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Reimagining the carbon ecosystem

Green Methanol Production from Atmospheric CO_2

DOE Award: DE-FE0032397

Presented by
Jonathan Peters, Principal Investigator

DOE Project Manager: Akhil Sathish

August 8, 2024

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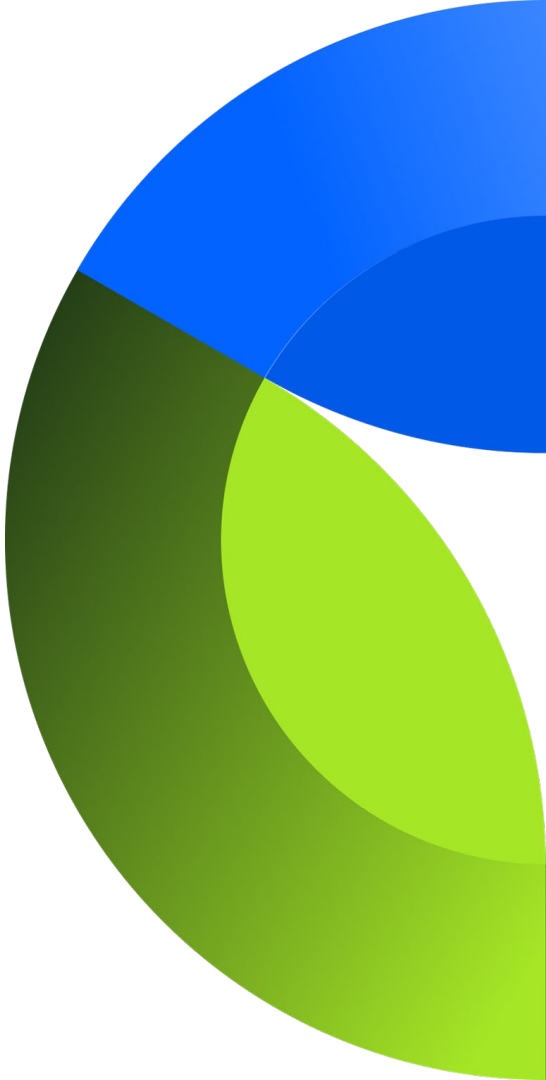

Project Overview

Title	Green Methanol Production from Atmospheric CO_2
Award No.	DE-FE0032397
Period of Performance	12/20/2023 – 12/19/2024
Project Funding	DOE: $400,000 Cost-Share: $100,000
Overall Project Goal	Develop an integrated process to utilize carbon dioxide (CO_2) and water (H_2O) extracted directly from air using carbon-free electricity to efficiently produce sustainable, carbon negative methanol at a production cost of less than $800/metric ton.
Project Participants	Susteon Inc. and Johnson Matthey
DOE/NETL Project Manager	Mr. Akhil Sathish

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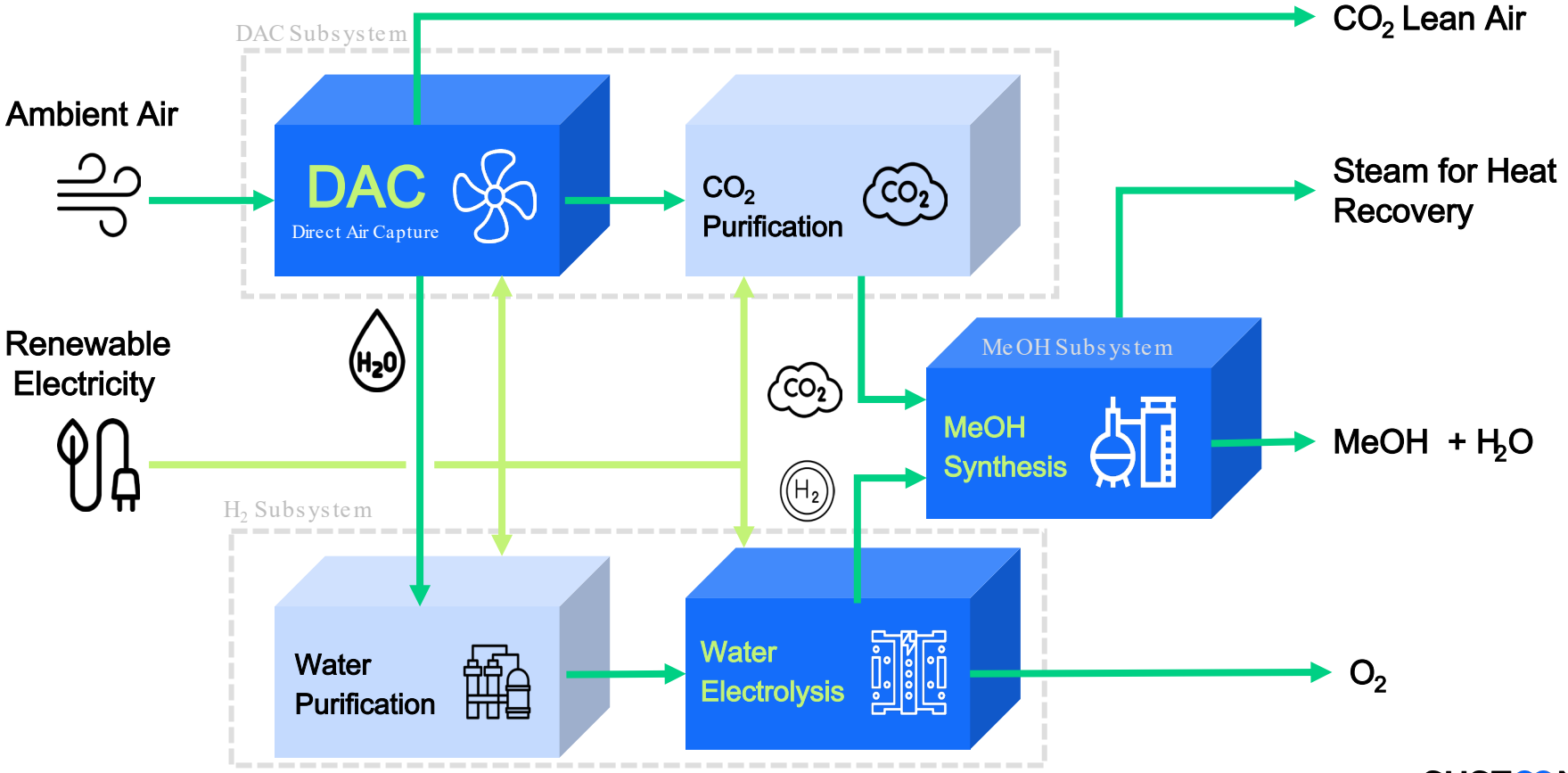
Green Methanol Production – Integrated Process



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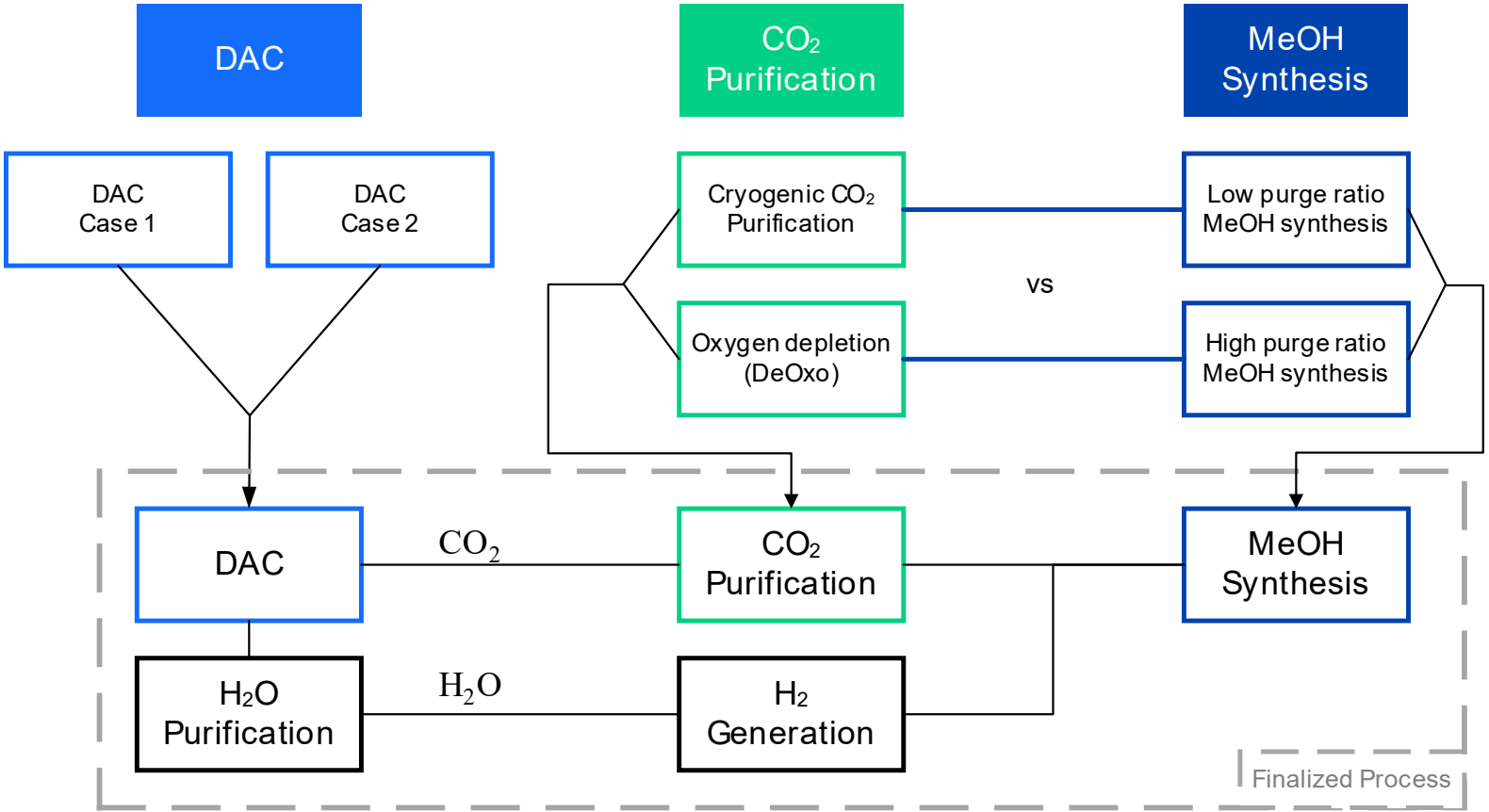
Project Objectives

- **Develop an integrated process to achieve <$800/t green methanol production at the 50,000 TPY scale**
  - Design the process for the reference plant. The prototype will demonstrate the critical components of the full-scale process.
  - Develop flowsheets for each subsystem: CO_2 production, H_2 production, and methanol synthesis
  - Develop an integrated process model
  - Optimize process to achieve cost target while maintaining net negative carbon emissions
- **Design an integrated bench -scale prototype to produce carbon negative methanol at 10kg/day scale.**
  - Develop flowsheets for each subsystem: CO_2 production, H_2 production, and methanol synthesis
  - Develop an integrated process model
  - Develop mass and energy balances, P&IDs, major equipment specs

Subsystem Selection Process



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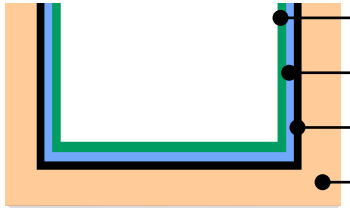
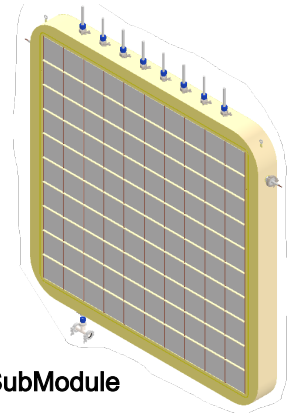
DAC Technology Background



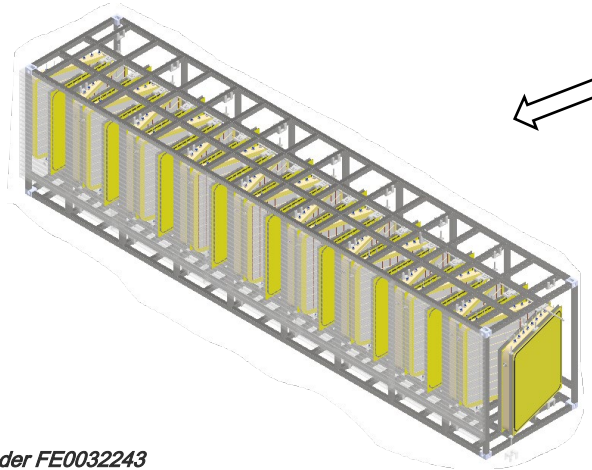
SMA

x196



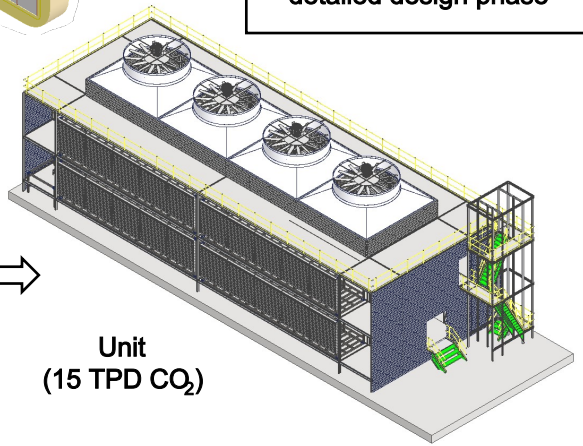
SubModule

x14

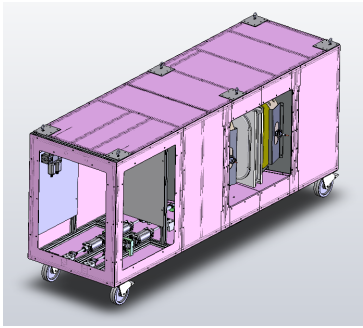


Module

x8



Unit
(15 TPD CO_2)



15 kg CO2/day in
detailed design phase

Developed under FE0032243

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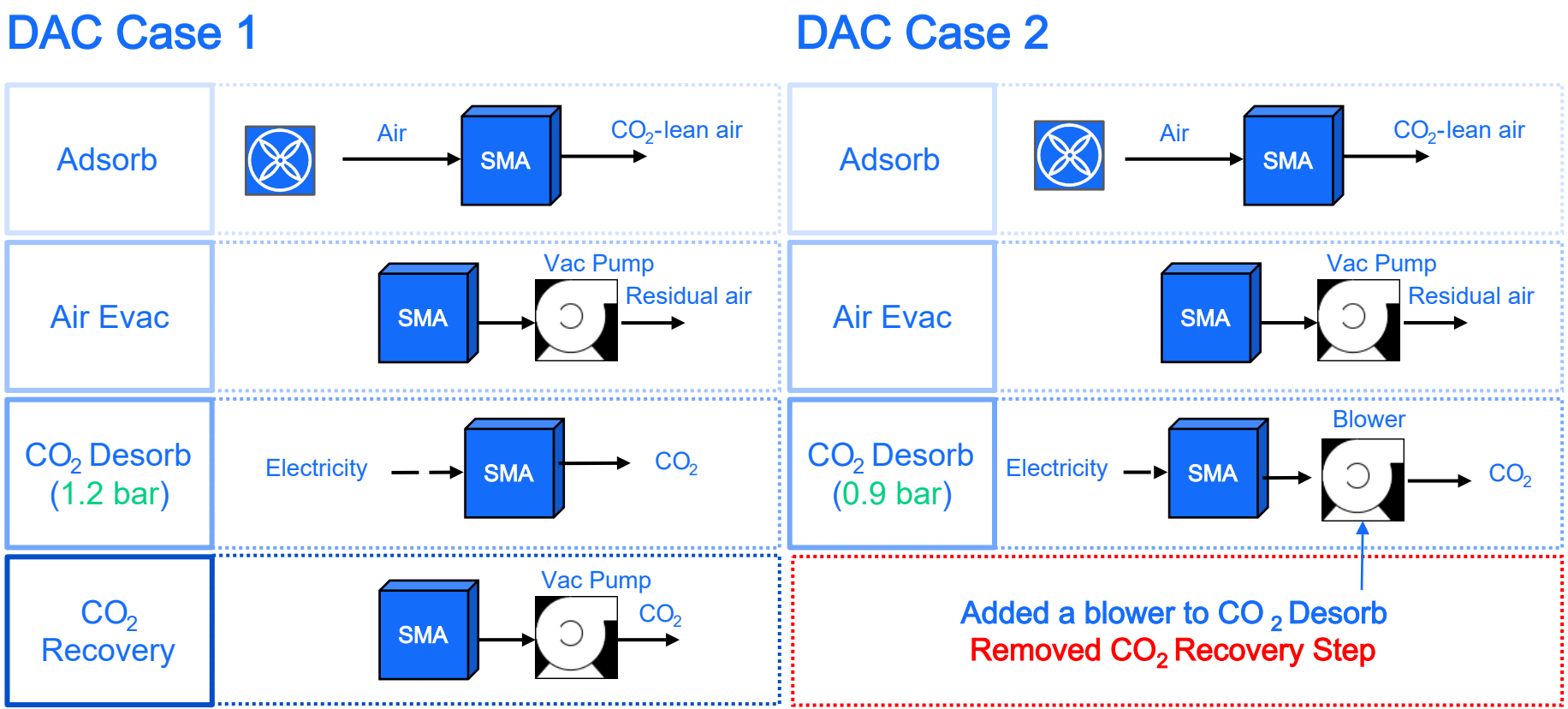
DAC Subsystem Comparison



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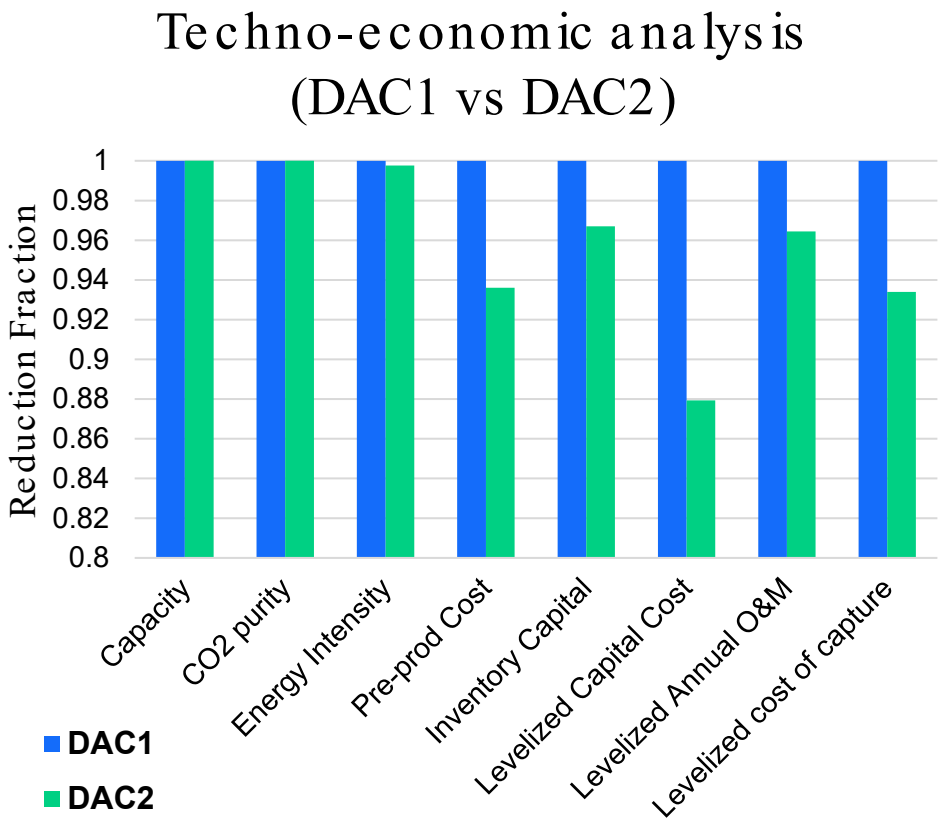
Cost Comparison between DAC 1 & DAC 2 (50,000 TPY)



Variables	Unit	DAC 1	DAC 2
CO_2-Sorbent Molar Capacity	mmol/gSorbent	1.3	1.3
H_2O: CO_2 Pickup Ratio	gH_2O/gCO_2	2	2
Average Adsorption Rate	$molCO_2$/kgSorbent/min	0.028	0.028
Average Desorption Rate	$molCO_2$/kgSorbent/min	0.152	0.152

Variables	Unit	DAC 1	DAC 2
Total CO_2 Capacity	tonne/day	256	262
CO_2 Product Purity (Mole Fraction)		0.9462	0.9467
Energy Intensity (Total)	kWh/tonne-CO_2	3074	3066
Desorption Energy		2671	2673
Unit Fan		384	374
Air Evacuation Pump		12	12
Instrument Air Compressor		4	4
CO_2 Recovery Pump/ Blower		3	4
Levelized Cost of Capture	$/tonne-$CO_2$	**352**	**329**

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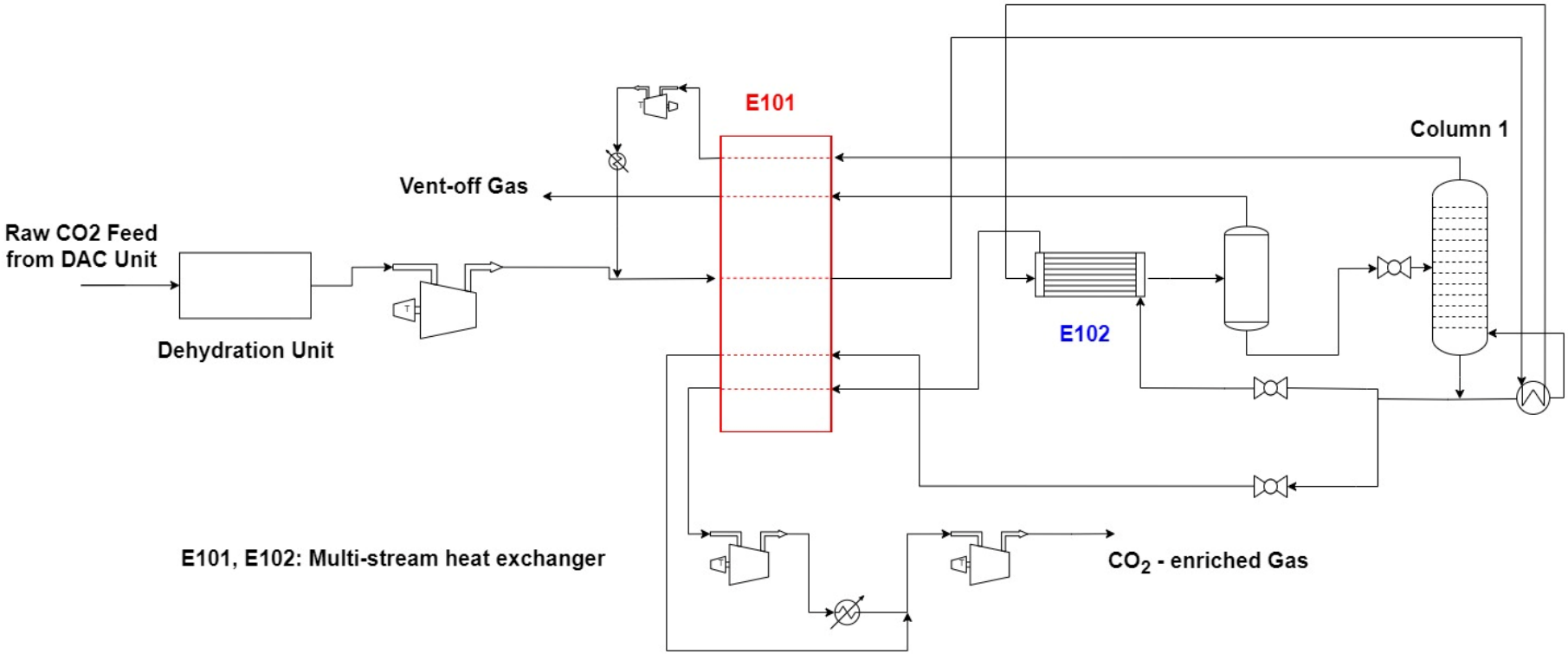
CPU: Compression and Purification (Using Distillation)



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CPU: Compression and Purification (Using Distillation)

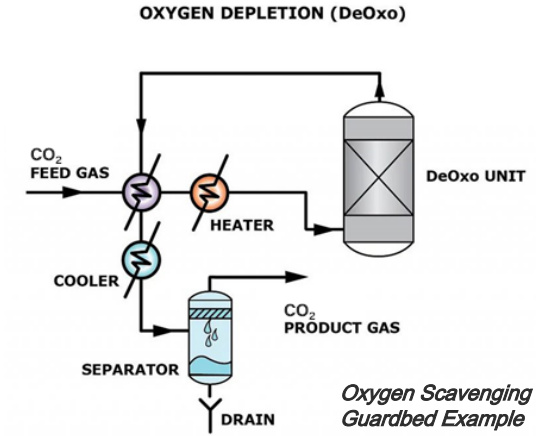
STREAM	UNIT	RAW CO2 FEED	VENT-OFF GAS	REMOVAL WATER	CO2-ENRICHED GAS
Temperature	℃	47.02	1.71	47.02	43.92
Pressure	bar	1.10	29.00	1.1	21.54
Flowrate	tonne/day	259.87	8.12	4.51	247.24
Mole fraction					
CO_2		0.9465	0.6473	0	0.999992
O_2		0.0026	0.0738	0	7.27E-6 (7 ppm)
Ar		0.0001	0.0033	0	2.77E-7
N2		0.0095	0.2756	0	8.51E-7
Water		0.0413	0	1	0

COST COMPONENT	UNIT	VALUE	PERCENT CONTRIBUTION (%)
Capital	$/tonne-CO2	15.71	38.41
Fixed	$/tonne-CO2	22.14	54.13
Variable*	$/tonne-CO2	3.05	7.46
Total	$/tonne-CO2	40.90	100.00

**$0.03/kWh*

Purification: Configuration 1: CO_2 DeOxo Unit w/Guard bed

- **Approach 1:** Oxygen Scavenging Guard bed
- **Approach 2:** Combustion
  - Co-feed H_2 to DeOxo Unit to reduce O_2 concentration and producing water
- **Approach 1 + 2:** Combining Oxygen Scavenging Guard bed and Combustion



Oxygen Scavenging Guardbed Example

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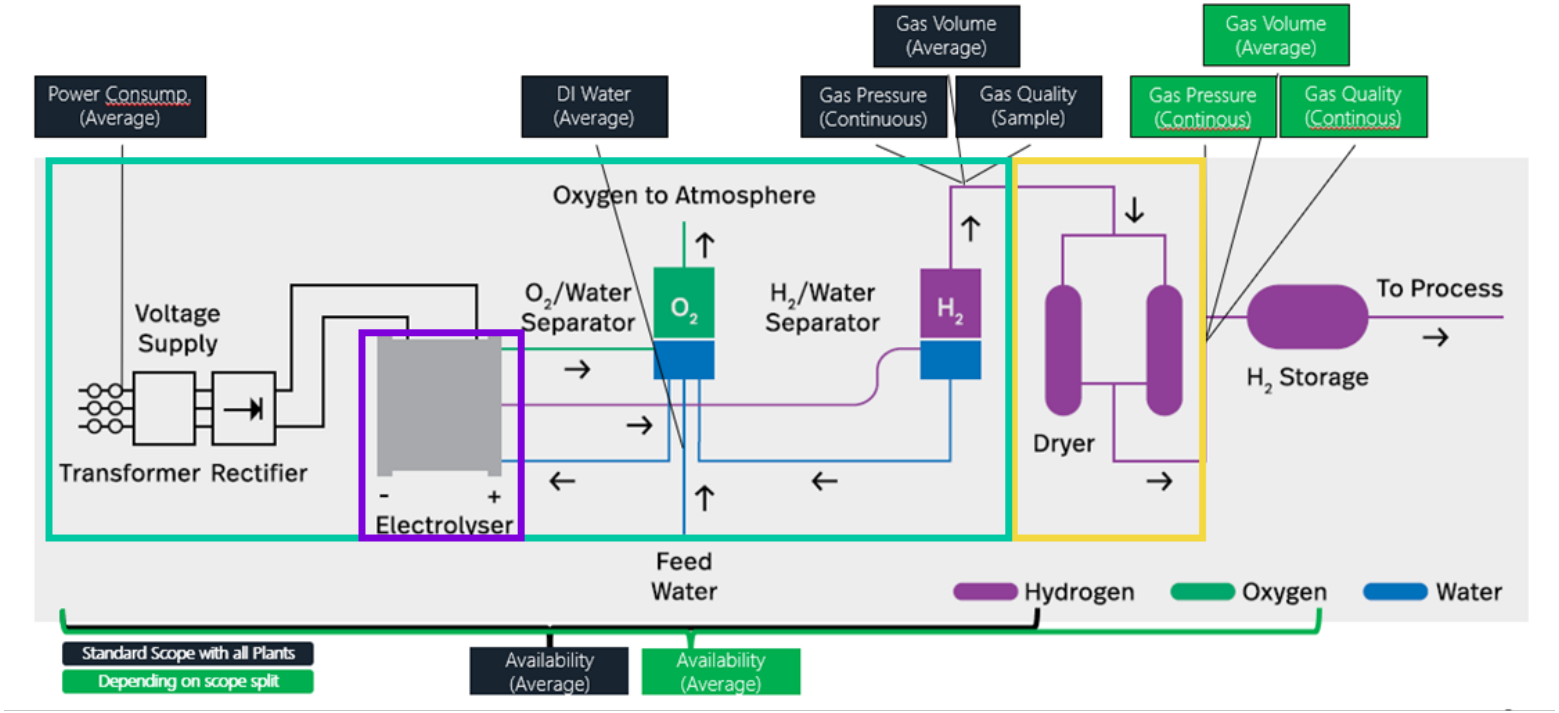
PEM Electrolyzer PFD



Nel cell stack module

Balance of system (ex-dryer)

Balance of system (dryer option)

PEM Electrolyzer

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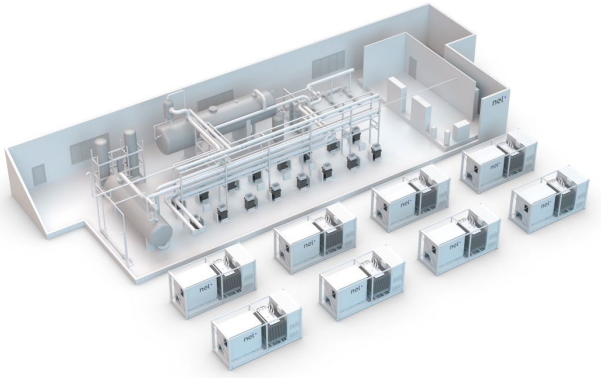

	S40 Series	M5000 Series (X3)
Methanol Capacity	10 kg/day	50,000 TPY
H_2 requirement	2.2 kg H_2/day	27 tonnes H_2/day
Power requirement	6.4 kW	56 MW
Water requirement	0.94 L H_2O/h	12,000 L H_2O/h

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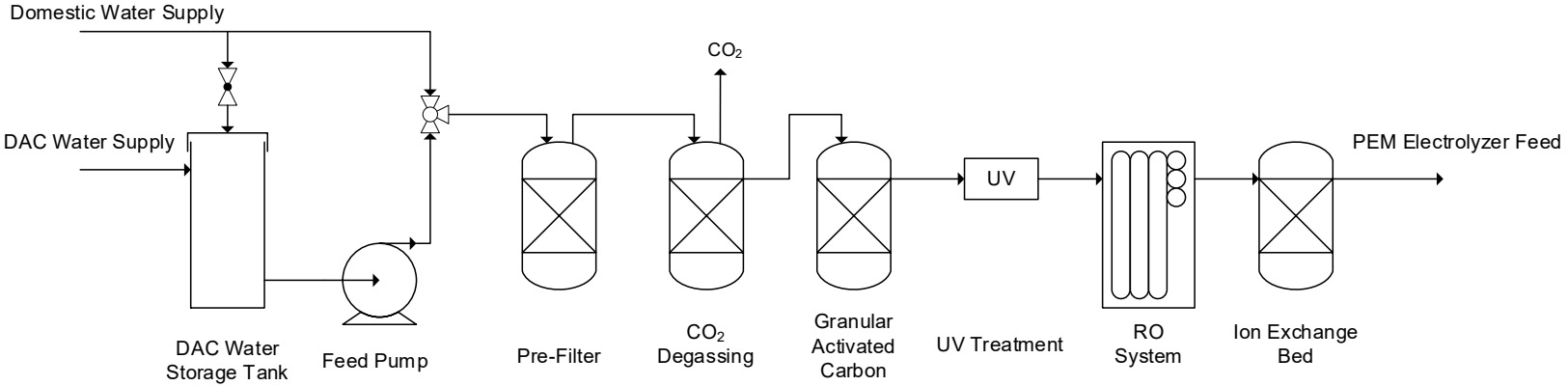
Water Purification PFD



Variables	Unit	Reference plant capacity	Bench scale capacity
Temperature	C	74.32	74.37
Pressure	bar	1.20	1.20
Flow rate	gal/min	114.60	0.0075 (0.5 gal/hr)
Mole Fraction			
N_2		3.08E-09	3.13E-09
O_2		1.16E-08	1.18E-08
Ar		4.99E-10	5.07E-10
CO_2		0.000020	0.000020
H_2O		0.999980	0.999980

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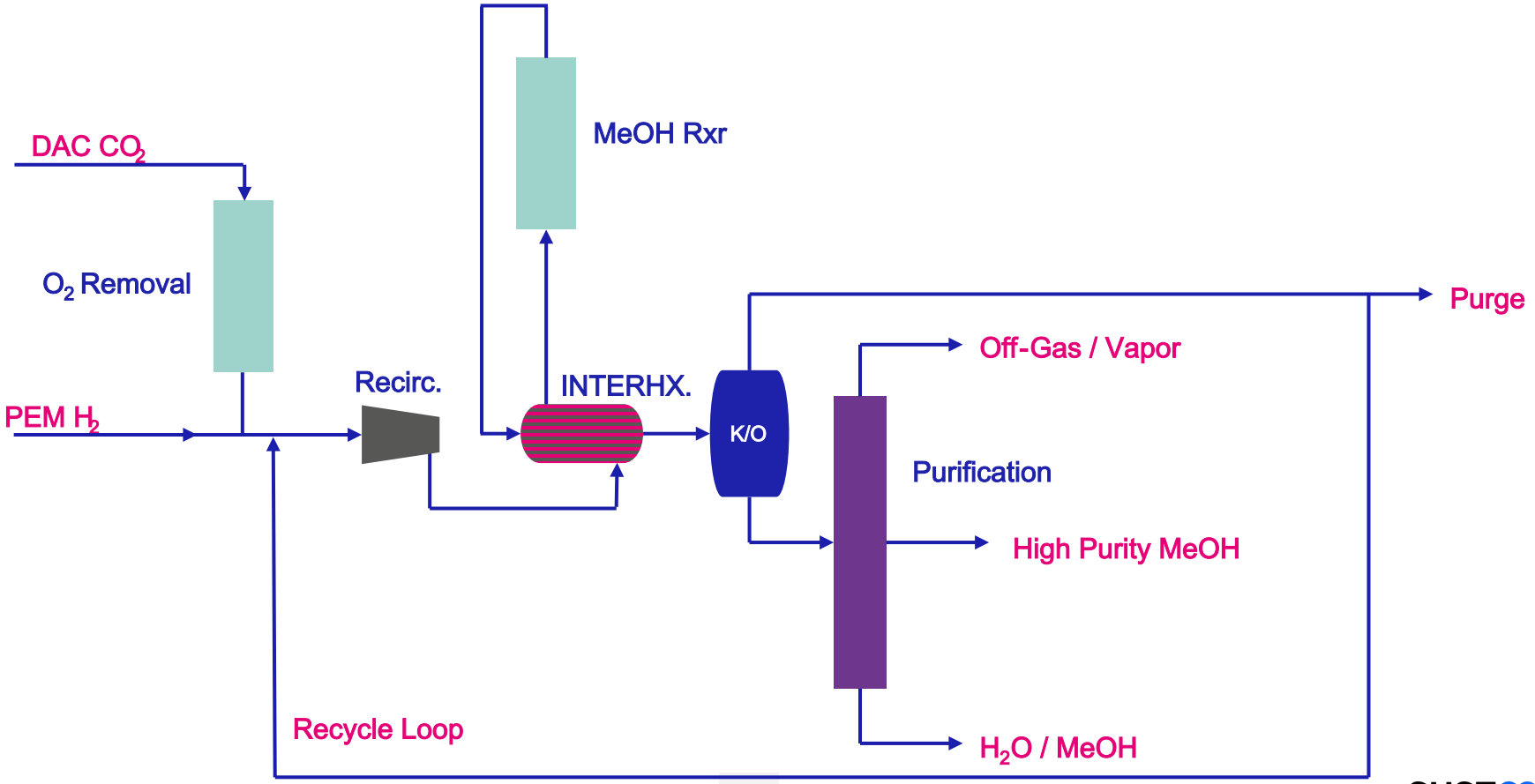
Methanol Synthesis PFD



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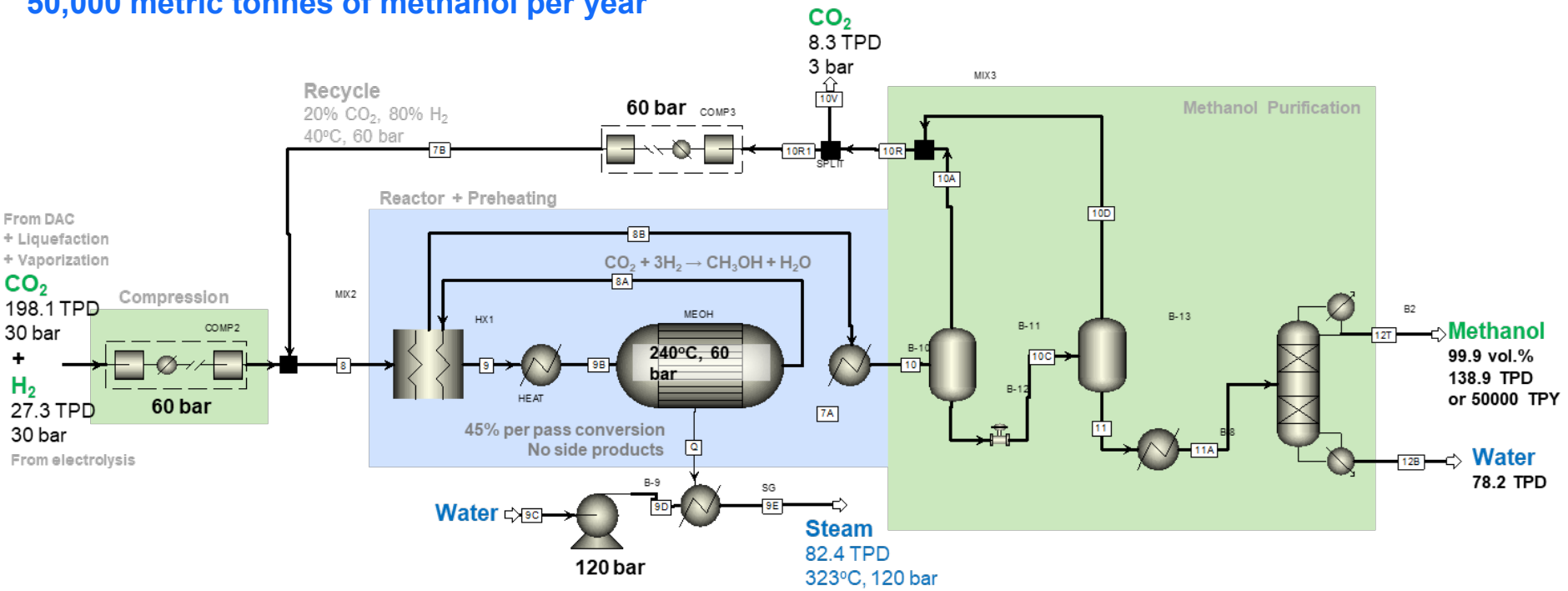
CO_2- Based Methanol Synthesis PFD

50,000 metric tonnes of methanol per year



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Summary

- Developed a process concept integrating Susteon's DAC technology with PEM electrolyzer and JM's CO_2-based methanol synthesis technology.
- Established cryogenic distillation costs to compare with oxygen depletion technology for CO_2 purification
- JM is completing the methanol synthesis PFD
- Completed water purification and electrolysis PFDs

Community Benefits Plan (CBP)

Susteon's CBP goal is to incorporate equity and justice principles, community engagement and partnership development into our R&D and subsequent technology development so that overall project outcomes are improved.

Susteon has partnered with The Equity Paradigm to help guide CBP development

Diversity, Equity, Inclusion, and Accessibility Plan

- Diversity of experience, background, thought and perspective are key components of Susteon's company culture and values.
- Emphasizes corporate policy, working environment and local MSI relationships

Justice40 Initiative Plan

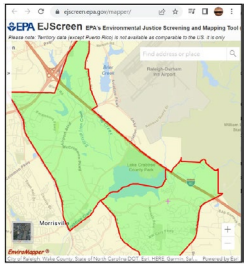
- Long term: environmental benefits
- Short term: MSI student project involvement and identify MWBE vendors

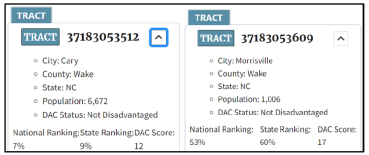
Community and Stakeholder Engagement Plan

- Outreach to local agencies and EJ organizations regarding community dynamics for validation projects
- Outreach to local MSI's for career planning opportunities.

Quality Jobs Plan

- Competitive total compensation and benefits packages. Assess areas for improvement.





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Next Steps

- Complete process models for subsystem configurations.
- Determine CAPEX for each subsystem configuration at 50,000 TPY scale.
- Develop process model for the 50,000 TPY integrated process.
- Develop Life Cycle Analysis for 50,000 TPY scale plant.
- Complete bench-scale (10 kg MeOH per day) design package.
- Submit proposal for Phase 2.

Acknowledgement

U.S. DEPARTMENT OF ENERGY

Award no. DE-FE0032397

The Equity Paradigm

Johnson Matthey
Inspiring science, enhancing life

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Thank You!

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