



**ASAP**  
**(American Solar Action Plan)**

**Panhandle Wind-PV Electrolytic Hydrogen System**

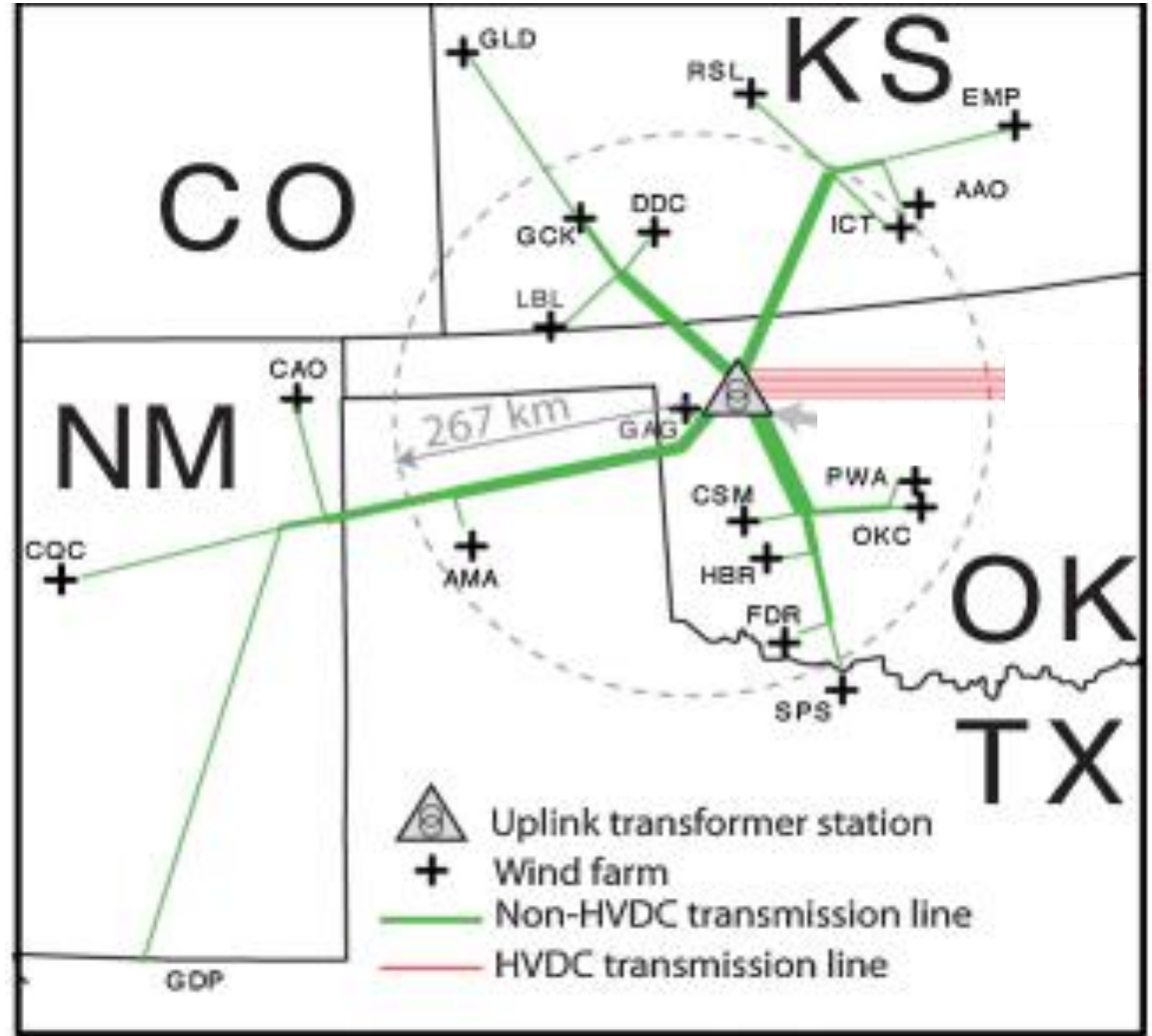
**July 2024**  
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**ASAP**

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# Premier Wind-PV Electrolytic Hydrogen Production Hub



# Panhandle Wind-PV Electrolytic Hydrogen System

## No Subsidies Are Included In This Analysis



- **Target Hydrogen Pump Price less than \$5.00/kg (including a \$0.51/kg State/Federal Fuel Tax)**
- **Annual Electrolyzer Purchase/Installation Capacity ( $\text{GW}_{\text{dc el-in}}$ ) Schedule**
  - 1 GW/Stage – Development Stages 1-4 (1 GW Electrolyzer = 100,000 tpa H<sub>2</sub>)
  - 3 GW/Stage – Development Stages 5-6 (Total Electrolyzer Capacity = 10 GW)
  - Delivered Cost of Wind and PV DC Electricity at \$0.035/kWh (Critical Maximum)
- **Initial Hydrogen Markets (1 GW Electrolyzer New Capacity per Annum in Stages 1-4)**
  - 80% for Refinery/Ammonia/Fertilizer Plants with Pipeline Hydrogen Delivery
  - 20% for Class 8 Fuel Cell Trucks with Fueling Centers with Pipeline Hydrogen Delivery
    - 6 Fueling Centers per Development Stage
    - Supports the Addition of 2,400 Class 8 Fuel Cell Trucks in Stages 1-4
- **Hydrogen Pipelines**
  - 600 Miles of Pipeline per Development Stage
- **Hydrogen Underground Salt Storage Facilities**
  - 2 Salt Caverns – Each 45 Mcf with 8,000 t of Working Gas Storage at 1,700 psi (Working Gas 67% of Volume)

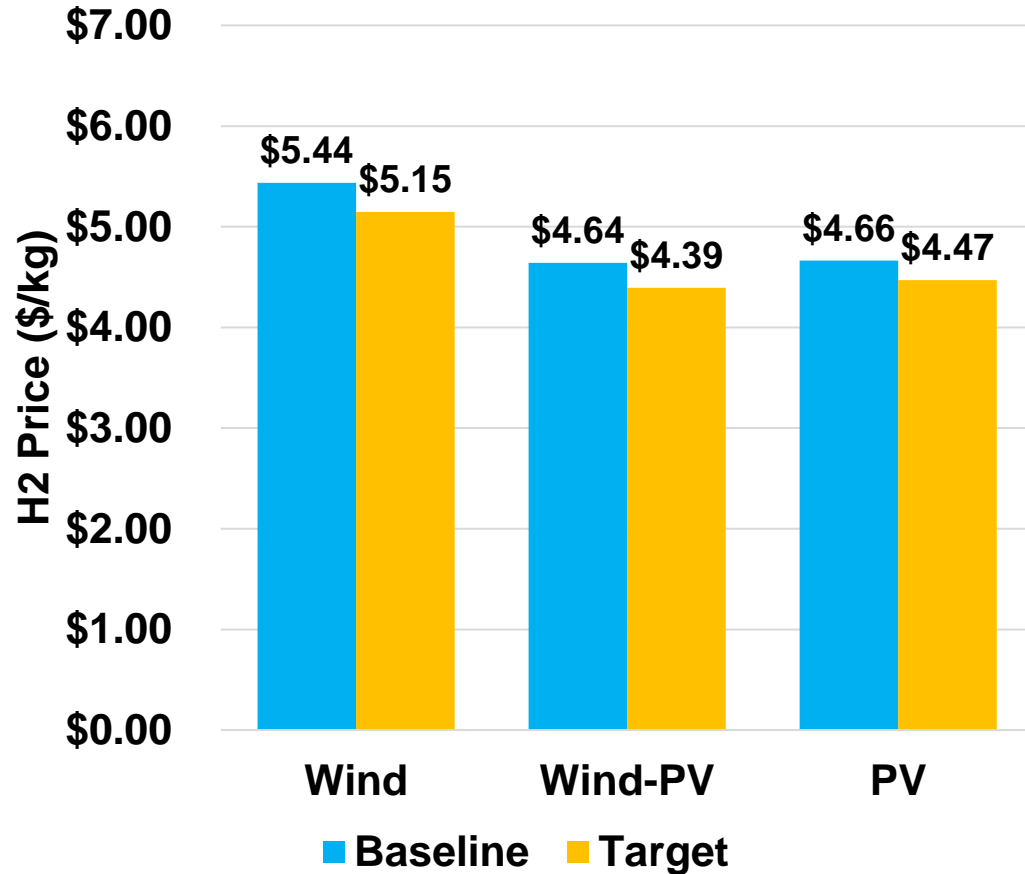
# Panhandle Electrolytic Hydrogen Price Estimates

Baseline – \$500/kW, 52.31 kWh/kg; Target – \$500/kW, 47.08 kWh/kg

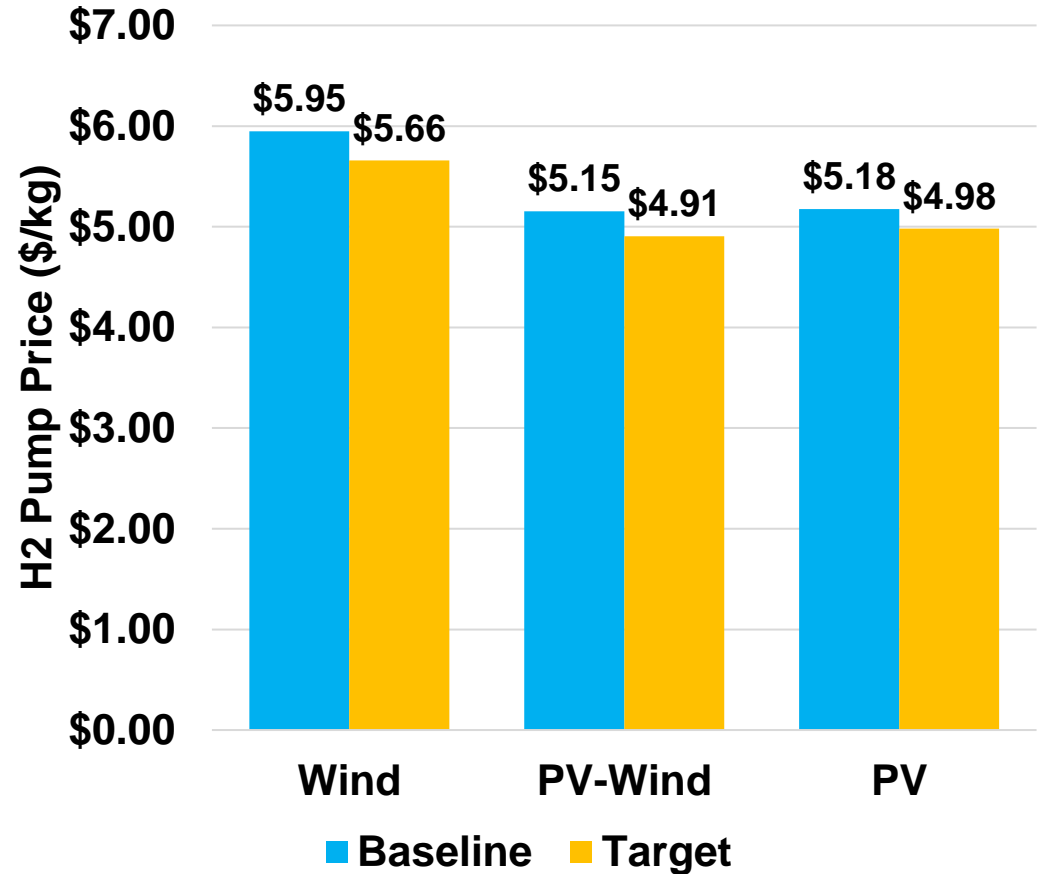
Electricity Cost: Wind \$0.053/kWh; PV \$0.035/kWh; Wgt. Avg. Wind-PV \$0.045/kWh



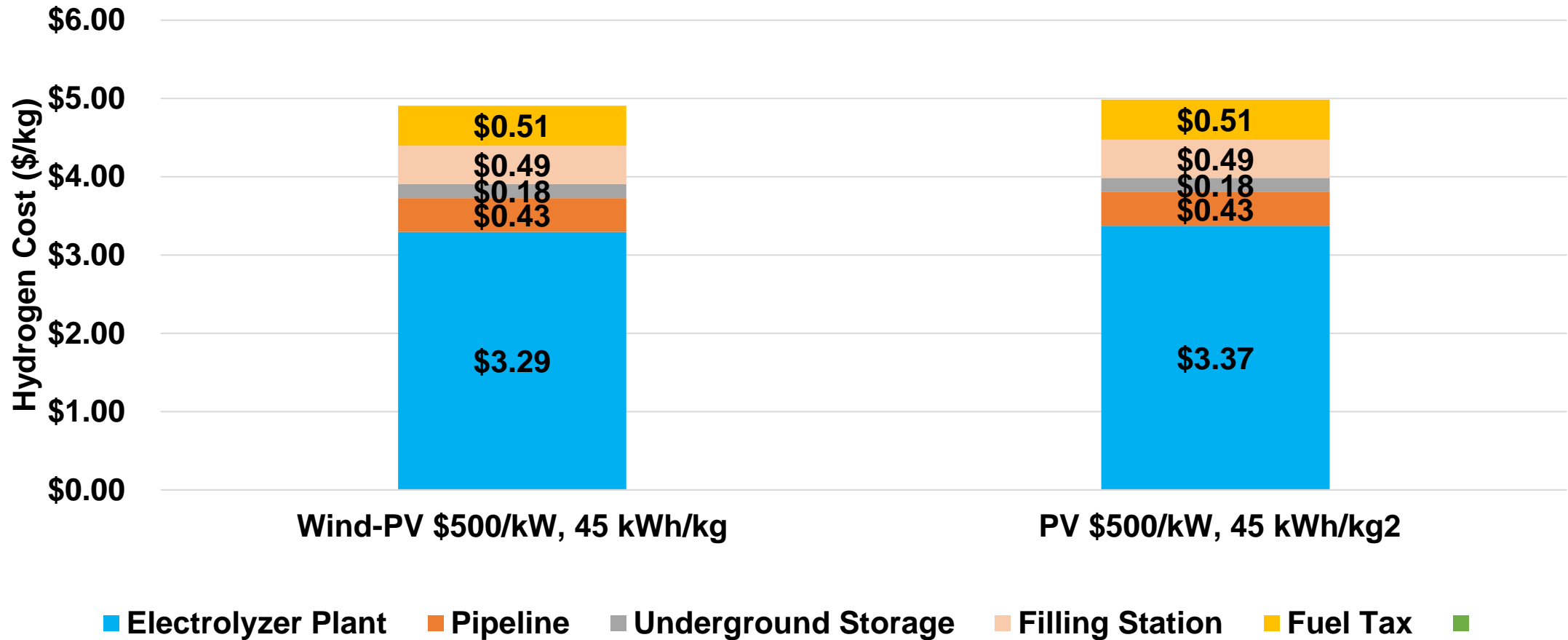
### H2 Price without Fuel Tax



### H2 Pump Price with Fuel Tax

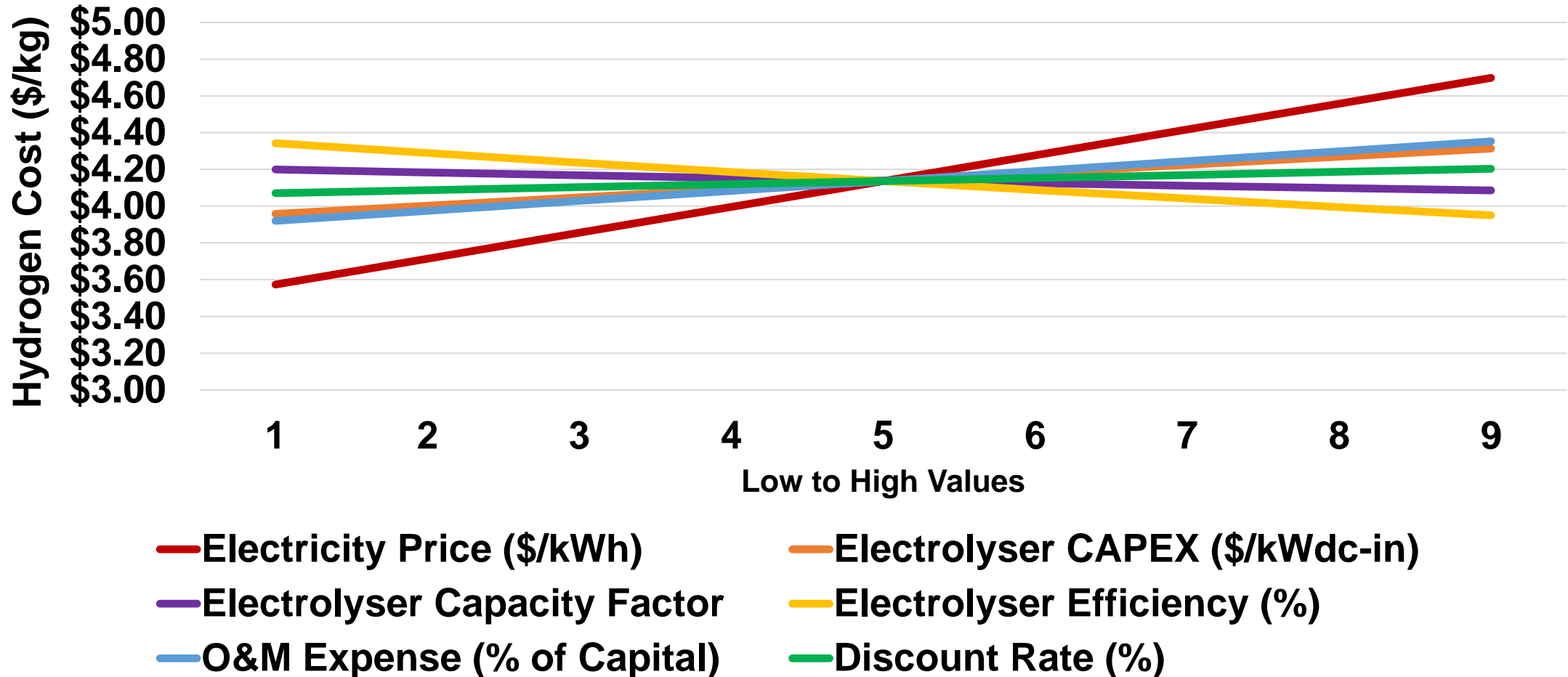


# Panhandle Wind-PV and PV Only Electrolytic Hydrogen System System Component Cost Estimates



# Sensitivity Analysis of Electrolytic Hydrogen Production Cost

## Electricity Cost Is Critical (Assume \$0.035/kWh)



# Wind-PV Electrolysis Plant Development with Hydrogen Production Growth



	Electrolyzer (GW)	Wind (GW)	PV (GW)	Hydrogen Growth (Mtpa)
Stage 1	1.0	1.3	1.3	0.1
Stage 2	1.0	1.3	1.3	0.1
Stage 3	1.0	1.3	1.3	0.1
Stage 4	1.0	1.3	1.3	0.1
Stage 5	3.0	3.9	3.9	0.3
Stage 6	3.0	3.9	3.9	0.3
Total	10.0	13.0	13.0	1.0

# PV Electrolysis Plant Development with Hydrogen Production Growth



	Electrolyzer (GW)	PV (GW)	Hydrogen Growth (Mtpa)
Stage 1	1.6	2.8	0.1
Stage 2	1.6	2.8	0.1
Stage 3	1.6	2.8	0.1
Stage 4	1.6	2.8	0.1
Stage 5	4.8	8.4	0.3
Stage 6	4.8	8.4	0.3
Total	16.0	28.0	1.0



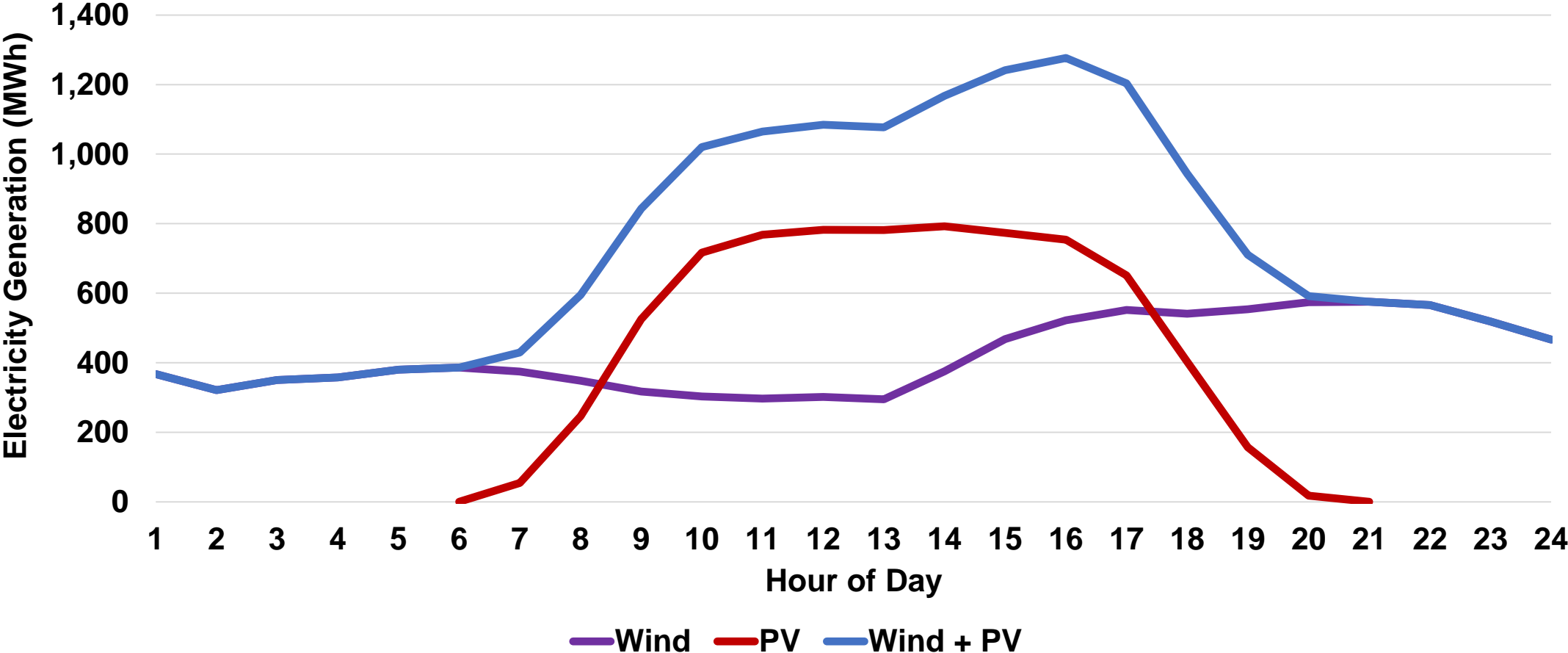
# Wind and PV Electrolytic Hydrogen System Capacity

Scaled for 100,000 tpa of Delivered Hydrogen



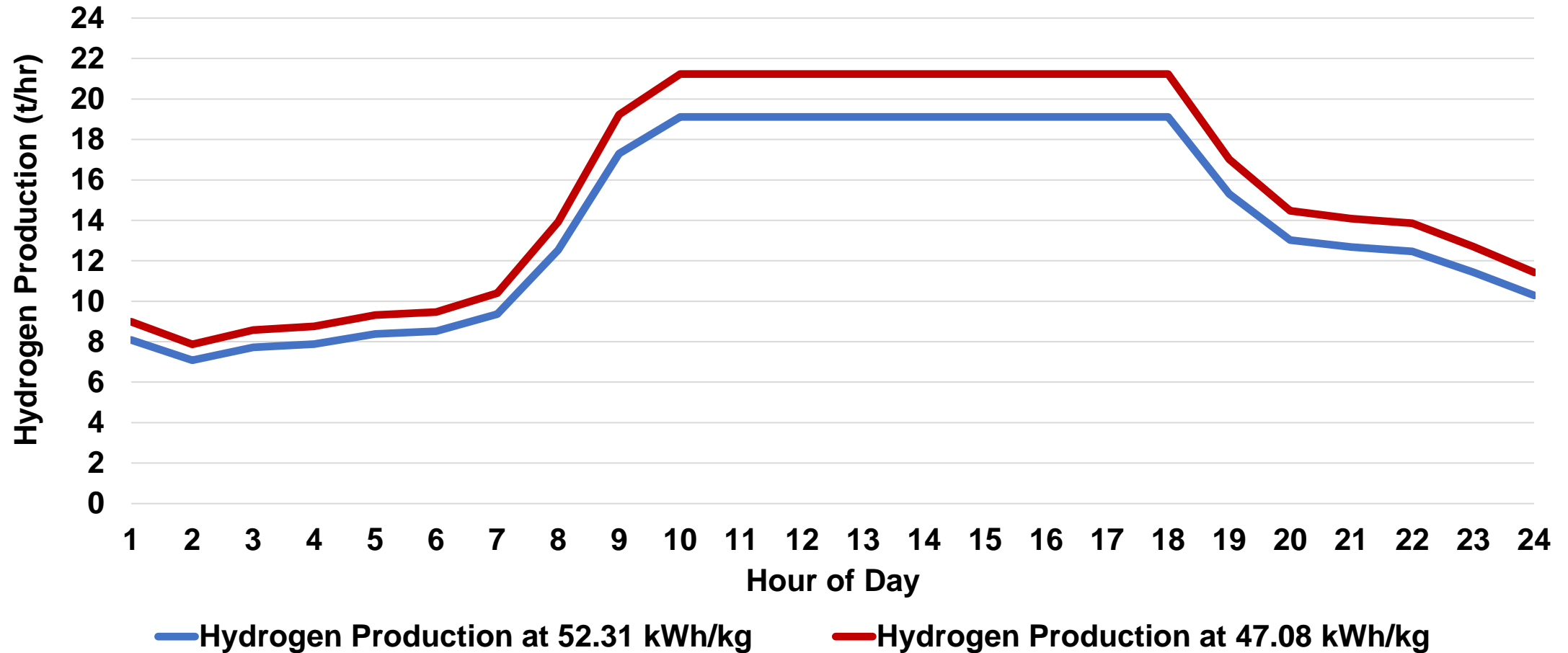
	Electrolyzer Capacity (MW)	PV Capacity (MW)	Wind Capacity (MW)	Hydrogen (Mtpa)
Wind	1,400	0	2,300	1.0
PV-Wind	1,000	1,300	1,300	1.0
PV	1,600	2,800	0	1.0

# Wind and PV Electricity Generation Daily Average for 1.3 GW PV and 1.3 GW Wind

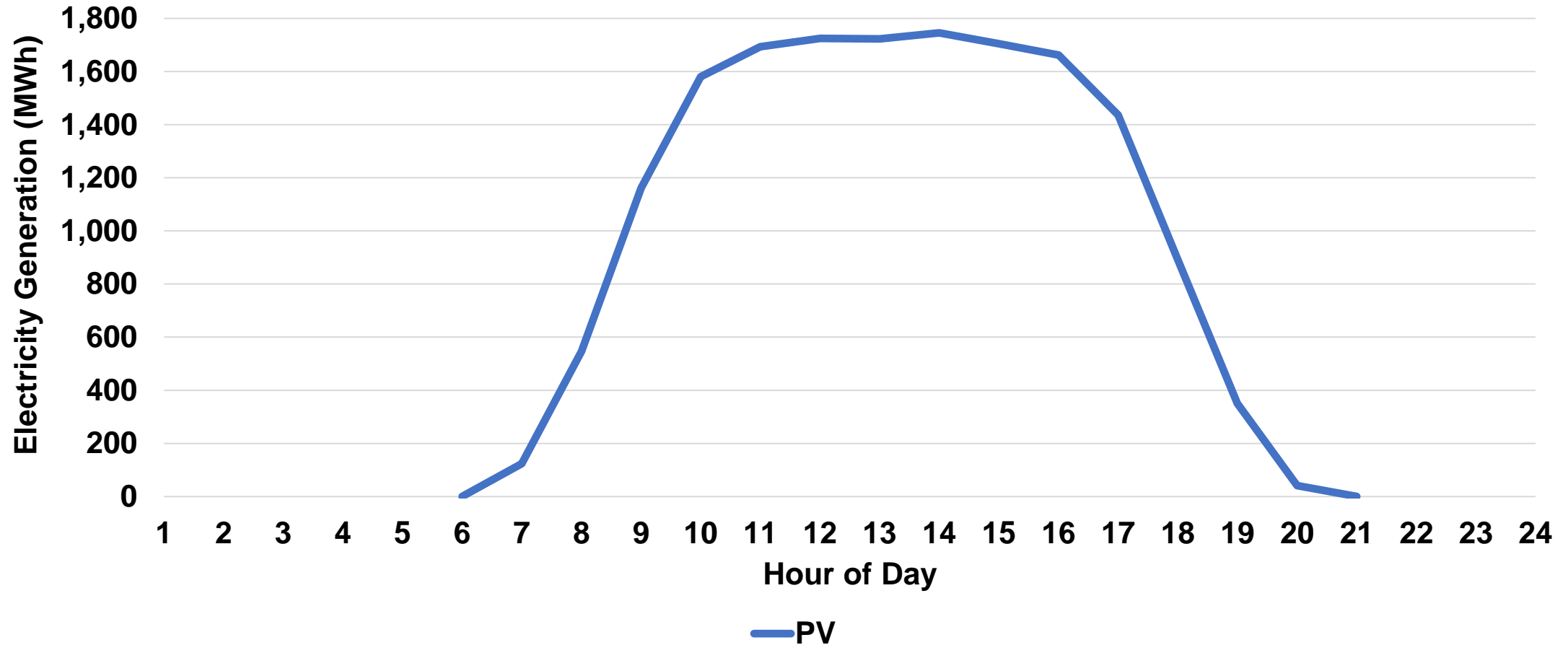


# Wind-PV Daily Average Hydrogen Production

Scaled to Deliver 100,000 tpa Hydrogen  
1.0 GW Electrolysis Plant; 1.3 GW Wind Farm; 1.3 GW PV Plant

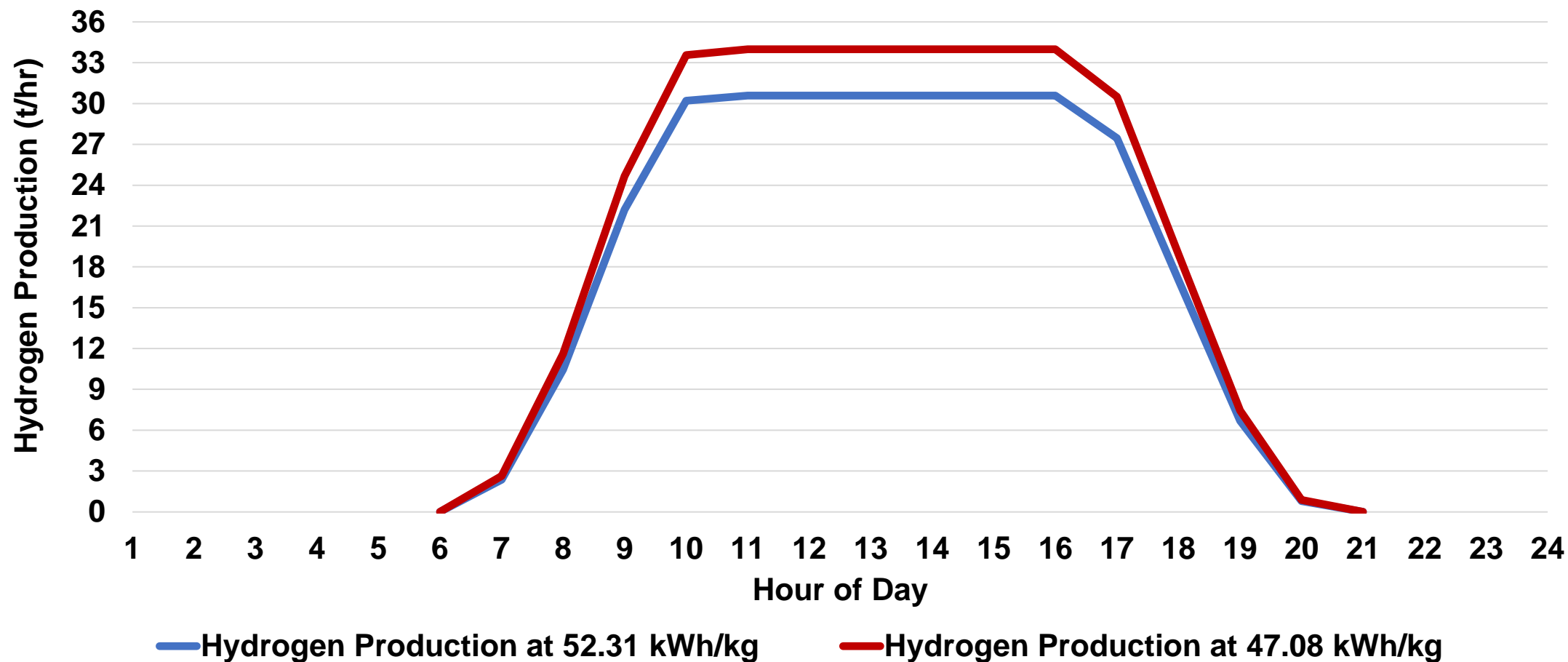


# PV Electricity Generation Daily Average for a 2.8 GW PV Plant



# PV Daily Average Hydrogen Production

Scaled to Deliver 100,000 tpa Hydrogen  
1.6 GW Electrolysis Plant and a 2.8 GW PV Plant



# Wind and PV Electrolytic Hydrogen System CAPEX

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

Electrolyzers \$500/kW<sub>dc-in</sub>    Wind Farm \$1,300/kW<sub>dc-out</sub>    PV Plant \$900/kW<sub>dc-out</sub>  
 600 Mile Pipeline – \$180,000,000;    Two Salt Storage Caverns – \$100,000,000;  
 Six Heavy Freight Truck Fueling Stations – \$90,000,000



	Electrolysis Plant	PV Plant	Wind Farm 1st Gen	Wind Farm 2nd Gen	Downstream Components	Total CAPEX
Wind	\$700,000,000	\$0	\$2,990,000,000	\$1,196,000,000	\$373,600,000	\$5,259,600,000
PV-Wind	\$500,000,000	\$1,170,000,000	\$1,690,000,000	\$676,000,000	\$373,600,000	\$4,409,600,000
PV	\$800,000,000	\$2,520,000,000	\$0	\$0	\$373,600,000	\$3,693,600,000

# CAPEX for Electrolysis Plant and Downstream Components

Scaled for 100,000 tpa of Delivered Hydrogen



<u>Capital Costs</u>	<u>Unit Cost</u>	<u>Capex</u>
Electrolyzer Plant Total Installed Cost All Components (\$/kW <sub>dc el-in</sub> )	\$500	\$500,000,000
Electrolyzer Plant Land, Site Design, and Preparation Costs (\$/kW)	\$50	\$50,000,000
Pipeline 600 Miles (\$/mile)	\$3,000,000	
Pipeline Portion Allocated to 100,000 tpa H2 Plant	10%	\$180,000,000
Pipeline Compressor Stations Total Installed Cost (12 Stations – 50 mile)	\$1,500,000	
Pipeline Compressor Stations Portion Allocated to 100,000 tpa H2 Plant	10%	\$1,800,000
2 Underground 45-Mcf Salt Storage Caverns (\$/Cavern)	\$50,000,000	\$100,000,000
6 Fueling Stations (\$/Station)	\$15,000,000	\$90,000,000
<b>Total Capex</b>		<b>\$923 million</b>

# Financial Assumptions

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## Discount Rate - Weighted Average Cost of Capital

<b>Discount Rate</b>	<b>10.1%</b>
<b>Annual Inflation</b>	<b>3.0%</b>
<b>Capital Recovery Period</b>	<b>20 Years</b>
<b><u>Capital Structure</u></b>	
<b>% Equity Capital</b>	<b>5.0%</b>
<b>% Debt Capital</b>	<b>95.0%</b>
<b><u>Cost of Capital</u></b>	
<b>Cost of Equity Capital</b>	<b>15.0%</b>
<b>Cost of Debt Capital</b>	<b>9.0%</b>
<b>Federal/State Income Tax Rate (Federal = 21%, Texas State Franchise Tax = 0.75%)</b>	<b>21.75%</b>
<b>CAPEX Depreciation</b>	<b>MACRS 20-yr</b>
<b>Replacement Costs Depreciation</b>	<b>MACRS 10-yr</b>



# Electrolytic Hydrogen System Assumptions

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<b>Electrolyzer Annual Degradation Rate (%/annum)</b>	<b>1.0%</b>
<b>System Fugitive Hydrogen Loss Rate (%/annum)</b>	<b>3.0%</b>
<b>Compressors Powered by Grid Electricity (Grid Electricity Cost)</b>	<b>\$0.05/kWh</b>
<b>Pipeline Diameter to Deliver 1.0 Mta (diameter inches)</b>	<b>10.0</b>
<b>Pipeline Compressor Stations (Miles between Stations)</b>	<b>50</b>
<b>Underground Salt Storage 2 45-Mcf Sites (tonnes Working Gas H2 Storage at 1,700 psi)</b>	<b>16,000</b>
<b>Annual Hydrogen Storage Cycle (tonnes)</b>	<b>6,000-11,000</b>
<b>FC Class 8 Trucks Servicing San Antonio/Austin/Corpus Christi/Houston Freight Routes</b>	<b>2,400</b>
<b>Filling Station Pumps (# Pumps per Station – 2 Trucks/Hour for 10 Hours/Day)</b>	<b>20</b>
<b>Filling Station Truck Capacity/Station (# FC Class 8 Trucks)</b>	<b>400</b>

# Annual System Expense Estimates

Scaled for 100,000 tpa of Delivered Hydrogen



<b>Expenses</b>	<b>Unit Expense</b>	<b>Total Expense</b>
<b>Wind and PV Electricity Electrolysis Expense (\$/kWh)</b>	<b>\$0.035</b>	<b>\$192,500,000-\$173,300,000</b>
<b>Electrolyzer Efficiency (Avg kWh/kg H2)</b>	<b>52.31-47.08</b>	
<b>Electrolyzer Degradation (%/annum with Rebuild Year 10)</b>	<b>1.0%</b>	
<b>Electrolysis Plant O&amp;M (% Capex)</b>	<b>3.0%</b>	<b>\$15,000,000</b>
<b>Pipeline O&amp;M Expense (% Capex)</b>	<b>2.0%</b>	<b>\$3,600,000</b>
<b>Compression Station O&amp;M Expense 12 Stations (% Capex)</b>	<b>4.0%</b>	<b>\$720,000</b>
<b>Underground Storage O&amp;M Expense (% Capex)</b>	<b>2.0%</b>	<b>\$2,000,000</b>
<b>Filling Station O&amp;M Expense 6 Stations (% Capex)</b>	<b>25.0%</b>	<b>\$18,000,000</b>
<b>Insurance Expense (% Capex)</b>	<b>0.5%</b>	<b>\$4,618,000</b>
<b>Compression Electricity Expense (\$/kWh)</b>	<b>\$0.050</b>	<b>\$17,016,237</b>
<b>Water Expense Desalinated (\$/1000 gallons)</b>	<b>\$10.00</b>	<b>\$3,132,417</b>
<b>Total Expenses</b>		<b>\$279,000,000-\$260,000,000</b>

# Hydrogen System Water Consumption and Expense

## Gulf Coast Desalination Plant and Pipeline Water Delivery

### Delivered Water Cost - \$10.00/1000 gallons (\$0.010/gal)



Water Cost (\$/gal)	\$0.01200	
	Quantity (gal)	Water Expense
H2 Electrolyzer Water Expense (11.13 liters water/kg H2)	303,117,004	\$3,031,170
Electrolyzer Cooling Water Expense (300 liters water/kg H2)	7,461,449	\$74,614
Pipeline Compressor Cooling Water Expense (50 liters water/kg H2)	1,243,575	\$12,436
Storage Compressor Cooling Water Expense (50 liters water/kg H2)	146,762	\$1,761
Filling Station Compressor Cooling Water Expense (50 liters water/kg H2)	1,243,575	\$12,436
<b>Total Water Consumption and Expense</b>	<b>313,213,002</b>	<b>\$3,132,417</b>

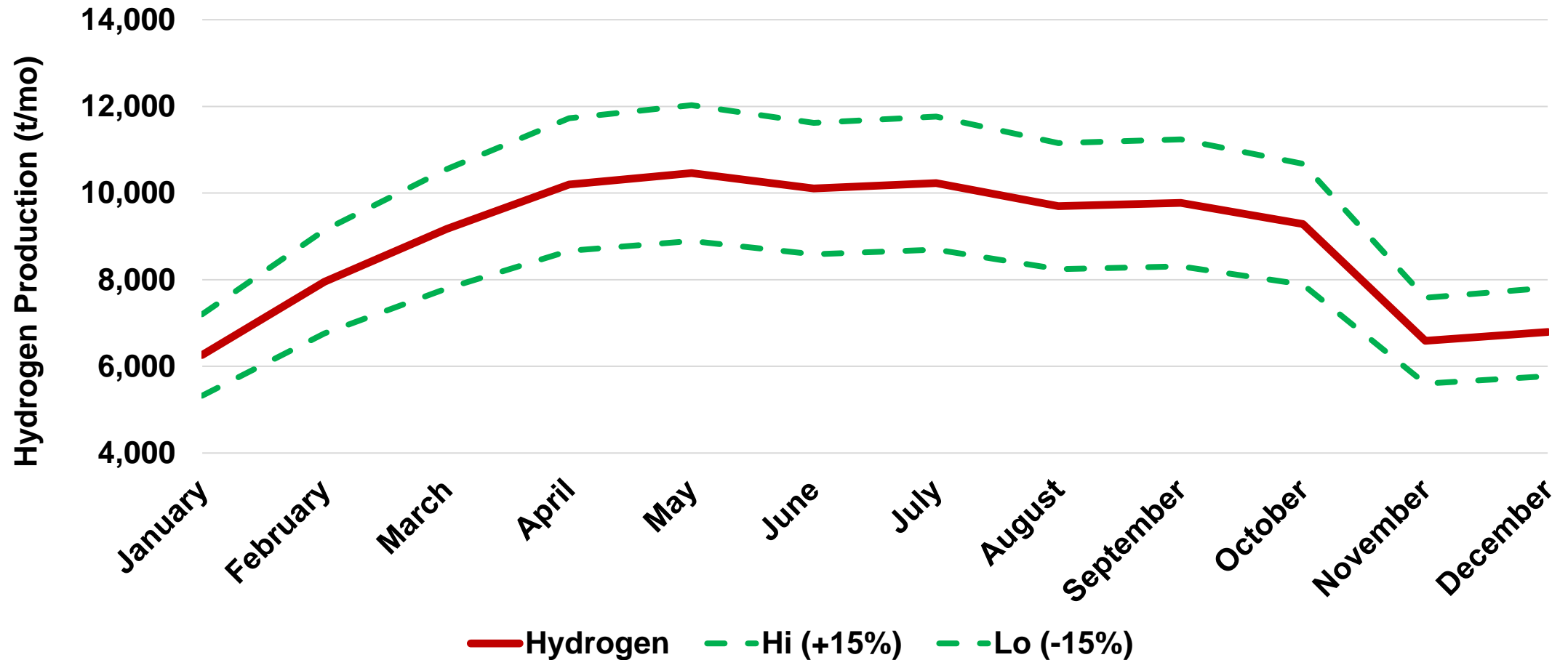
# Hydrogen Compression Energy Estimates

## Grid Electricity Expense



Grid Electricity Cost (\$/kWh)	\$0.050				
	Quantity	Pressure (Begin and End)	Energy		Electricity Expense
<b>Electrolyzer Plant to Pipeline</b>	103,093 tpa	290-1000 psi	0.770 kWh/kg		\$3,969,081
<b>Compressor Stations (12)</b>	103,093 tpa	700-1000 psi	0.130 kWh/kg		\$8,041,254
<b>Filling Stations (6)</b>	100,000 tpa	900-12760 psi	1.757 kWh/kg		\$9,056,720
<b>Underground Storage (2)</b>	10,000 tpa	900-1700 psi	0.38 kWh/kg		\$190,000
<b>Total Electricity Expense</b>					<b>\$21,257,055</b>

# Panhandle Monthly Average Hydrogen Production with High and Low Estimates



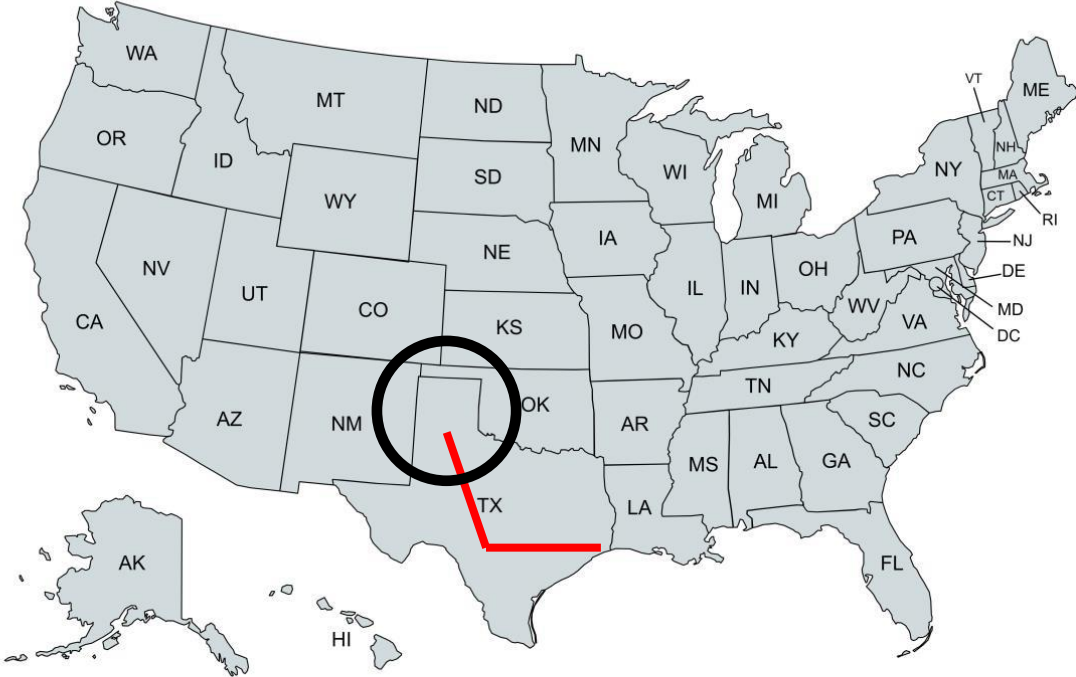
# Hydrogen Storage Estimates

## Assume a Constant 8,333 tpm of Delivered Hydrogen



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
<b>Total (Storage)</b>	<b>106,943</b>	<b>122,984</b>	<b>90,901</b>	<b>5,644</b>	<b>2,332</b>	<b>10,798</b>

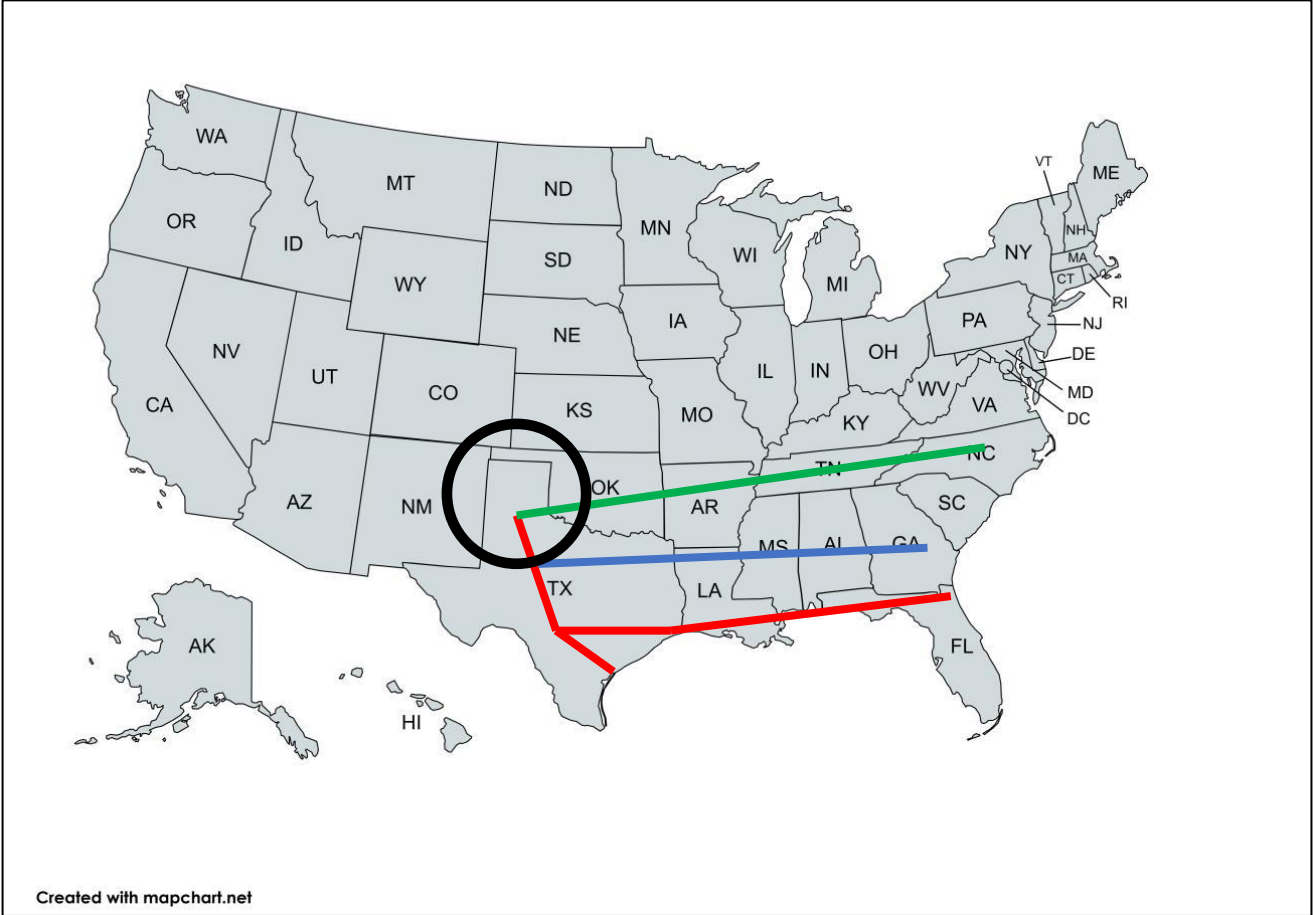
# Panhandle Hydrogen Hub with Stage 1 Pipeline



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# Panhandle Hydrogen Hub with Southern Pipeline Network Upon Stage 6 Completion

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# Hydrogen Hubs with Pipeline Distribution

