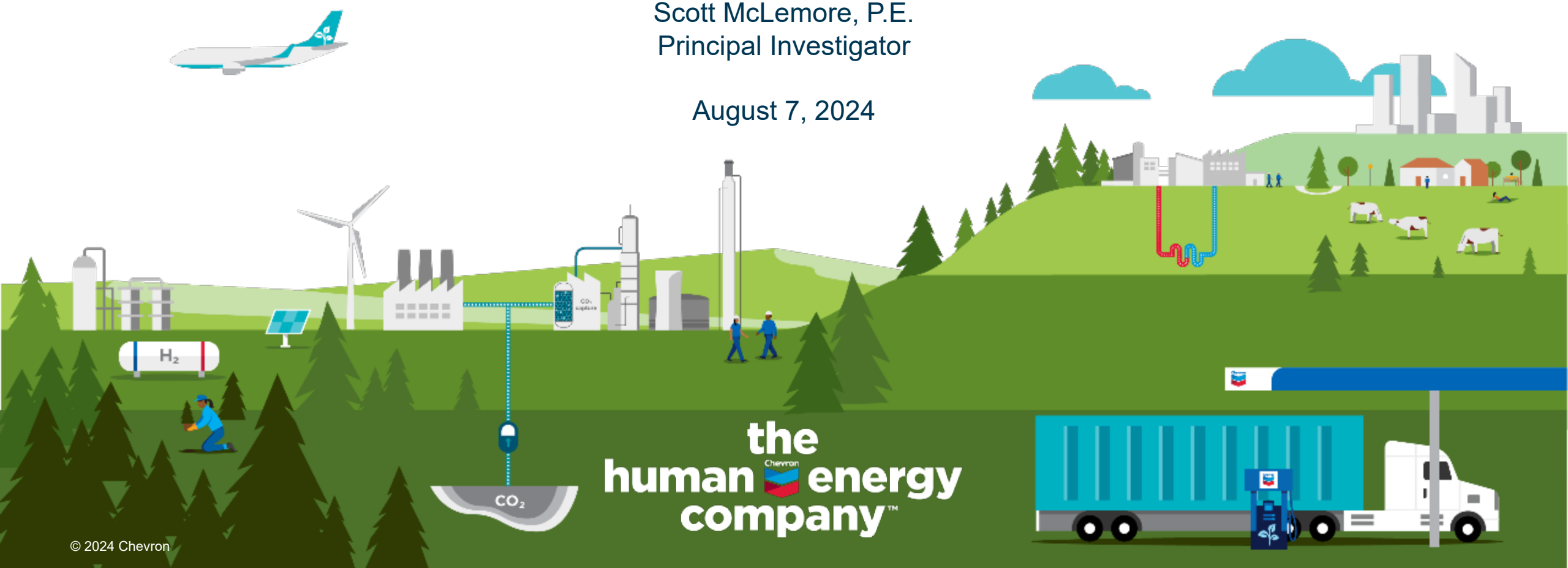
Chevron natural gas carbon capture technology testing project

Cooperative Agreement No. DE-FE0031944

Scott McLemore, P.E.
Principal Investigator

August 7, 2024



Project overview

Award Period

- 10/01/2020 through 08/30/2024

Project Funding

- Total Funding: $23,417,307
- Federal Funding: $13,000,000.00
- Cost Share Funding: $10,417,307 (Cash Contribution by Chevron)

Project Participants

- Chevron U.S.A. Inc., Prime Contractor, host site and cost share provider
  - Principal Investigator: Scott McLemore
  - Project Manager: Stan Cross
- Technology Provider: Svante, Inc.
- ISBL Engineering, Procurement and Construction: Kiewit Engineering Group Inc (KEGI) and Kiewit Power Constructors (KPC)
- Program Administrator: Electricore, Inc.
- Plant Operation and Maintenance: Offshore Technology Services (OTS)

DOE-NETL Team

- Grants Officer: Lisa Kuzniar, Project Manager: Nicole Shamitko-Klingensmith, Contracting Specialist: Kelly Haught

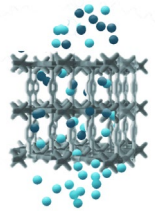
Project objectives

The project validated Svante's transformational solid sorbent-based carbon capture technology at an engineering scale under indicative natural gas flue gas conditions and continuous long-term operation at Chevron's Kern River oil field.

- Successfully completed the design, construction, commissioning, and long-term testing of an engineering-scale capture plant of approximately 25 tonnes per day (TPD) under steady-state conditions at varying flue gas carbon dioxide (CO_2) concentrations (~4–14%);
- Conducted a techno-economic analysis (TEA) on Svante's VeloxoTherm™ capture cycle as integrated into a nominal 550 MW (net) natural gas combined cycle (NGCC) power plant;
- Conducted a comprehensive gap analysis addressing the current stage of VeloxoTherm™ technology development for NGCC applications; and
- Summarize the research, development, and demonstration requirements to close identified gaps and approach the achievement of DOE's carbon capture performance goal of CO_2 capture with 95% CO_2 purity at a cost of $30/tonne of CO_2 captured by 2030.

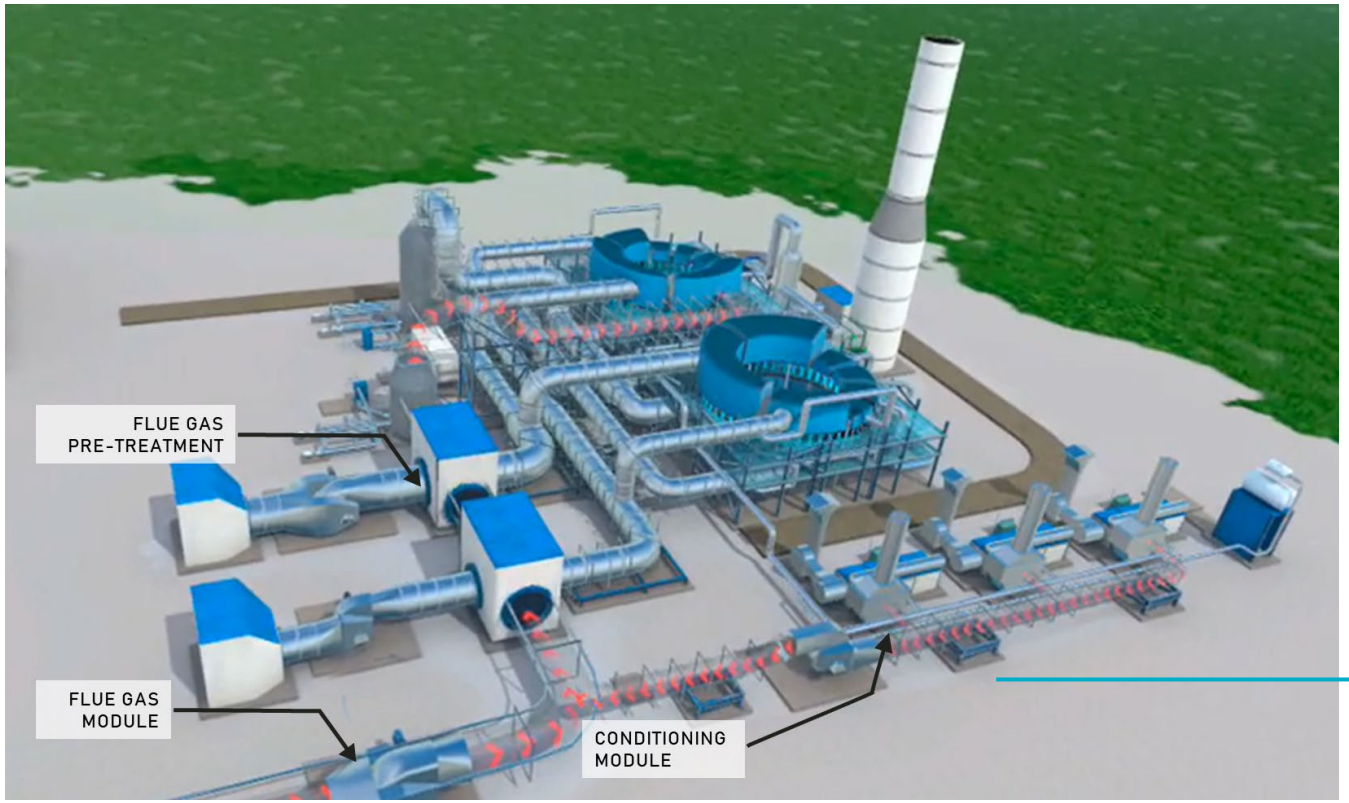
The Svante Carbon Capture Ecosystem

Scalable and Flexible



1. Solid Sorbents (MOFs)

Engineered to have high selectivity over water and N_2 and a high capacity for CO_2.

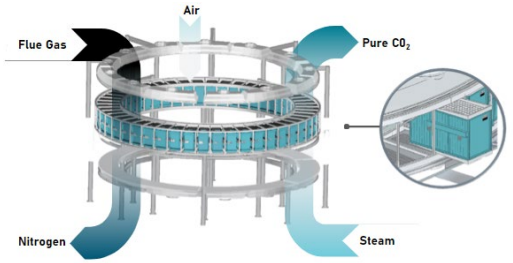


Nanoengineered Carbon Capture Filters

Solid sorbents are laid onto thin sheets of film and stacked to create a filter.

2. Contactor with Filters Inside

Robust machine design, Full-size prototype "Buck" in-house validation tests ongoing.



3. Performance and Lifetime

VeloxoTherm™ Rapid Temperature Swing Adsorption (RTSA) Cycle boasts and validated KPIs at demo units.

4. Carbon Capture Plant

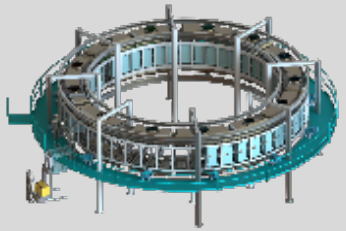
The overall design, integration, and optimization of the entire CO_2 capture plant that goes around the machine and process cycle.

Svante Technology Comparison

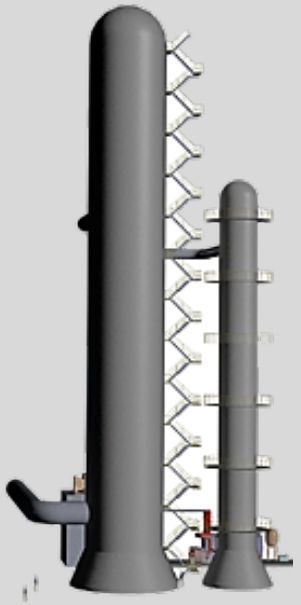
Novel Benefits Compared to Conventional

	Svante's Solid Adsorbent
Technology Description	– Separation relies on adsorption of CO_2 onto a solid surface – Regenerated using direct steam in an intensified temperature/concentration swing process that enables very rapid cycles
Modularization and Scalability	Adaptable and cost efficient at all scales due to the repeatability of the modular design
Ability to Deal with Intermittency of Emitters	High – rapid cycle speed
Toxic Fugitive Emissions	None – solid sorbent
Capital Intensity	Low – modular construction
Potential for Further Cost Reduction	New solid-state technology poised for significant cost reduction learning curve

System comparison



Svante's Solid Adsorbent Technology



Conventional Carbon Capture Technology Using Liquid Solvents

Kern River carbon capture plant

facility overview and objectives

San Joaquin Valley, CA USA

Natural gas-based flue gas testing

Understand and measure capture plant performance on boiler, NGCC and SMR feed flue gas

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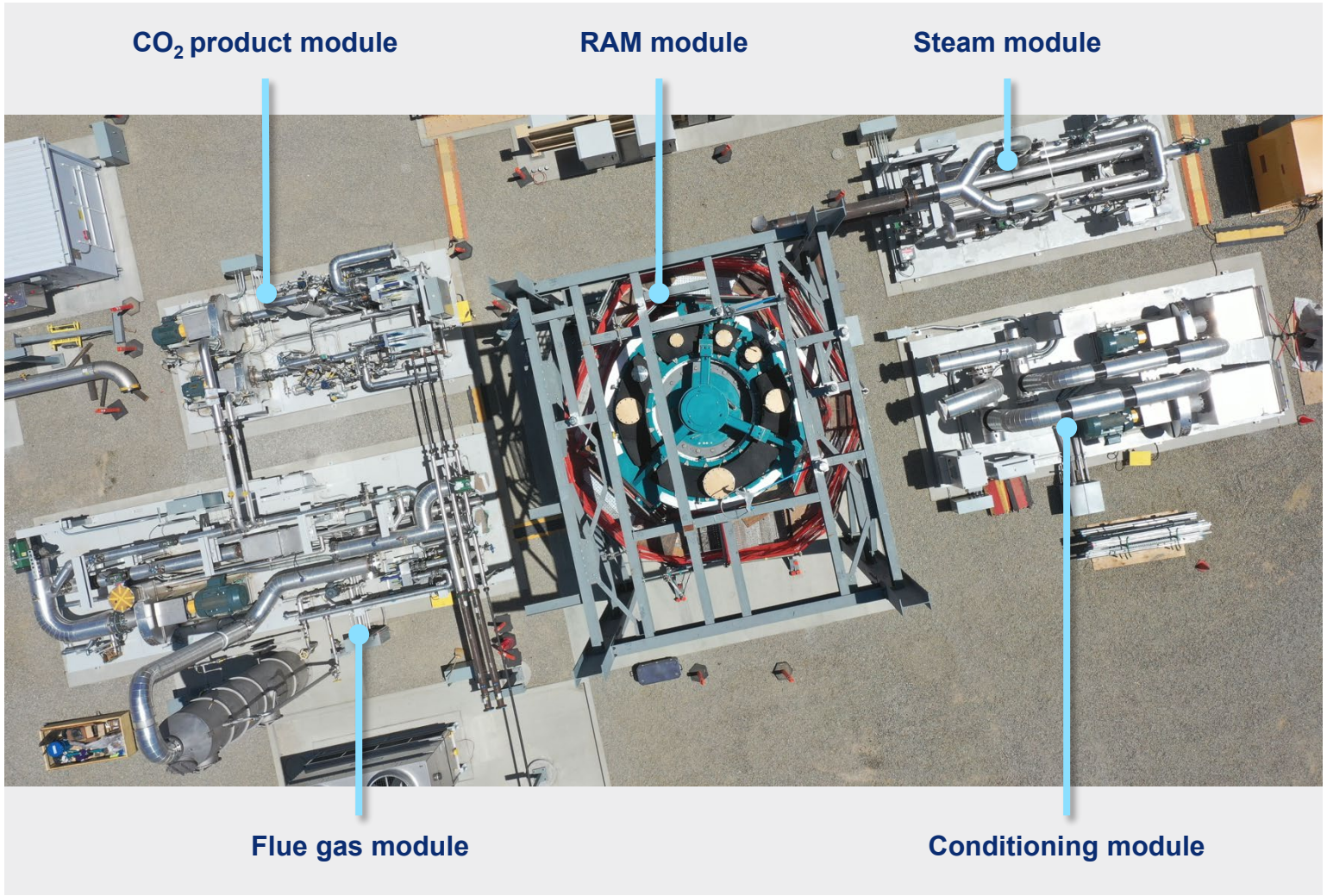
Skid-mounted modular design carbon capture plant

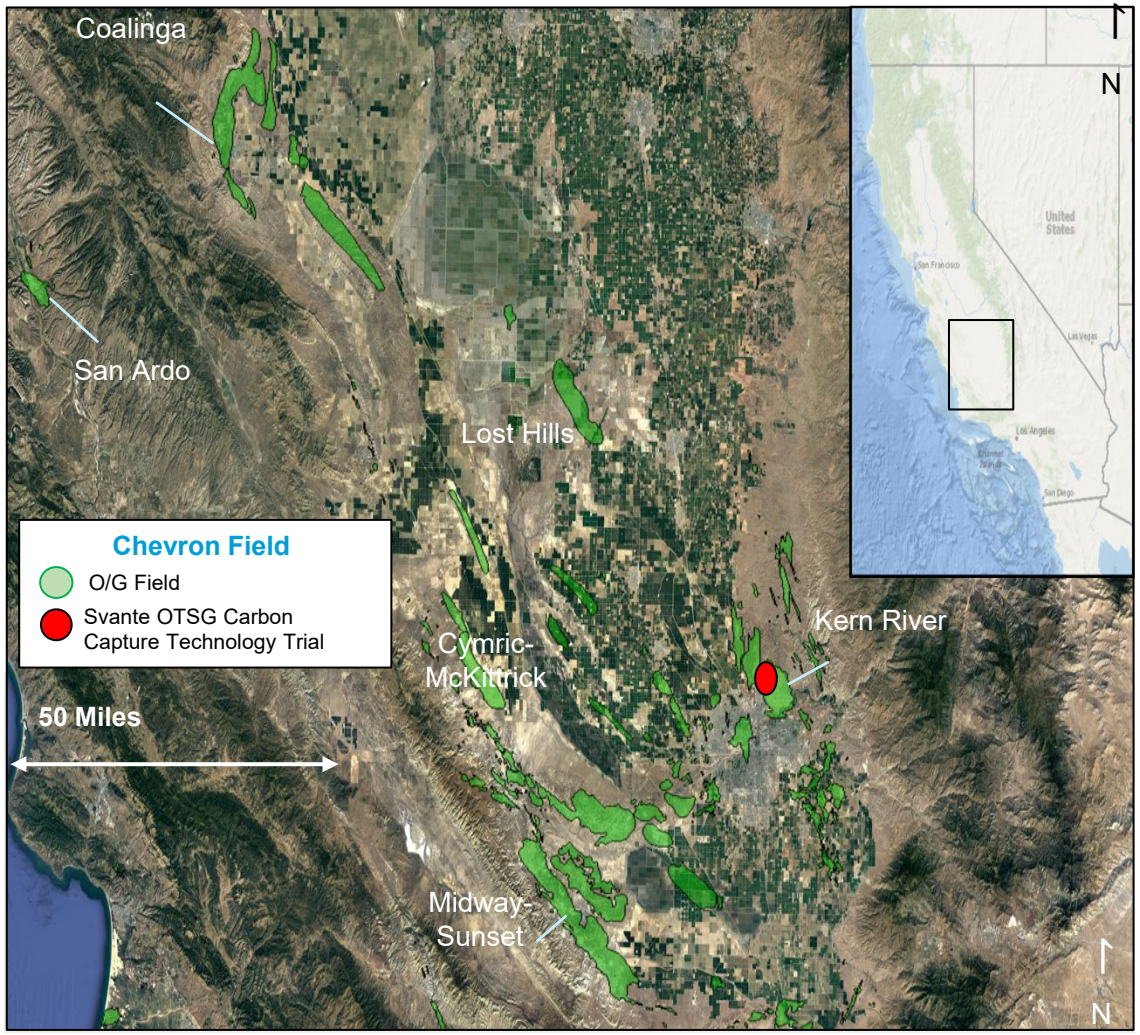
New metallic organic framework (MOF) sorbent beds

95% CO_2 product purity and lower steam ratio compared to conventional solvent technology



Project location — Kern River Oilfield

Reducing the carbon intensity of our operations through scalable demonstration projects



Technical approach

This project is conducted over three (3) budget periods

- ☑ **Budget Period 1**
  - ☑ Process Engineering
  - ☑ Design Criteria
  - ☑ Sorbent Certification
- ☑ **Budget Period 2**
  - ☑ Detailed Engineering
  - ☑ Procurement, Fabrication and Installation
  - ☑ Pre-Startup Safety Review, Commissioning and Test Planning
- ❑ **Budget Period 3**
  - ☑ Engineering Scale Testing and Analysis
  - ❑ Technology Assessment **(In Progress)**

Success criteria

Successful completion
of all work proposed

Completion of engineering scale VeloxoTherm™ testing
with natural gas flue gas

State-point data table

EH&S report

Techno-economic analysis

Submission of a final report
that details pathway to achieve DOE's performance goals
(CO_2 capture with 95% CO_2 purity at a cost of $30/tonne of CO_2 captured by 2030)

Progress and Current Status

List of testing completed

1. 14% Indicative Coal Flue Gas Feed Testing
2. 4% Indicative NGCC Flue Gas Feed Testing
3. Base Performance and Steady State Testing
4. Load Following & Intermittence Testing

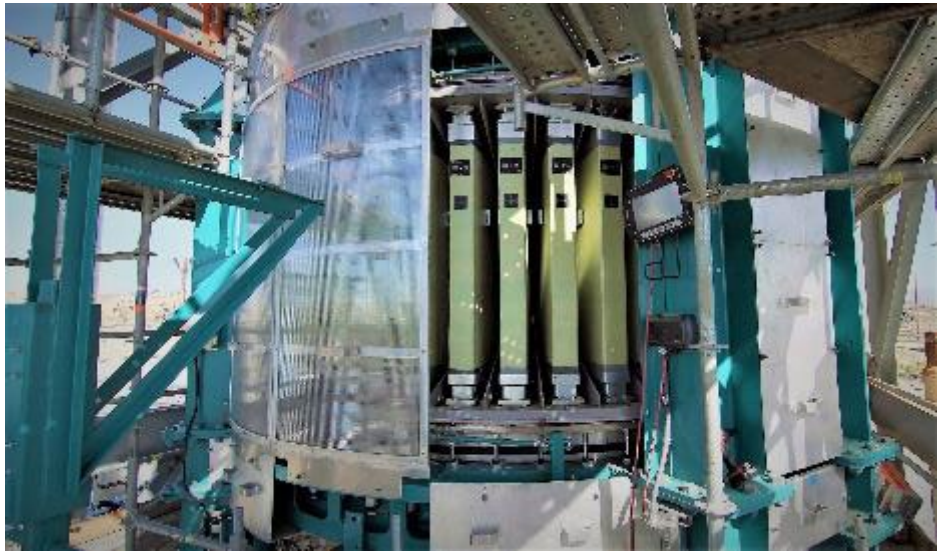
Key Summary of Tests

Stable operation over the duration of each test case; KPIs remain flat, no significant change

BOP limitation impacted data gathering & achievement of project set KPIs; reverified after modification

Load following responded as anticipated – 60 sec. cycle for Adsorption/Desorption/Conditioning

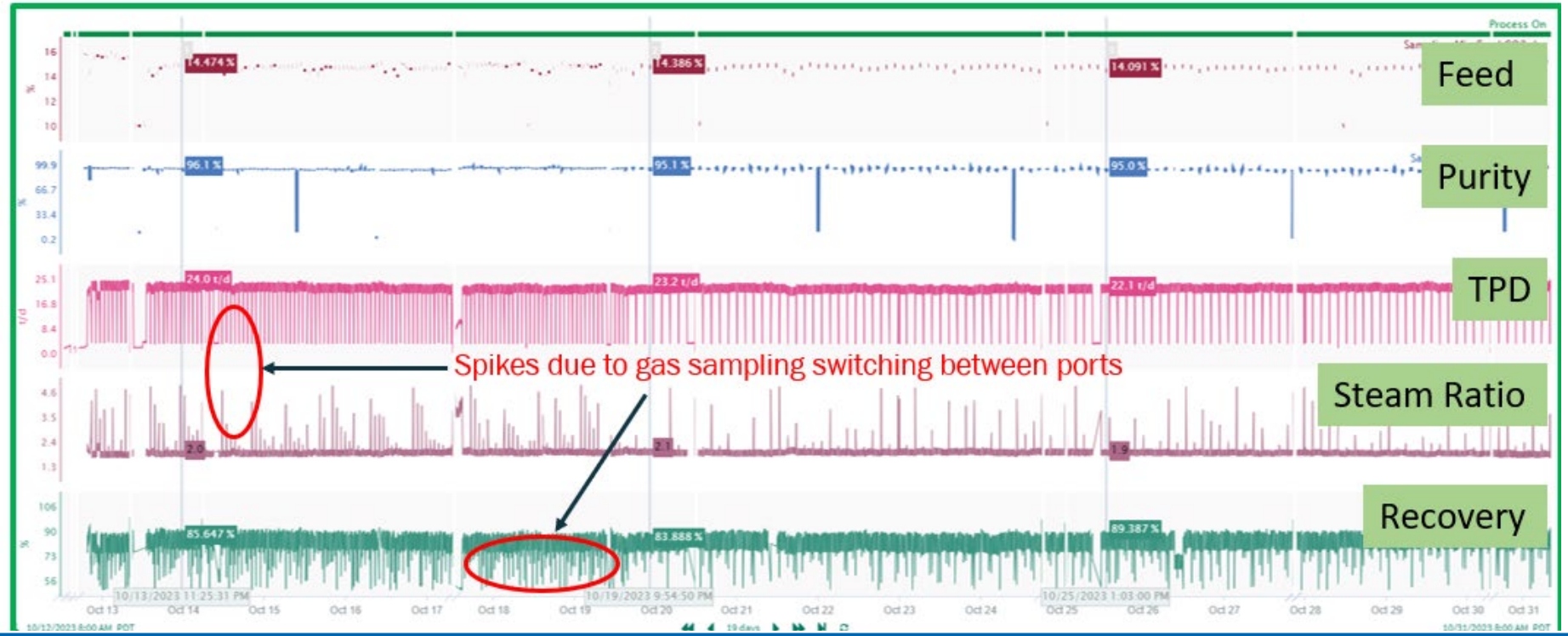
Progress and current status of project




FLUE GAS

Progress and Current Status of Project

Test Data – Performance Target vs Actual Data (14% CO_2)

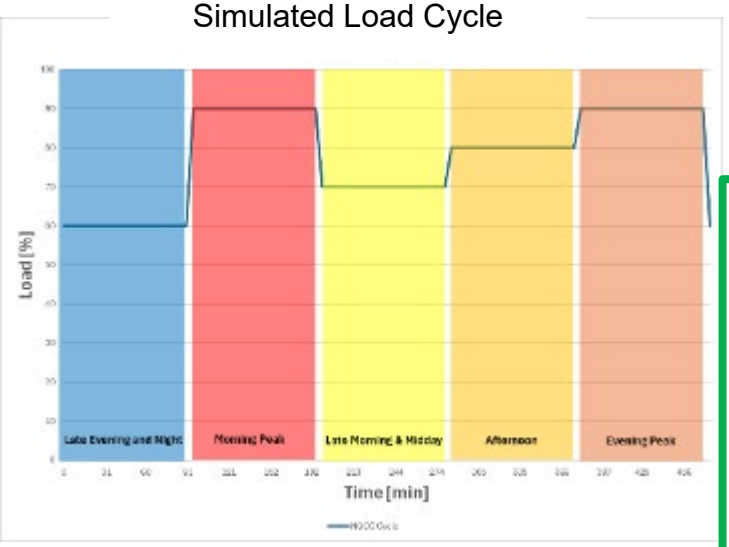


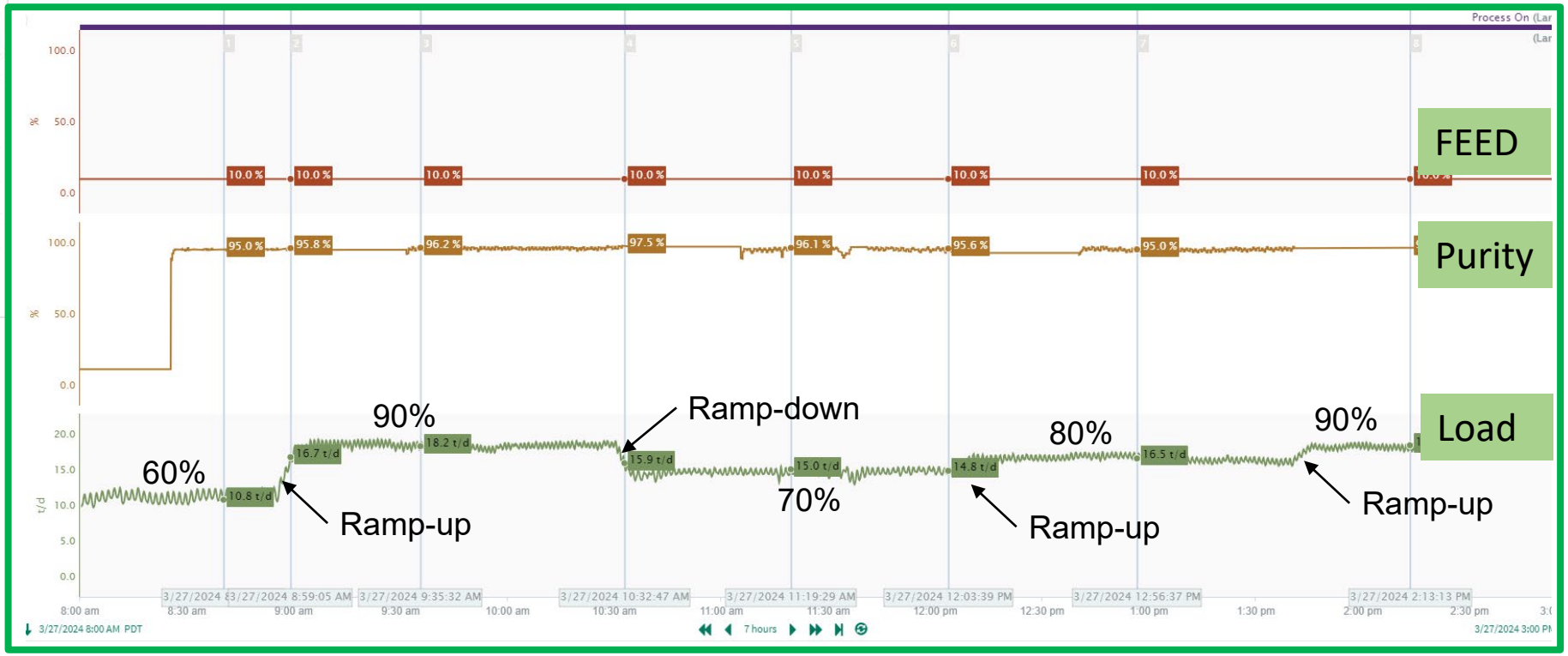
PRIMARY PERFORMANCE TARGETS				
		Indicative Coal	Actual (~ 725 hrs.)	Gap
Capture Plant Inlet Flue Gas CO_2 Concentration	dry mol%	~ 14%	14% – 15%	
Product CO_2 Purity	dry mol%	95	95	
CO_2 Capture Recovery	%	85	~ 83	• SAB/SAB Variability • Asynchronous data logging used in Recovery calculation
Steam:Product CO_2 Ratio	kg/kg CO_2	1.8	1.8 – 2.1	• Pinched by Product vacuum level (-7 kPag vs. -15 kPag target) • Pinched by Reflux flow/vacuum level
CO_2 Production Capacity	TPD	23 - 24	21 - 24	• Pinched by Reflux loop and stable boiler operation at rated condition

Progress and Current Status of Project

Test Data – Simulate Load Following at 60%-90%

Simulated Load Cycle





- Product purity maintained at 95% through out simulated load following; 5 minutes ramp
- 60 seconds response time for Svante's adsorption/desorption/conditioning process

Project Milestones – Budget Period 3

Milestone log					
Budget period	Task	Milestone description	Planned completion date	Actual completion date	Verification method
3	7.1	Start-up and operator hand-off	08/21/2023	8/20/2023	RPPR File
3	7.2	Parametric testing and steady state operation performance report	02/06/2024	4/12/2024	Updated Test Report
3	7.3	14% Indicative Coal Flue Gas Feed Testing	11/30/2023	10/31/2023	Preliminary Test Report
3	7.4	4% Indicative NGCC Flue Gas Feed Testing	12/22/2023	11/23/2023	Updated Test Report
3	7.6	System Decommissioning	TBD		Final Report file
3	8.1	Technology EH&S Risk Assessment	TBD		Topical Report and summary in Final Report
3	8.2	Techno-Economic Analysis (TEA)	TBD		Topical Report and summary in Final Report
3	8.3	State-Point Data Table	07/30/2024		State-Point Data Table file
3	1.0	Draft Final Report	07/30/2024		Final Report file

Lessons Learned

- Validated Svante's MOF filters & Carbon Capture process @ Engineering Scale Pilot
- 95% CO2 product purity was achieved
- Load following responded as anticipated – 60 sec. cycle for Adsorption/Desorption/Conditioning
- Ease of operation – start-up, steady state and shutdown
- BOP limitation impacted data gathering & achievement of project set KPIs

Commercial Scale Facilities and Manufacturing

Plans for Future Testing/Development/Commercialization

Next Steps for this Project

- Leverage early learnings to increase operational efficiently of the existing facility and validate data gathered against original target KPIs
  - Modify balance of plant equipment to increase vacuum and throughput
  - Extend operating period of BP3 to allowed for additional data collection at varying concentrations
  - Provided original and validated data in final reports and TEA
- Formal proposal on this opportunity has been provided and will provide updates once approval is given

Svante's Pathway to Commercial Readiness

Acceleration of learnings in development of industrial solutions

1. Production:

Solid Sorbent-Lined Filters

- ✓ Commercial supply of solid sorbent (MOF) via BASF
- ○ Filter manufacturing facility starting up in 2025

2. Design:

Industrial Contactor (Carbon Capture Machine)

- ✓ In-house operation of full-sized industrial contactor
- ○ Continuous improvement and optimization of seal material

3. Testing & Optimizations:

Tracking, Measuring & Optimizing Performance

- ✓ Rapid temperature swing adsorption (RTSA) cycle optimization & enhancements
- ✓ Validation of KPIs via in-house and external units

4. Plant:

Carbon capture plant design

- ✓ Optimized for waste heat recovery and integration with industrial host site (brownfield and greenfield).

✓ = Completed ○ = In Progress

Building Commercial Momentum

Svante to Deploy First-of-a-Kind Commercial-Scale Carbon Capture Plant at Delek US's Texas Refinery with DOE Support

PRESS RELEASES

Selected for Award by the US DOE for up to $95 MM USD of funding for a 145,000 tonne/yr CO_2 capture project from a Fluid Catalytic Cracker at Delek US's Big Spring Refinery

Climeworks and Svante Collaborate in Development and Supply for Direct Air Capture

PRESS RELEASES

This collaboration enables Svante to begin filter production from its commercial manufacturing facility in 2025 – Climeworks is a partner in the Project Cypress DAC Hub, which has been selected for $650 MM USD funding by the US DOE for a 1 megatons per year FOAK DAC.

Filter Manufacturing Plant No. 1 in Canada

New HQ & Global Center of Excellence

Combined Manufacturing and R&D Centers

Production Line Automation

Sustainability & Net-Zero Building Targets

Sq. ft	141,000
Staff	300
Throughput	10+ mmtpa CO_2 equivalent (in industrial filters)

Summary

Technology Assessment

Chevron will compile and analyze the experimental and computational results to assess technology performance and propose next steps in the technology development pathway. Final deliverables include:

- Technology Environment, Health and Safety (EH&S) Risk Assessment
- Techno-Economic Analysis (TEA)
- State-Point Data Table
- Technology Maturation Plan (TMP)
- Final Technical Report

Thank you

Thank you to our project sponsors

U.S. Department of Energy

Office of Fossil Energy and Carbon Management

NETL – National Energy Technology Laboratory

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U.S. DEPARTMENT OF ENERGY | Fossil Energy and Carbon Management

NATIONAL ENERGY TECHNOLOGY LABORATORY

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Questions and answers