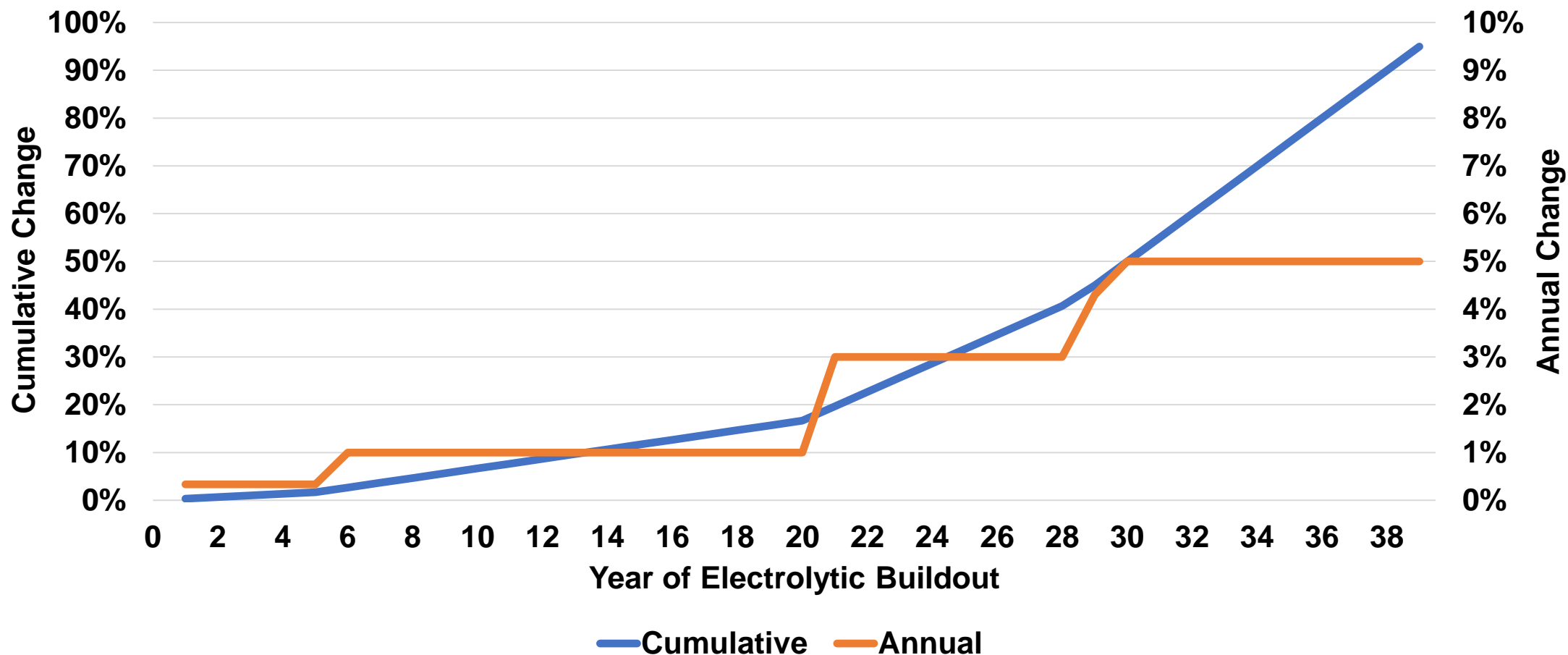
Hydrogen Storage Estimates

Assume a Constant Monthly 8,333 tonnes of Hydrogen Delivery



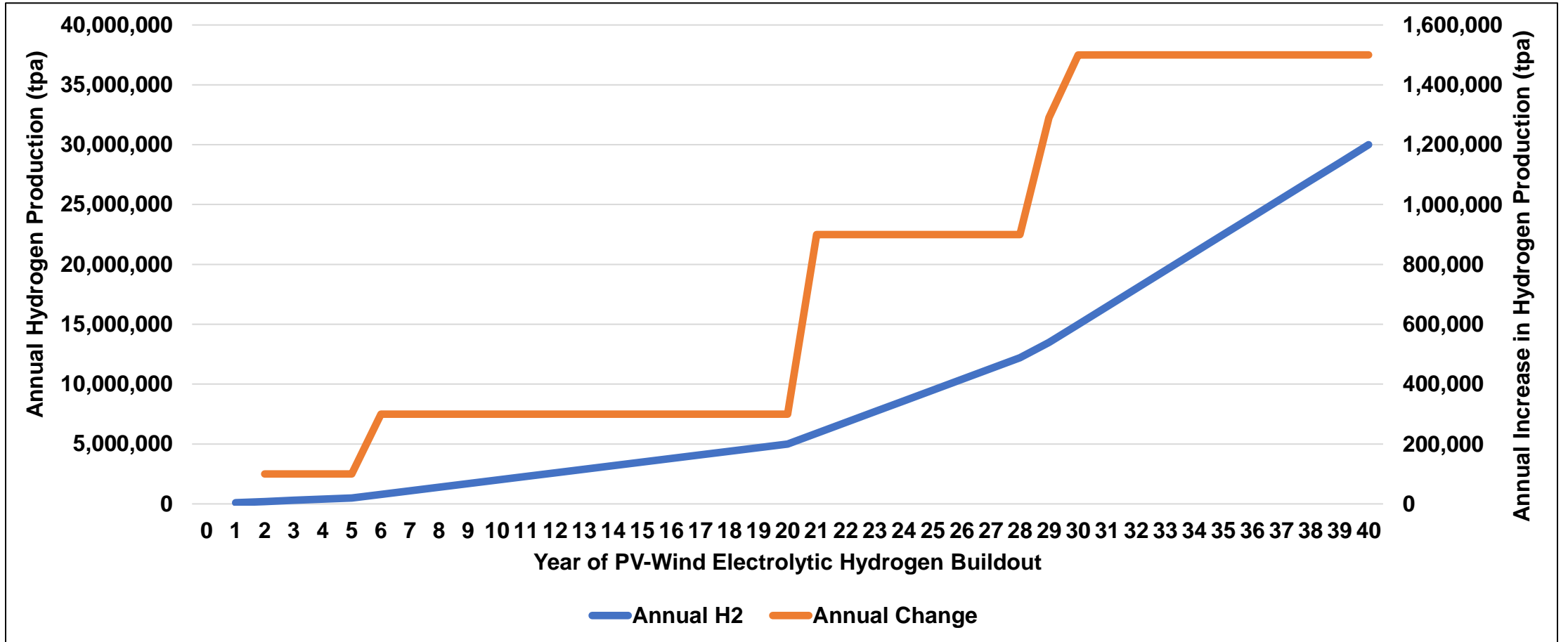
Tonnes	<u>Production</u>			<u>Storage</u>		
	Average	Hi (+15%)	Lo (-15%)	Average	Hi (+15%)	Lo (-15%)
January	6,318	7,265	5,370	2,015	1,068	2,963
February	7,978	9,175	6,781	355	0	1,552
March	9,213	10,595	7,831	0	0	502
April	10,233	11,768	8,698	0	0	0
May	10,526	12,105	8,947	0	0	0
June	10,168	11,693	8,643	0	0	0
July	10,292	11,836	8,748	0	0	0
August	9,718	11,176	8,260	0	0	73
September	9,792	11,260	8,323	0	0	10
October	9,313	10,710	7,916	0	0	417
November	6,598	7,588	5,609	1,735	745	2,724
December	6,794	7,814	5,775	1,539	519	2,558
Total (Storage)	106,943	122,984	90,901	5,644	2,332	10,798

40-Year Buildout of Electrolytic Hydrogen System For Saturation of Heavy Freight Truck Fuel Market Assume Saturation at 30 Million Tonnes of Hydrogen per Annum



40-Year Buildout of Electrolytic Hydrogen System For Saturation of Heavy Freight Truck Fuel Market

Assume Saturation at 30 Million Tonnes of Hydrogen per Annum

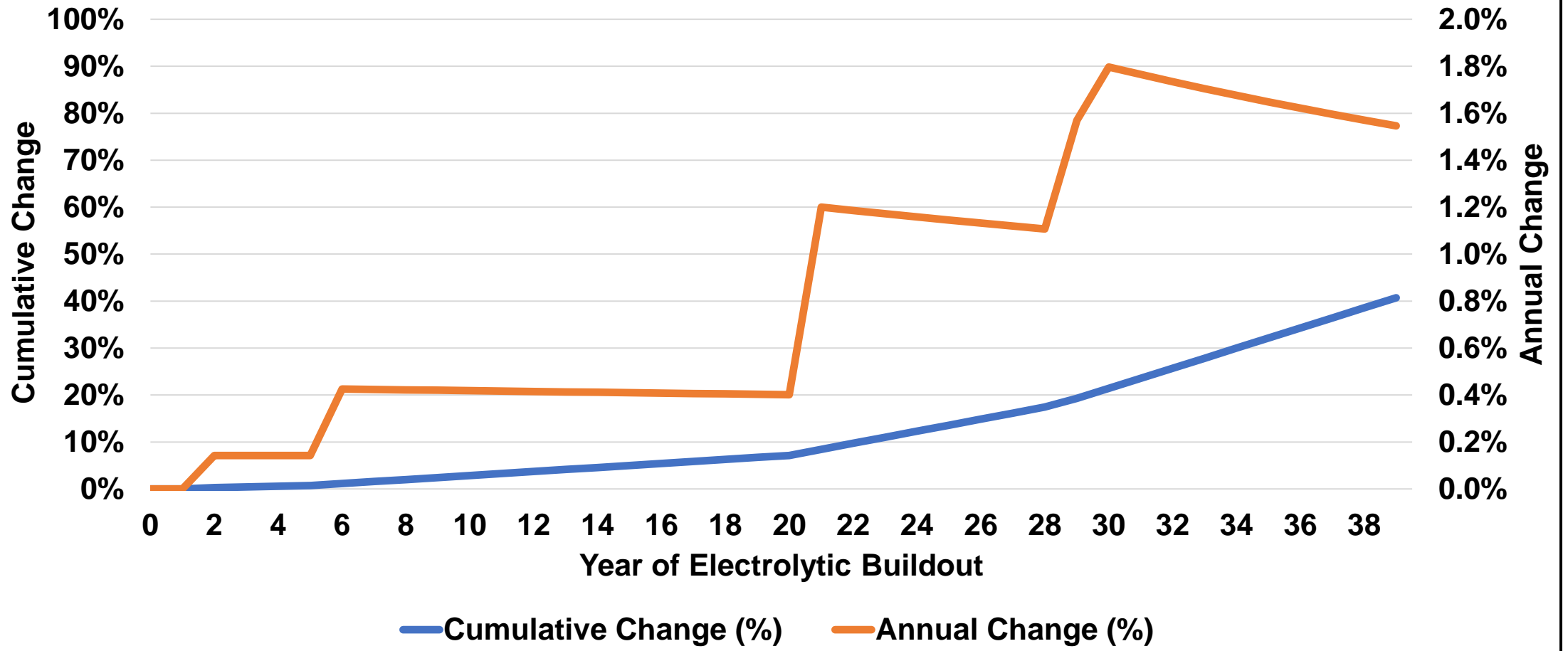


1.0 Mtp Electrolytic Hydrogen Plant Development Schedule

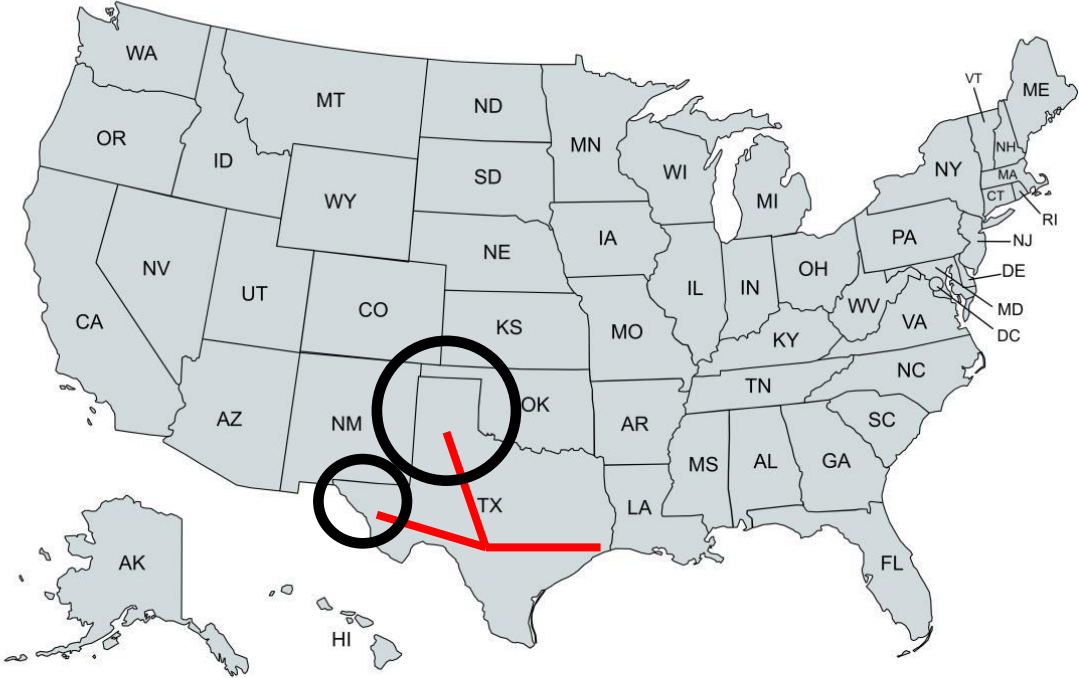


Year		H2 Sales (tpa)	Class 8 Trucks (H2)
2025	Purchase Agreement, Vender Quotes, Site Selection		
2026	Permitting and Vendor Contracts		
2027	Land Preparation for Construction		
2028	Begin Construction 1st Stage		
2029	Construction 1st Stage		
2030	Commissioning 1st Stage	50,000	7,000
2031	Evaluation 1st Stage, Begin Construction 2nd Stage	100,000	7,000
2032	Construction 2nd Stage		
2033	Commissioning 2nd Stage, Begin Construction 3rd Stage	100,000	14,000
2034	Construction 3rd Stage		
2035	Commissioning 3rd Stage, Begin Construction 4th Stage	100,000	14,000
2036	Construction 4th Stage		
2037	Commissioning 4th Stage, Begin Construction 5th Stage	100,000	14,000
2038	Construction 5th Stage		
2039	Commissioning 5th Stage, Begin Construction 6th Stage	300,000	39,000
2040	Construction Sixth Stage, Commissioning 6th Stage	300,000	39,000
Total		1,000,000	134,000

Effect of \$5/kg Hydrogen on Heavy Freight Truck Fuel Costs 40-Year Buildout for Saturation of Electrolytic Hydrogen Base Pump Price of Diesel \$3.50/gallon



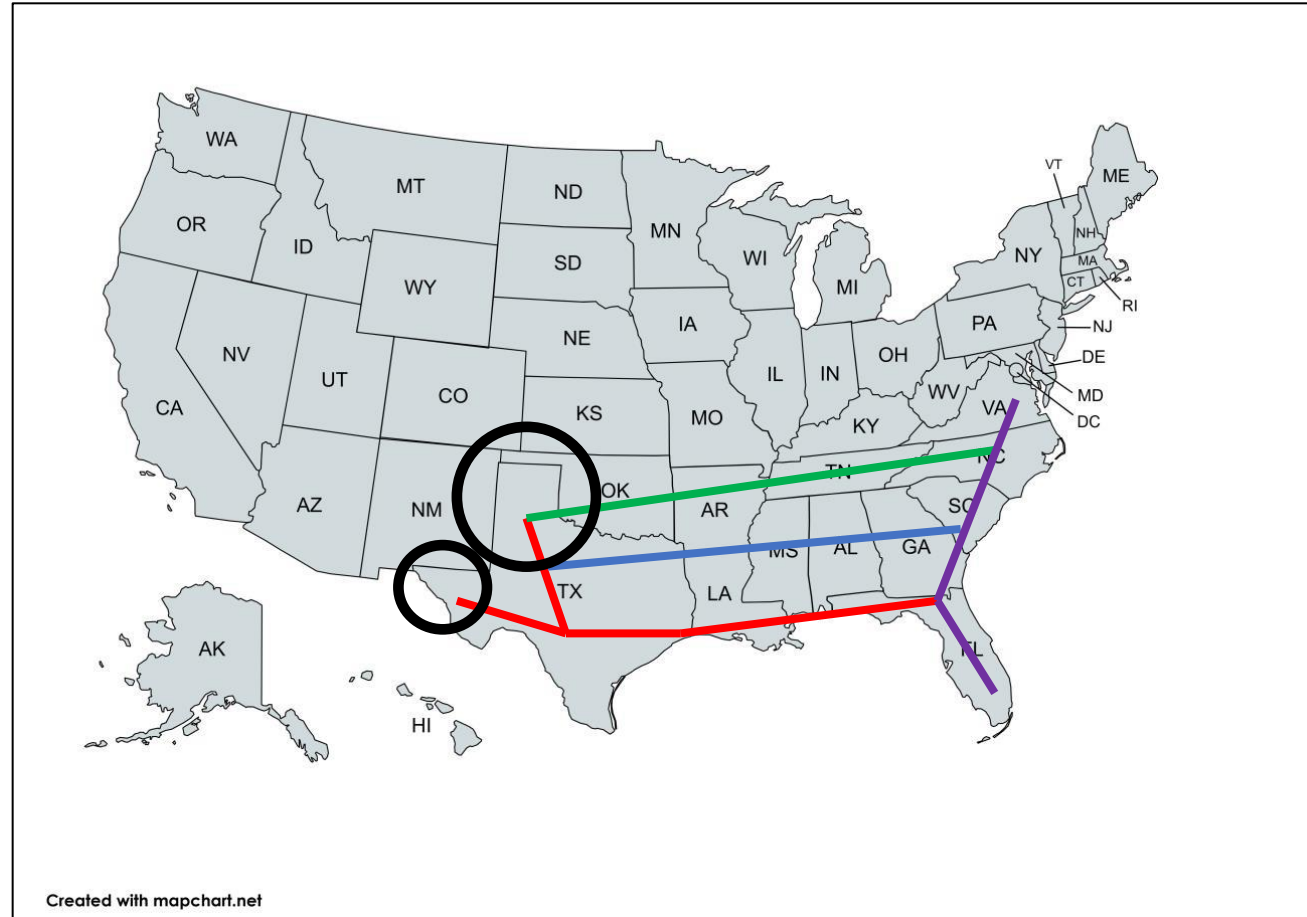
West Texas PV-Wind Electrolytic Hydrogen Plants with 800 Miles of Hydrogen Pipeline



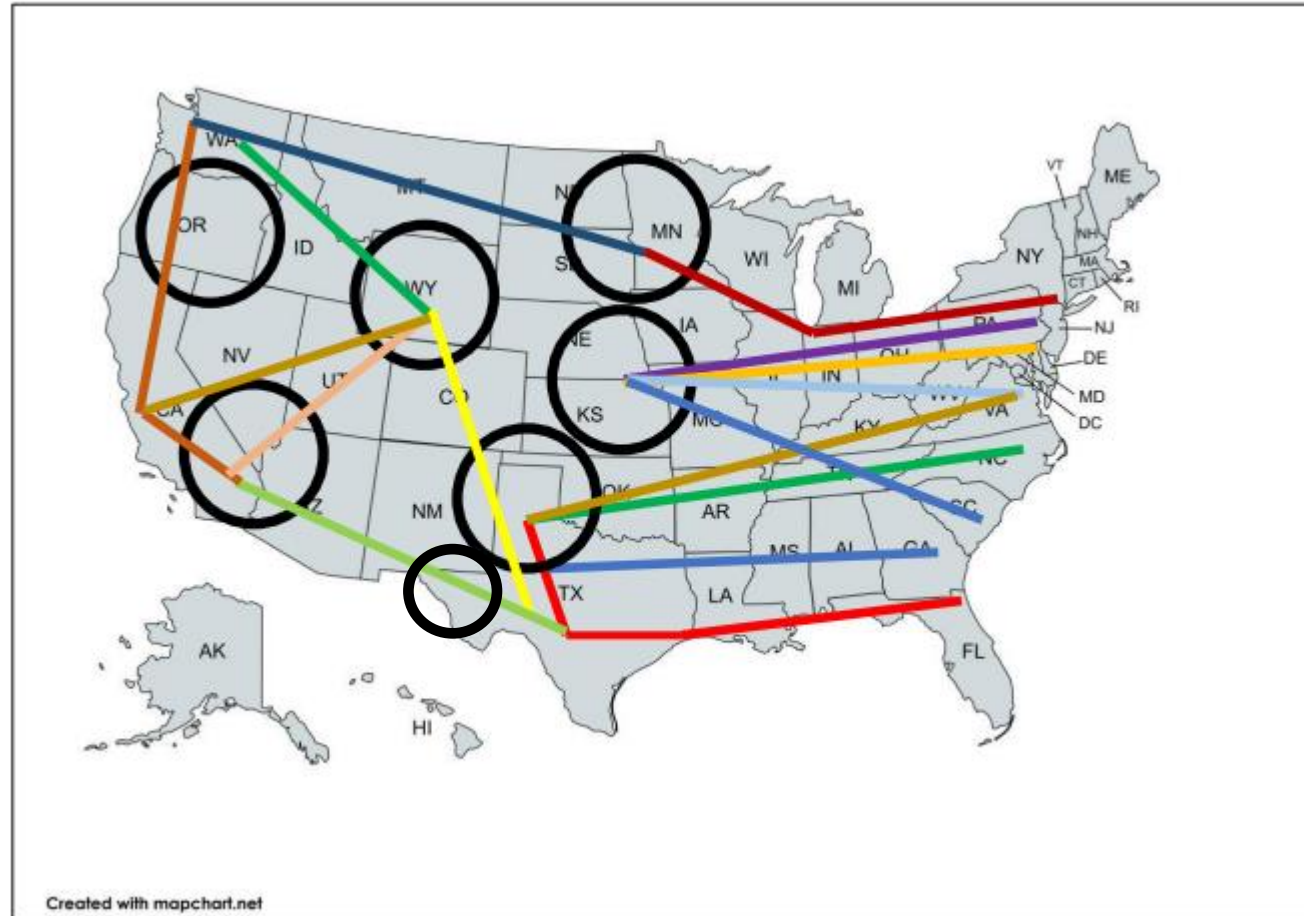
Created with mapchart.net

West Texas Hydrogen Hubs with Southern Pipeline Network

2040: 5,000 Miles of Pipeline – 100 Fueling Centers – 100,000 Heavy Trucks



U.S. Hydrogen Hubs with Pipeline Distribution



National PV and Wind Electrolytic Hydrogen System



- **Buildout of a National Hydrogen Production and Distribution System**
 - **West Texas PV-Wind Electrolytic Hydrogen System Is a Small Part of the Whole**
- **U.S. Transportation Motor Gasoline and Diesel in 2022 Was 189 million tonnes H2 Equivalent**
- **2.0 Terawatts of PV Can Produce 50 million tonnes of Electrolytic Hydrogen**
- **Lowest Cost PV and Wind Electricity Is Paramount**
- **Need for 50-Year Bonds to Finance PV-Wind Farms; H2 Pipelines; and H2 Fueling Centers**
 - **\$4.0 Trillion in 50-Year Bonds for PV and Wind Farms**
 - **\$500 Billion in 50-Year Bonds for National Hydrogen Trunk Pipeline System**
 - **200,000 Miles of Hydrogen Pipelines**
 - **\$50 Billion in 50-Year Bonds for Hydrogen Fueling Centers**
- **Electrolysis Plants Financed with Conventional 20-year Loans**