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Hydrogen at UT Austin: Projects Related to H_2 and Water

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Dr. Ning Lin – Bureau of Economic Geology

Dr. Emily Beagle – Webber Energy Group

Dr. Vaibhav Bahadur (VB) – Mechanical Engineering

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Agenda

- Overview of H2@UT and Intro – Mike Lewis
- Demand of Water for Hydrogen in Texas – Ning Lin
- Hydrogen policy in Texas – Emily Beagle
- Possible PW treatment technologies - VB

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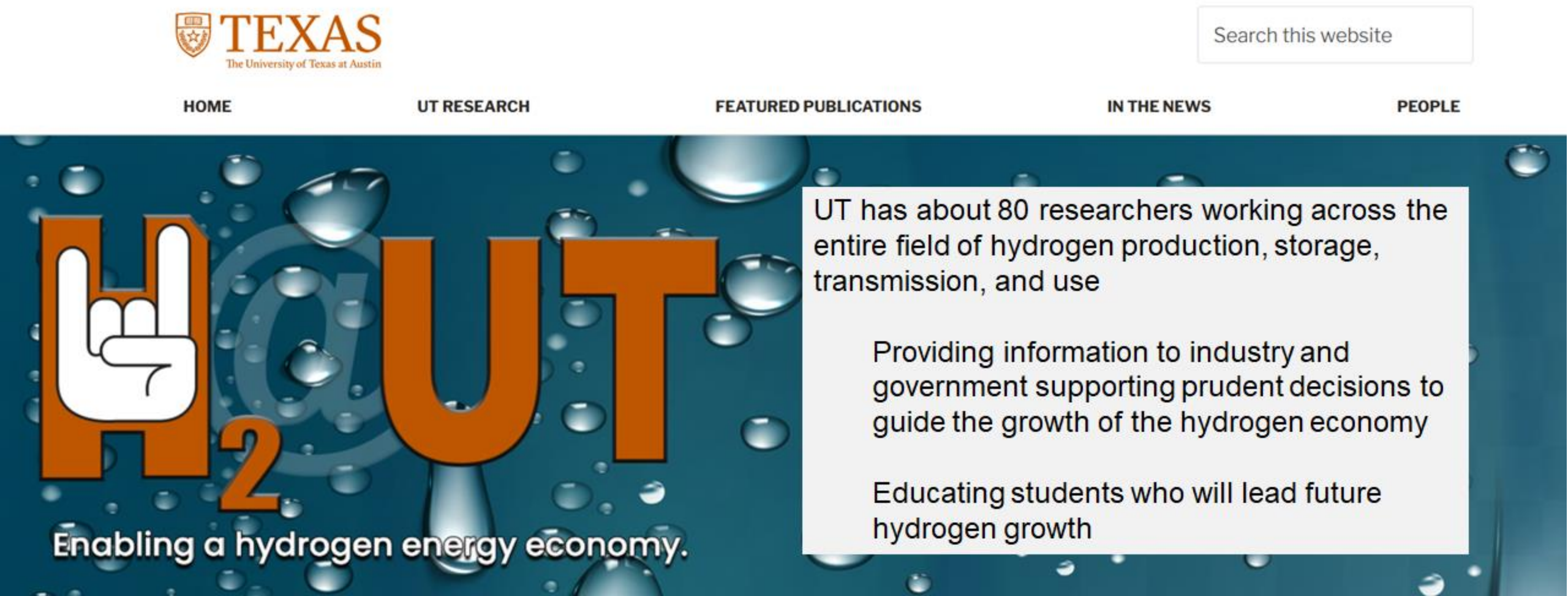
H2@UT - https://sites.utexas.edu/h2/



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The Texas Hydrogen ProtoHub

First-of-a-kind hydrogen facility with multiple forms of generation and end use

Renewable H_2 generation

- 30 kg/day SMR
  - Renewable landfill gas
- 40 kg/day PEM electrolyzers
  - Time matched to wind and solar resources

Large scale, industry H_2 user

- 100kW PEM fuel cell providing power to the Texas Advanced Computing Center

Vehicle refueling

- 350 bar and 700 bar per SAE J2601-4

Hydrogen and Water Use

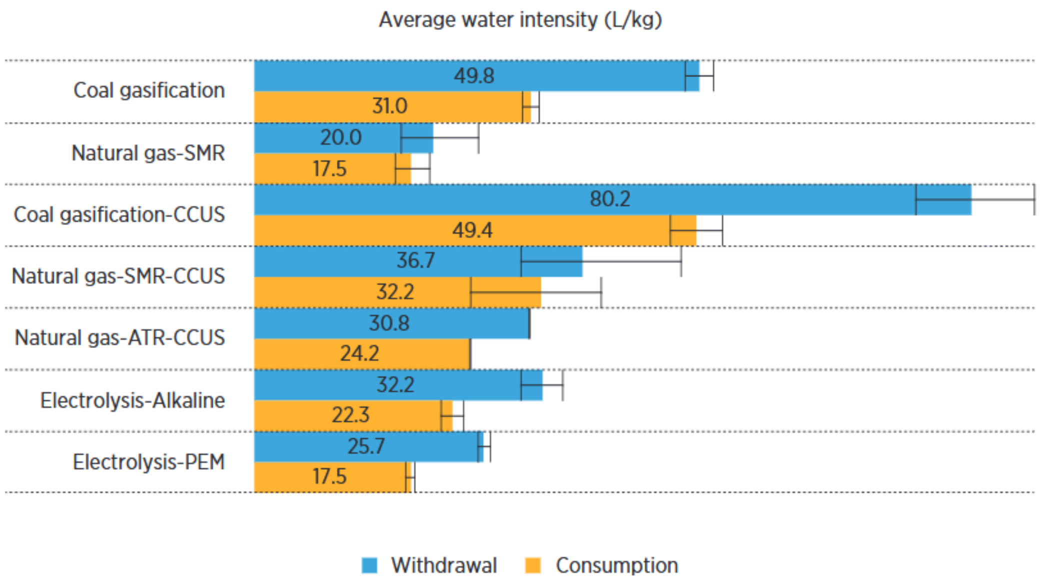
Understanding water requirements for hydrogen production is essential for water stressed areas.

- Electrolysis H2: ~20L-H_2O/Kg-H_2
- SMR + CCS H2: ~30L-H_2O/Kg-H_2
- ATR + CCS H2: ~25L-H_2O/Kg-H_2

Today, about 2.2 billion m^3 of freshwater is withdrawn for global hydrogen production every year; this accounts for 0.6% of the energy sector's total freshwater withdrawal.

Freshwater withdrawals for global hydrogen production could more than triple by 2040 and increase six-fold by 2050, compared with today.

FIGURE S1 A comparison of average water withdrawal and consumption intensities by hydrogen production technology



Note: Tap water (or sources with similar water quality) is (are) used or assumed to be the water source(s) behind these data points. For blue hydrogen, the cooling requirements for CCUS systems are included. For PEM and ATR, available data points are limited since these technologies are relatively new – thus the much smaller ranges of values. ATR = autothermal reforming; CCUS = carbon capture, utilisation and storage; kg = kilogramme; L = litre; PEM = proton exchange membrane; SMR = steam methane reforming.

https://www.irena.org/Publications/2023/Dec/Water-for-hydrogen-production

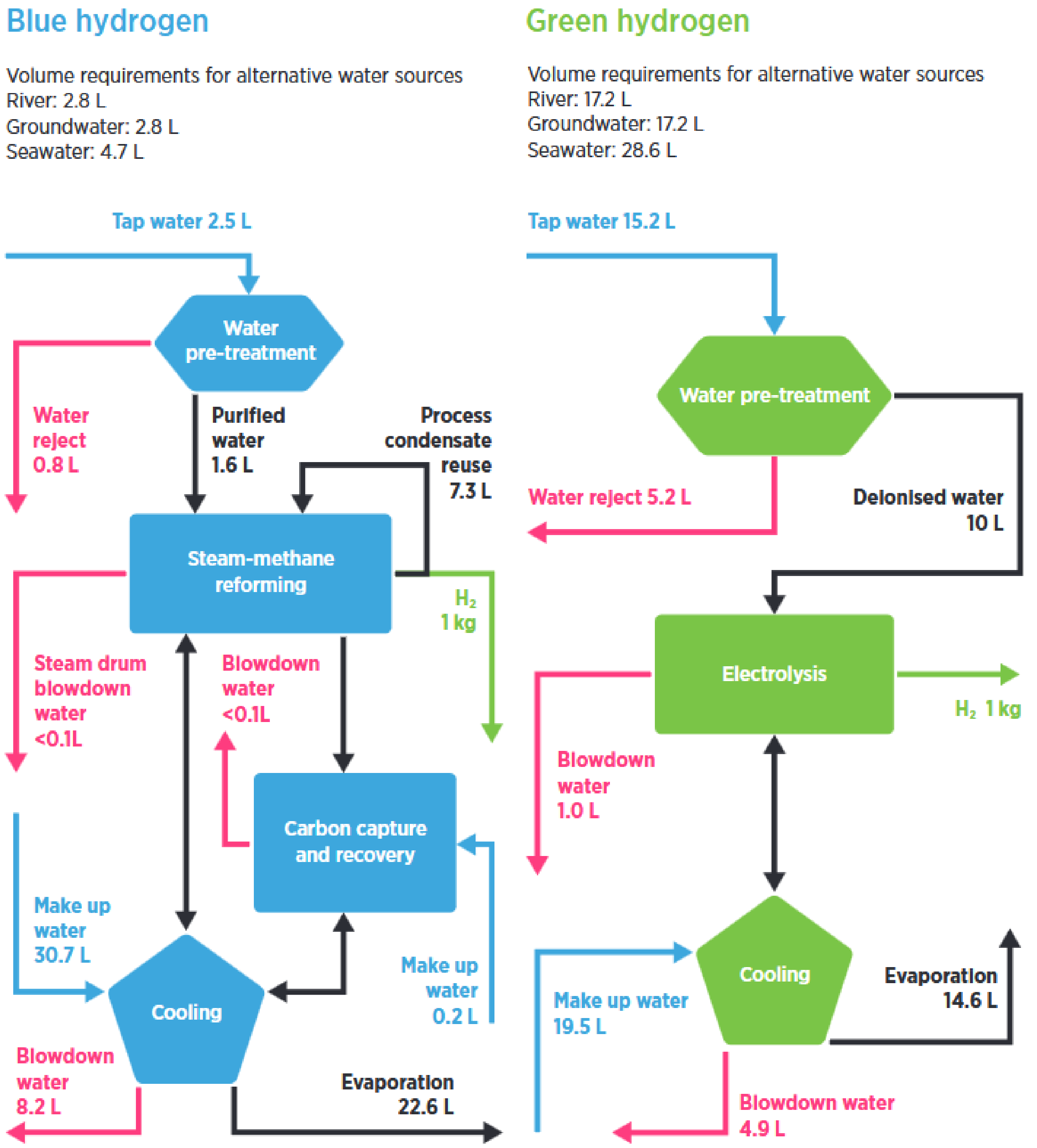
Water use in hydrogen production varies based on production method.

- Process feedstock
- Cooling and thermal management
- Carbon capture for blue H_2

Water treatment is required on front end for feedstock water

- Green H_2 water quality requirement is greater than Blue H_2

Less pure water needed for cooling and carbon capture

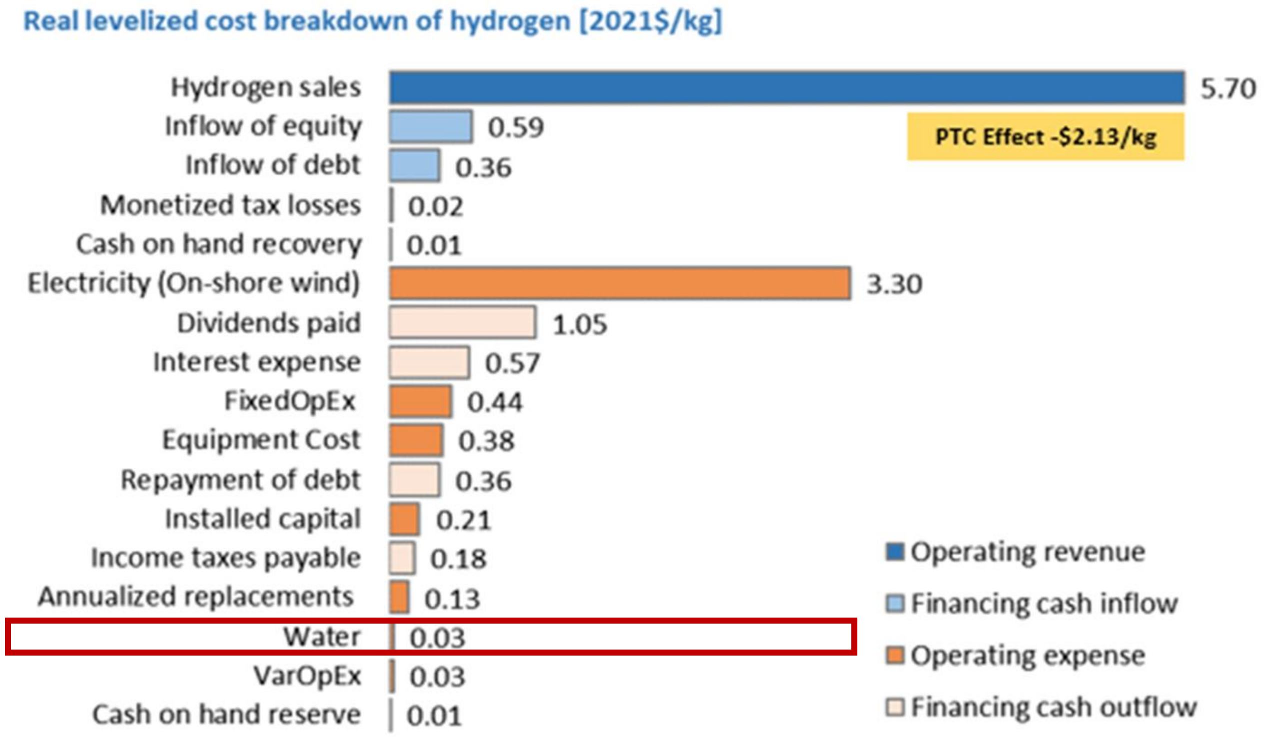


Levelized Cost of Hydrogen

The cost of hydrogen production is relatively insensitive to the cost of water

Provides an opportunity to absorb the clean-up costs associated with the use of non-freshwater sources

- Sea water, produced water



Assessing Future and Demand on Texas Water Resource

by Ning Lin, Mariam Arzumanyan, Edna Rodriguez Calzado and Jean-Philippe Nicot

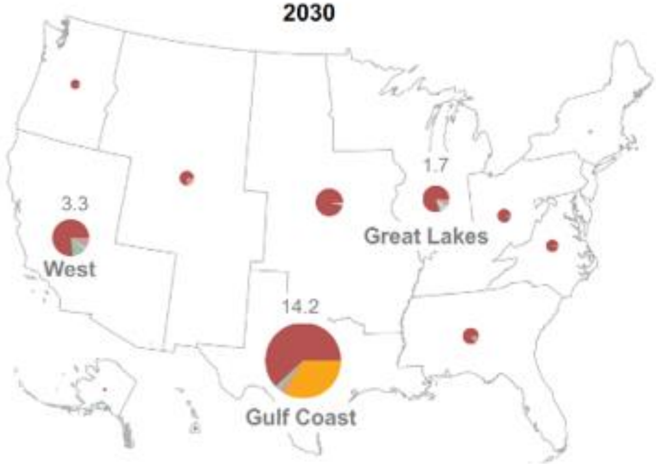
Bureau of Economic Geology

All the contents is part of a journal publication - Water Requirements for Hydrogen Production: Assessing Future Demand and Impacts on Texas Water Resources (Sustainability, Jan 2025)

Aggregate Demand for Hydrogen in Texas

1 Net Zero Scenario (NZ)
2030: 14.2 million metric tons per year
2050: 44.3 million metric tons per year

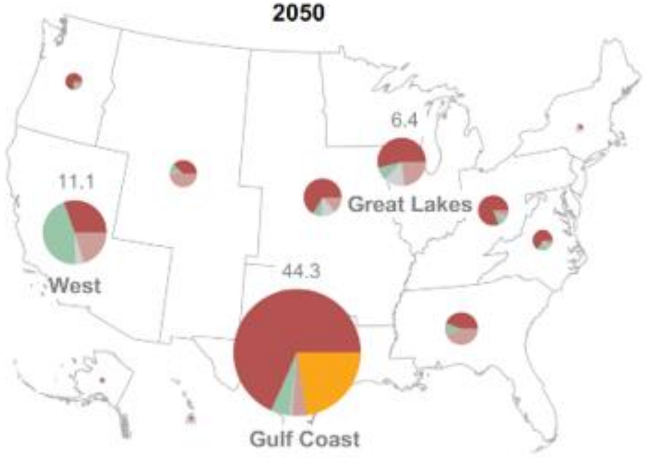
2 Stated Policy Scenario (SP)
2030: 9.5 million metric tons per year
2050: 30.1 million metric tons per year



Net Zero Scenario

Regional Competitive Advantages

Gulf Coast
Natural gas and solar/wind resource advantages; Access to infrastructure; Potential and anchor demand
West
Policy for mobility applications such as LCFS, ACT/ACF
Great Lakes and Appalachia
High wind capacity; Appalachia natural gas access



Exports | Residential & Commercial | Power | Transportation | Industrial

Source: MIT modeling for NPC Hydrogen study
Demand in MMTpa (Million metric tons per annum)
LCFS– Low Carbon Fuel Standard
ACT– Advanced Clean Transportation
ACF– Advanced Clean Fleets

NPC study (2024) has projected two scenarios of regional demand for hydrogen led by the Gulf Coast (TX and LA). These scenarios are the base for estimating hydrogen demand for Texas in the study.

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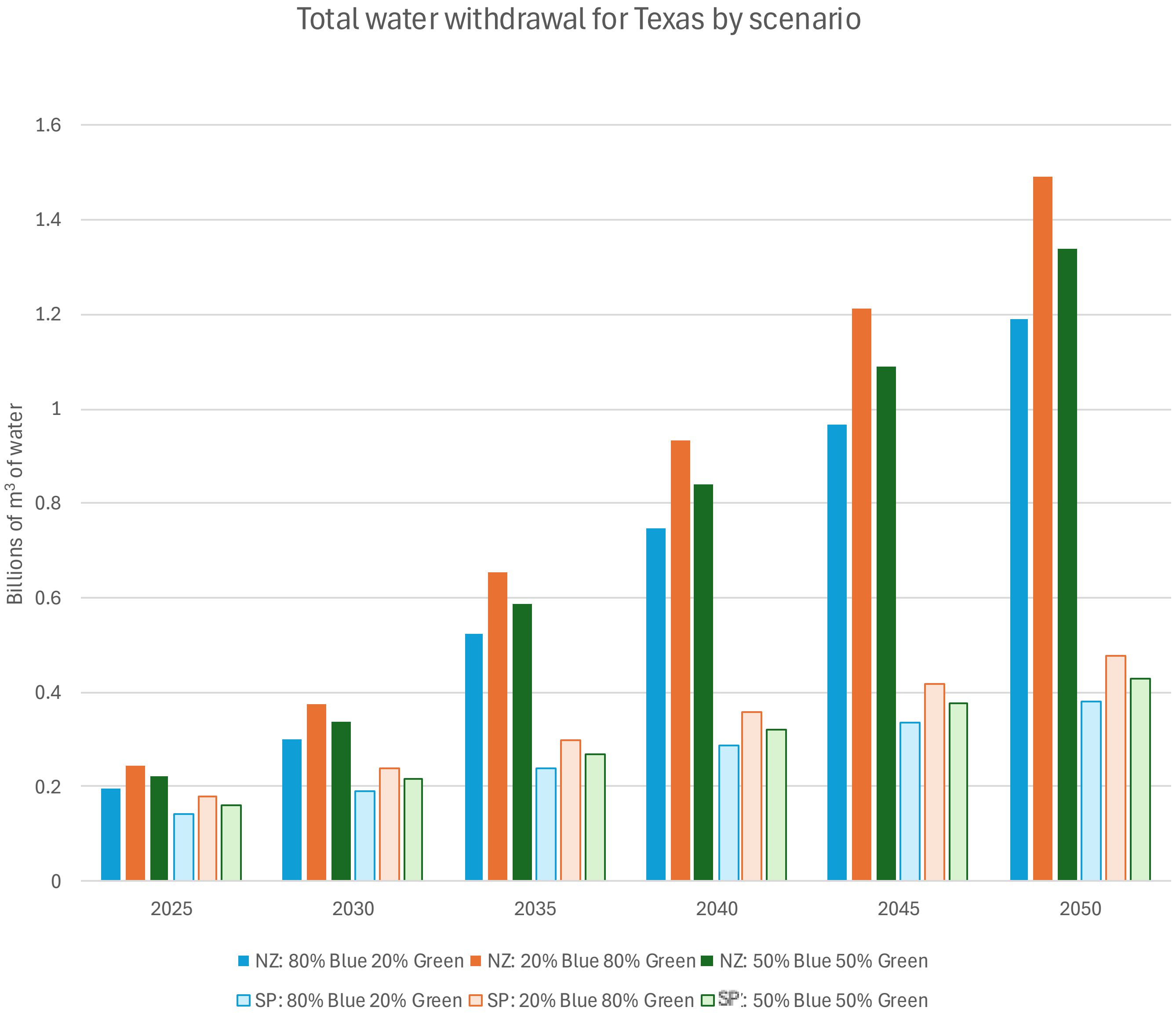
Aggregated Water Demand by Scenario

This projection assumes a steady ramp-up in hydrogen demand driven by industrial, transportation, and power sectors.

Production Mix Scenarios: Two scenarios are considered for the hydrogen production mix:

1. Scenario 1: 80% blue hydrogen (SMR/ATR + CCS) and 20% green hydrogen (electrolysis).
2. Scenario 2: 20% blue hydrogen and 80% green hydrogen.
3. Scenario 3: 50% blue hydrogen and 50% green hydrogen with high end estimates of water.



Let us talk about the scale of water demand for hydrogen!

Table 3. 2026 Texas State Water Plan's Regional Water Demand Projections for 2030–2050 by demand sector as percentages of total water demand in Texas [13].

Demand Sectors	2030	2040	2050
Irrigation	48.3%	45.0%	41.1%
Livestock	1.7%	1.8%	1.8%
Manufacturing	9.4%	9.8%	10.3%
Mining	2.4%	2.3%	2.3%
Municipal	34.4%	37.3%	40.7%
Steam Electric Power	3.8%	3.8%	3.8%
Total (in billion m^3)	21.4	21.9	21.9
Hydrogen Sector Percentage			
State Policy Scenario	1.0%	1.5%	2.0%
Net-Zero Scenario	1.8%	3.8%	6.8%

Note: Hydrogen projections are from 50% blue hydrogen and 50% green hydrogen mix. The hydrogen percentages are calculated against the original state total.

Stated Policy Scenario: (business as usual, no major policy shift): Hydrogen production consumes ~2% of state water use by 2050.

Net Zero Scenario (net-zero push with strong hydrogen deployment): Hydrogen production could reach ~6.8% of Texas water use by 2050.

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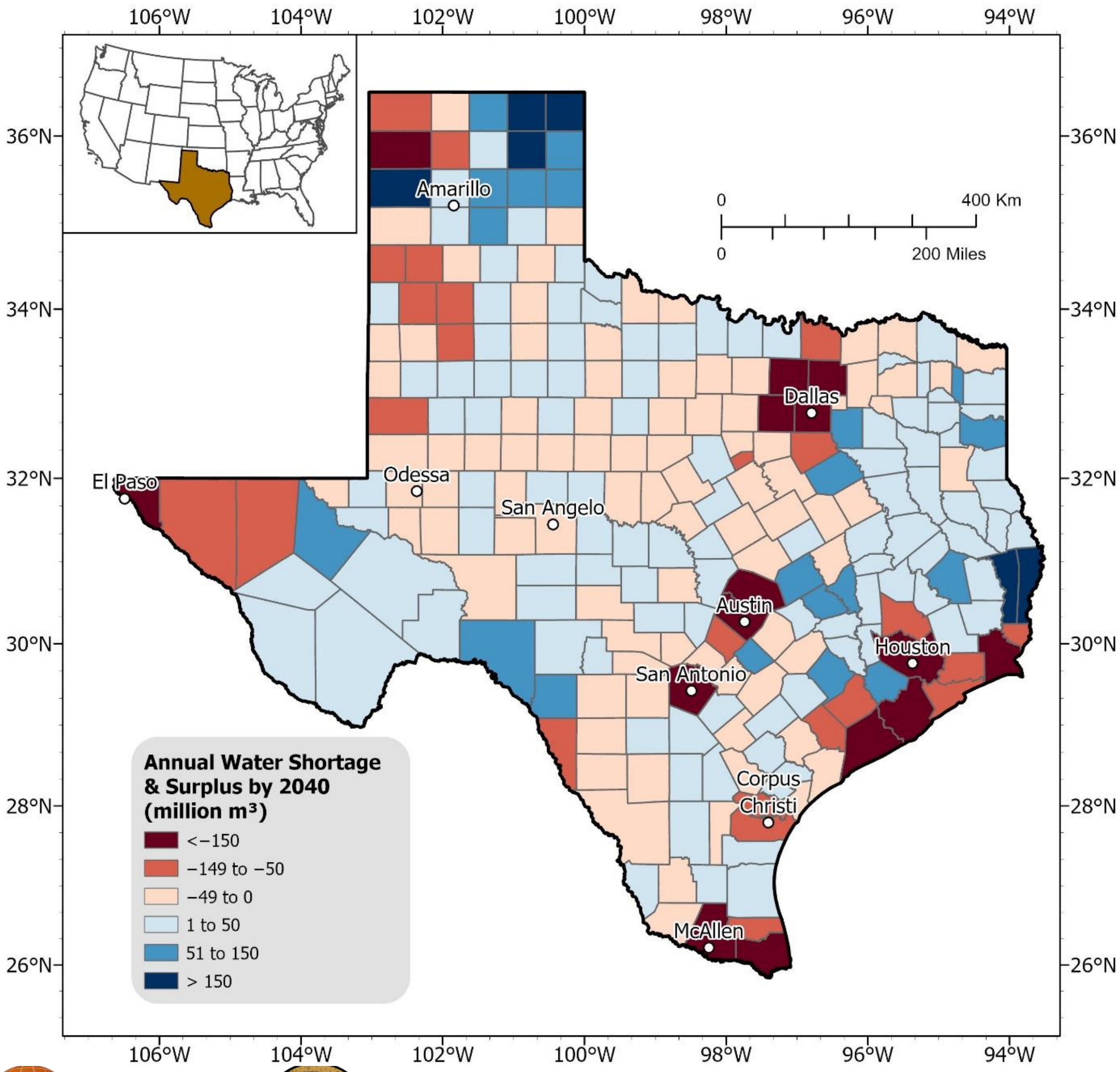
GeoH$_2$

Projected annual water needs (in terms of shortage and surplus) per county by 2040 (units: million m3).



Locational Considerations and Water Management in Texas

Houston-Gulf Coast

1

Access to surface water, but high competition from refining & petrochemical industries.

West Texas & Permian Basin

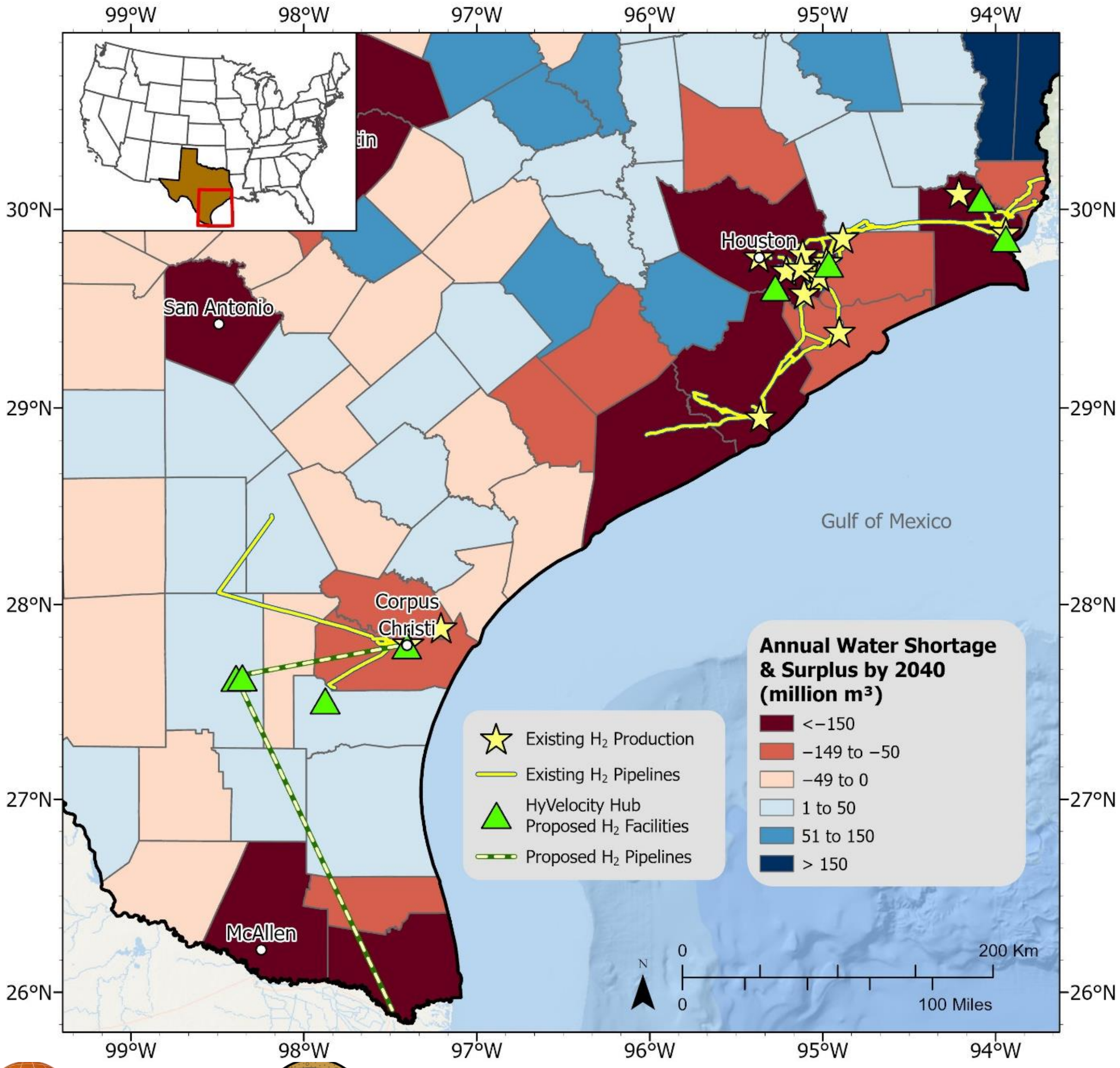
2

Limited groundwater, potential to **reuse produced water** from oil & gas.

South Texas (Corpus Christi)

3

Proximity to desalination but **higher costs**.



Key Takeaways

- Hydrogen production requires substantial water, but impact varies by pathway (SMR vs. electrolysis).
- Texas will see increased water demand from hydrogen, but localized challenges are key.
- Water costs & infrastructure will influence where hydrogen projects are feasible.
- State Water Plan does not currently account for hydrogen—future integration needed.
- Locational strategies (recycling, alternative sources) will be critical for sustainability.

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GeoH2

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Texas Water and Hydrogen Policy

Shanthanu Katakam[1], Grace Childers[2], Michael Lewis[3], Emily Beagle[1,4], Yael Glazer[1,4], Sandra Banda[4], Vaibhav Bahadur (VB)[1], Michael E. Webber[1,4]

[1]Walker Department of Mechanical Engineering
[2]McKetta Department of Chemical Engineering
[3]Center for Electromechanics
[4]LBJ School of Public Affairs

Strategic Energy Seed Grant Program

Research Question:
What are the economic and policy implications and barriers for using produced water for hydrogen production in Texas?

U.S. Federal Hydrogen Policy Does Not Include Water Requirements for Eligibility

- U.S. Federal 45V Clean Hydrogen Production Tax Credit passed in the Inflation Reduction Act
- Clean hydrogen eligibility based upon lifecycle carbon intensity (kg CO_2e/kg H_2)

Life Cycle Emissions (kg CO_2/kg H_2)	**PTC Value (\$/kg H_2)**
4.0 - 2.5	$0.60
2.5 - 1.5	$0.75
0.45 - 1.0	$1.00
< 0.45	$3.00

Legislation for Produced Water has been introduced in the current Texas Legislative Session

1. S.B. No. 1145 (Filed 89th Legislature, Regular Session)
    - Overview: This bill amends Section 26.131 of the Texas Water Code to enhance the authority of the Texas Commission on Environmental Quality (TCEQ) regarding the issuance of permits for the land application of treated produced water from mining and oil and gas extraction operations.
    - Key Provisions:
        - TCEQ's Authority: TCEQ is granted the authority to issue permits for the land application of treated produced water, defined as water that has been treated for beneficial use.
        - Pollution Prevention Standards: The bill mandates the adoption of standards for land application, ensuring that practices prevent the pollution of both surface and subsurface water.
        - Replacement of RRC with TCEQ: The bill replaces references to the Railroad Commission of Texas (RRC) with TCEQ in the context of issuing permits for waste discharge related to these activities.

Legislation for Produced Water has been introduced in the current Texas Legislative Session

1. H.B. No. 1808 (Filed 89th Legislature, Regular Session)
    - Overview: This bill focuses on enhancing the regulation and management of produced water from oil and gas operations in Texas. It amends the Natural Resources Code to include provisions for the recycling and beneficial use of produced water while protecting public health and the environment.
    - Key Provisions:
        - Railroad Commission's Role: A new subdivision is added to Section 91.101 of the Natural Resources Code, outlining the responsibilities of the Railroad Commission of Texas in managing produced water alongside its existing regulations for drilling, production, and waste disposal.
        - Permit Application Assistance: The bill modifies Section 26.131 of the Water Code to require the TCEQ to provide assistance to applicants seeking permits for the discharge of produced water, hydrostatic test water, and gas plant effluent. This assistance aims to facilitate permit applications and ensure compliance with established water quality standards.

Legislation for Produced Water has been introduced in the current Texas Legislative Session

- H.B. No. 2584 (Filed 89th Legislature, Regular Session)
- Overview: This bill expands the Texas Commission on Environmental Quality (TCEQ)'s authority to issue permits for the land application of produced water from mining and oil and gas extraction operations. It establishes standards to ensure environmental protection while allowing for the beneficial reuse of treated produced water.
- Key Provisions:
  - TCEQ Permit Authority: The bill authorizes TCEQ to issue permits for the land application of treated produced water from mining and oil and gas activities.
  - Regulatory Oversight: The Railroad Commission of Texas (RRC) retains its authority over waste discharge permits, but land application permits for treated produced water now fall under TCEQ's jurisdiction.

Analysis on Hydrogen Costs Show Minimal Sensitivity to Input Water Price

Sourced Freshwater $0.005/gal

		Utilization (%)					
		15	20	40	60	80	90
	0.02	$ 5.32	$ 3.78	$ 1.46	$ 0.68	$ 0.02	$ 0.17
	0.04	$ 6.53	$ 4.99	$ 2.67	$ 1.89	$ 1.51	$ 1.38
Electricity Cost [$/kWh]	0.055	$ 7.44	$ 5.89	$ 3.57	$ 3.10	$ 2.42	$ 2.29
	0.08	$ 8.95	$ 7.41	$ 5.09	$ 4.31	$ 3.93	$ 3.80
	0.1	$ 10.16	$ 8.62	$ 6.30	$ 5.52	$ 5.14	$ 5.01

LCOH of Hydrogen found using NREL H2A-Lite Cost Tool considering variations in input water cost, electricity cost, and electrolyzer utilization (assuming $3/kg PTC)

20X increase in input water cost ($0.005/gal to $0.10/gal) increases LCOH by **$0.50**

Higher Range of Treated Wastewater Cost $0.10/gal

		Utilization (%)					
		15	20	40	60	80	90
	0.02	$ 5.82	$ 4.28	$ 1.96	$ 1.18	$ 0.80	$ 0.67
	0.04	$ 7.03	$ 5.49	$ 3.17	$ 2.39	$ 2.01	$ 1.88
Electricity Cost [$/kWh]	0.055	$ 7.94	$ 6.39	$ 4.07	$ 3.30	$ 2.91	$ 2.78
	0.08	$ 9.45	$ 7.91	$ 5.59	$ 4.81	$ 4.43	$ 4.30
	0.1	$ 10.66	$ 9.12	$ 6.80	$ 6.02	$ 5.64	$ 5.51

Modeling Hydrogen Production Water Demand and Produced Water Supply

Current Annual Hydrogen Production in Texas[1]	3.5 MMT/yr
Water Required for H_2 Production Process (including cooling)[2] → Will vary in a sensitivity study as part of next steps	19.9 liters/kg H_2
Annual water usage for H_2 Production	**70 billion liters/yr**
Estimated Produced Water in Permian Basin[3]	425 billion liters/yr
Fraction of produced water consumed if current hydrogen production were sourced using produced wastewater as feedstock	**16%**

[1] HyVelocity Hub Information

[2] Water Requirements for Hydrogen Production: Assessing Future Demand and Impacts on Texas Water Resources, Sustainability, 2024

[3] Texas Produced Water Consortium Report, 2022

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Produced water treatment technologies: Technical and techno-economic analysis

Shanthanu Katakam[1], Grace Childers[2], Michael Lewis[3], Emily Beagle[1], Yael Glazer[1], Vaibhav Bahadur (VB)[1]

[1]Walker Department of Mechanical Engineering
[2]McKetta Department of Chemical Engineering
[3]Center for Electromechanics

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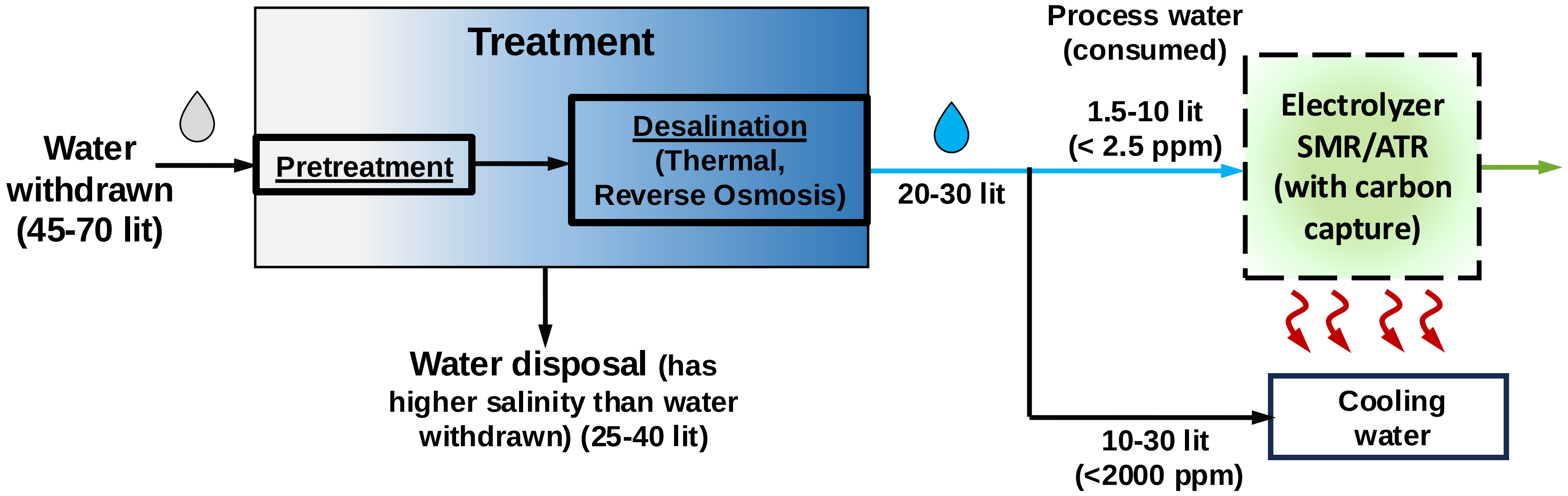
Water requirements for hydrogen

- Hydrogen production requires significant water
- Quantity & quality matter
- Water needed for
  - Process (Electrolysis, Methane reforming): Ultrapure water needed (Total Dissolved Solids < 2.5 ppm)
  - Cooling: Industrial quality-water needed (Total Dissolved Solids < 2000 ppm)
- Picture below outlines water requirements for H_2
- Overall, 1kg H_2 requires 20-30 liters water



Based on reports from IRENA, NETL, NREL, DOE etc#

Water Requirements for Hydrogen Production: Assessing Future Demand and Impacts on Texas Water Resources, Sustainability 2024

Water requirements breakdown

- Green Hydrogen (GH_2) - Renewables powered electrolysis
- Blue Hydrogen (BH_2) - Steam Methane (SMR) or Autothermal Reforming (ATR) with CO_2 Capture

Detailed breakdown of freshwater requirements for clean hydrogen production

Process	Process water (lit_{water}/ kg_{H2}) (TDS: < 2.5 ppm)	Cooling water (lit_{water}/ kg_{H2}) (TDS< 2000 ppm)	Total water Demand (lit_{water}/ kg_{H2}) (Process + Cooling Water)
GH_2	10	10	20
SMR w/ CO_2 Cap.	1.5	30	31.5
ATR w/ CO_2 Cap.	2.5	28	30.5

Based on reports from IRENA, NETL, NREL, DOE etc#

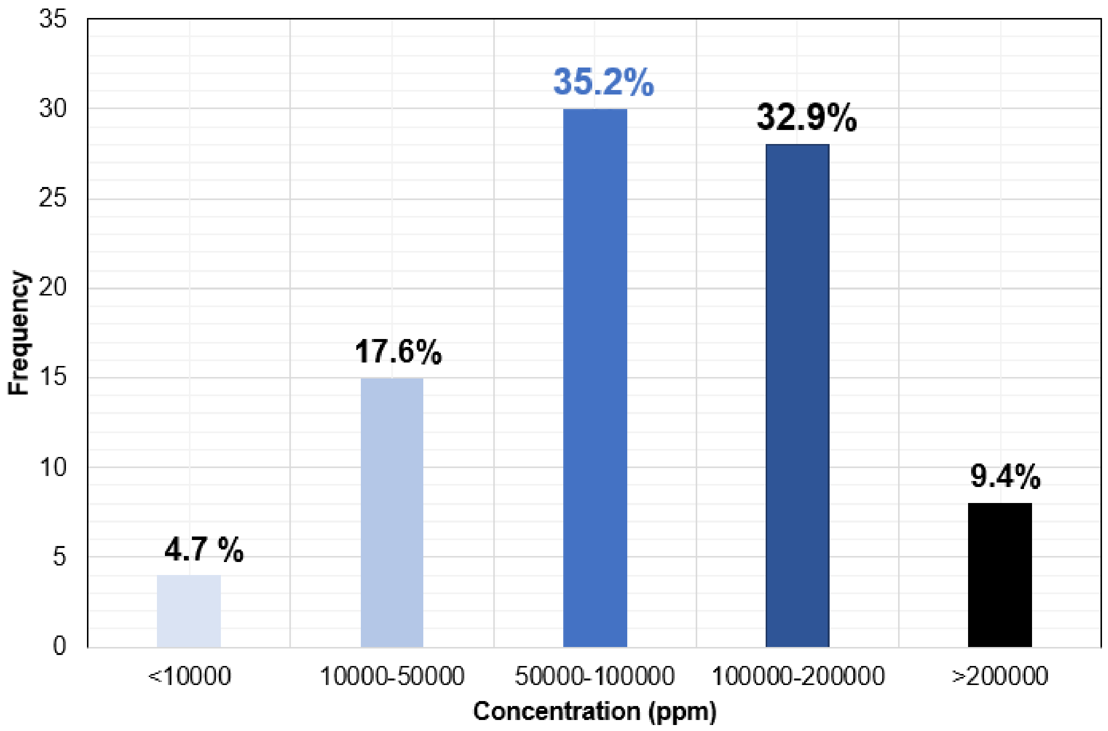
Water Requirements for Hydrogen Production: Assessing Future Demand and Impacts on Texas Water Resources, Sustainability 2024

Produced Water in Permian Basin

- Produced Water (PW) – Hypersaline brine from oil-gas operations
- Volume of produced water: 20+ million barrels/day
- Salinity & water output of well varies with time
- Histogram shows wells grouped as per various ranges of Total Dissolved Solids (TDS) (in ppm)
  - Based on data from ~85 wells
  - Flow data not available

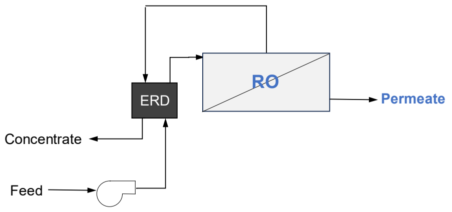
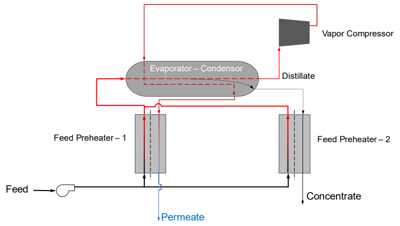
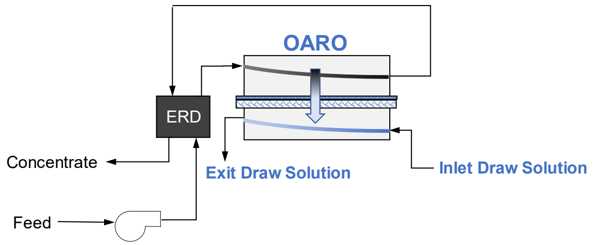
There is no shortage of PW
Technical challenge is to clean it up to levels required

Average PW concentration = 93,815 ppm
Composition = 95-98% NaCl



Dec 2023 USGS Data for wells in Permian basin

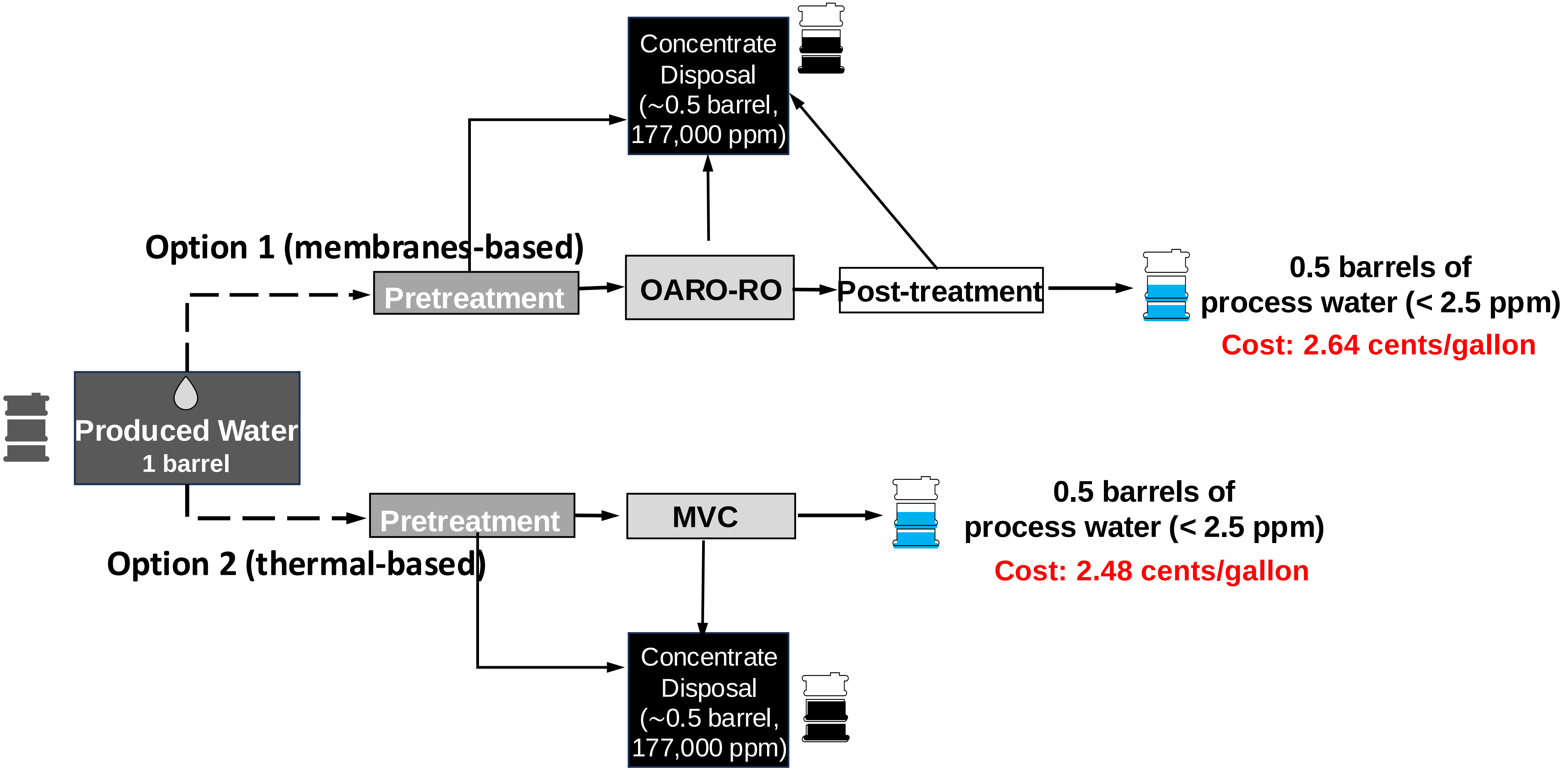
Overview: 3 water treatment technologies

	Reverse Osmosis (RO)	Mechanical Vapor Compression (MVC)	Osmotically Assisted Reverse Osmosis (OARO)
What feed concentration can it handle?	0-50,000 ppm TDS	50,000 - 200,000 ppm TDS	50,000 - 100,000 ppm TDS
What % of Permian water can be treated?	22 %	75 %	35 %
Working Principle	Membrane based pressure driven separation 	Thermal energy driven separation 	Membrane based pressure driven separation 
Advantages	Low energy consumption	Suitable for hypersaline feed; extensive pretreatment not required	Energy efficient & partially suitable for hypersaline PW feed
Disadvantages	Extensive pretreatment required; restricted suitability due to burst pressure limitations	Energy & CAPEX intensive	Extensive pretreatment required; Not yet commercialized

How much process water can we get and what is the cost?

Results of technical and techno-economic analysis

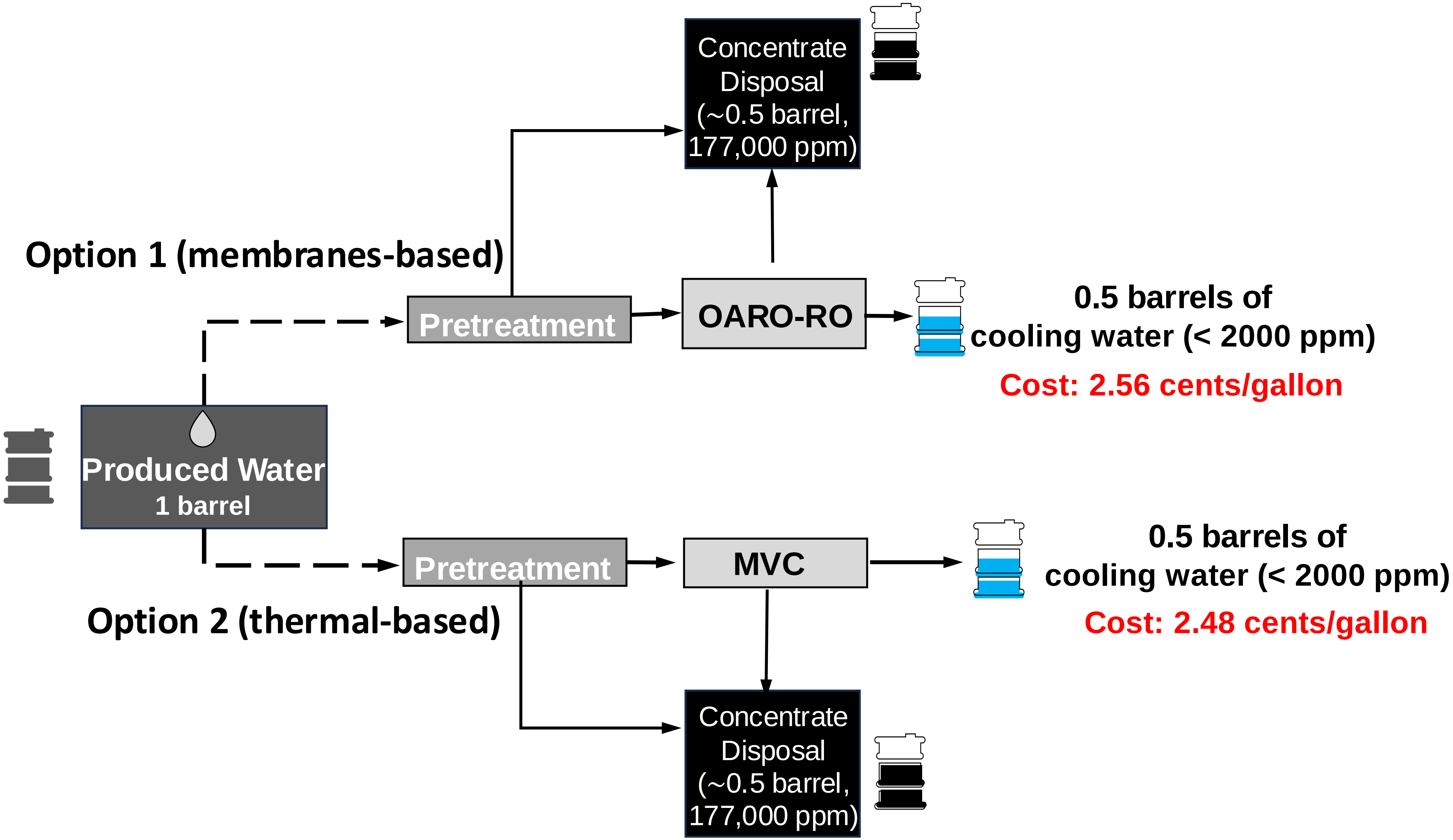
Treatment of 1 barrel of produced water from Permian of average salinity (~95,000 ppm)



How much cooling water can we get and what is the cost?

Results of technical & techno-economic analysis

Treatment of 1 barrel of produced water from Permian of average salinity (~95,000 ppm)



Takeaways

- Significant potential for PW use
- Cooling water: Less complex; much less treatment required
- Process water: Multi-step treatments required
- Treatment approach needs to be tailored to specific streams
- Costs depend on specific streams (more accurate cost models being looked at; can expect costs to be 2.5-3 cents/gallon)

THANK YOU.

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Innovation starts here