National Carbon Capture Center (FE0022596)

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Southern Company
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U.S. Department of Energy
National Energy Technology Laboratory
2022 Carbon Management Project Review Meeting

Nation Carbon Capture Center (NCCC)

- A centralized test facility providing comprehensive support for technology testing and evaluation
  - Process, engineering, operational, analytical, troubleshooting and maintenance
- Goal: Accelerating technology development, scale-up, cost reduction and commercialization
  - CO_2 capture, utilization and removal

- Sponsored by DOE/NETL, research and industrial partners; managed by Southern Company
  - Coal, utility, research, oil & gas, policy
  - Project period: 2014-2025 (Current BP7)
  - Total $348MM (DOE $253.4MM / Non-DOE $94.6MM)
  - PI: John Northington, Director of NCCC

NCCC – Technical Program

CO_2 Capture

- Capture from coal-fired power plant since 2009
- Added capture from NG-derived flue gas in 2020
- Solvent, catalyst, membrane, sorbent, hybrid technologies

CO_2 Utilization

- Added in 2020
- CO_2 to value-added products like building materials, fuels, plastics, chemicals & algae
- Evaluate additional infrastructure needed

CO_2 Removal - DAC

- Added in 2020
- Evaluate additional infrastructure as needed
- Look to collaborate w/ national labs, universities and other research institutions

DAC: Direct Air Capture

NCCC – Facility Infrastructure

Plant Gaston: Host Site

- Unit 5 (U5) -890 MWe supercritical
  - Dual fuel – coal and natural gas
  - 35,000 lb/hr slipstream flue gas (FG) from U5
  - Exhaust gas from NCCC returns to U5 stack
- Low/Medium pressure steam, water (demin, potable, filter-treated), instrument air and power
- Wastewater returns to plant Gaston for treatment and disposal

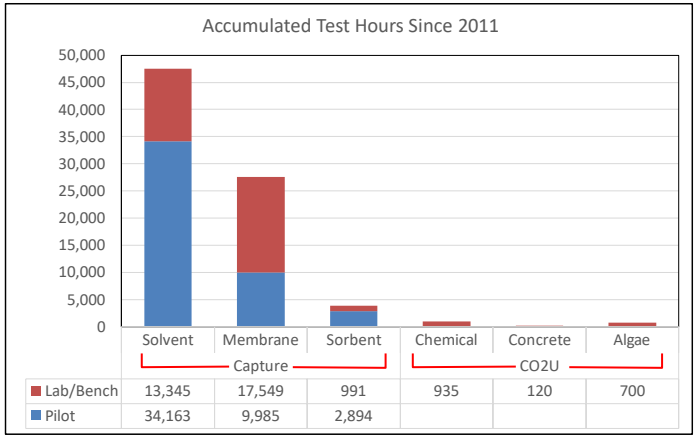
NCCC

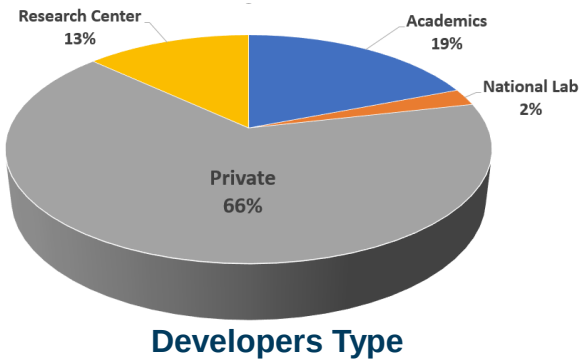
- NG flue gas from package boiler (new 2021)
  - 40,000 lb/hr flue gas
  - Exhaust stack
- Low pressure steam, nitrogen and cooling water
- Test equipment, test bays and infrastructure

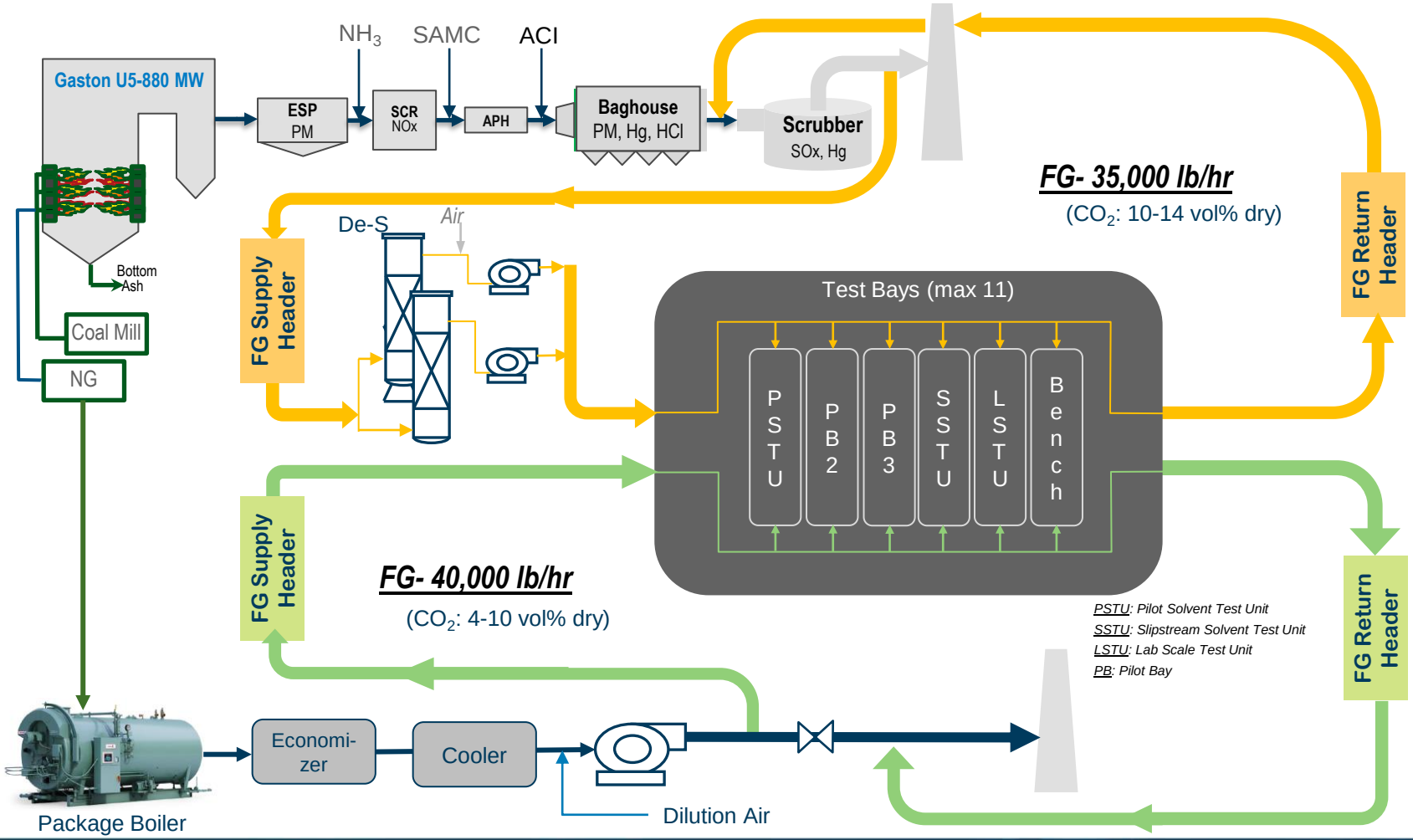
Test Facility for Post-Combustion CO_2 Capture, CO_2 Utilization and DAC Technologies

NCCC by Numbers (2011-2022)

- 80,000+ hours of performance data collected
  - Post-combustion capture and CO_2 utilization
- 50 technologies from 37 developers tested or planned
  - Solvent, membrane, sorbent, phase change, & hybrid-based capture technologies
  - Chemical, fuel, concrete and algae-based utilization technologies
  - 66% are private companies
- 8 technologies scaled up (or ready) to 10+ MW
  - Aker, Carbon Clean, ION Clean Energy, Linde, MTR, RTI, Shell Cansolv and UT Austin
- International testing collaboration: 7 countries
  - Canada, China, Germany, India, Japan, Norway, UK

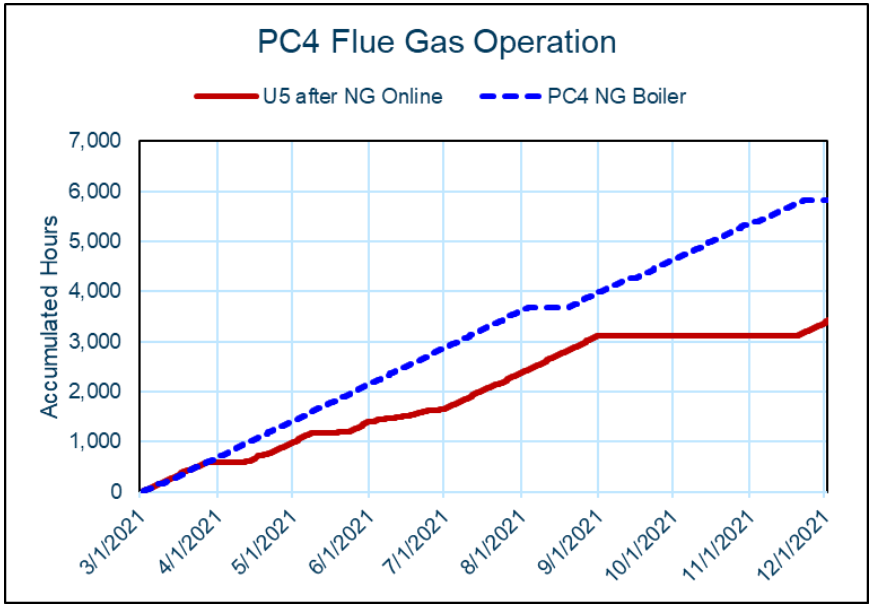





Gaston U5-880 MW
NH_3
SAMC
ACI
ESP
PM
SCR
NOx
APH
Baghouse
PM, Hg, HCl
Scrubber
SOx, Hg
Bottom Ash
Coal Mill
NG
De-S
Air
FG Supply Header
FG- 35,000 lb/hr
(CO_2: 10-14 vol% dry)
FG Return Header
Test Bays (max 11)
PSTU
PB2
PB3
SSTU
LSTU
Bench
FG Supply Header
FG- 40,000 lb/hr
(CO_2: 4-10 vol% dry)
FG Return Header
PSTU: Pilot Solvent Test Unit
SSTU: Slipstream Solvent Test Unit
LSTU: Lab Scale Test Unit
PB: Pilot Bay
Economi-zer
Cooler
Dilution Air
Package Boiler
Coal FG Config
NG FG Config

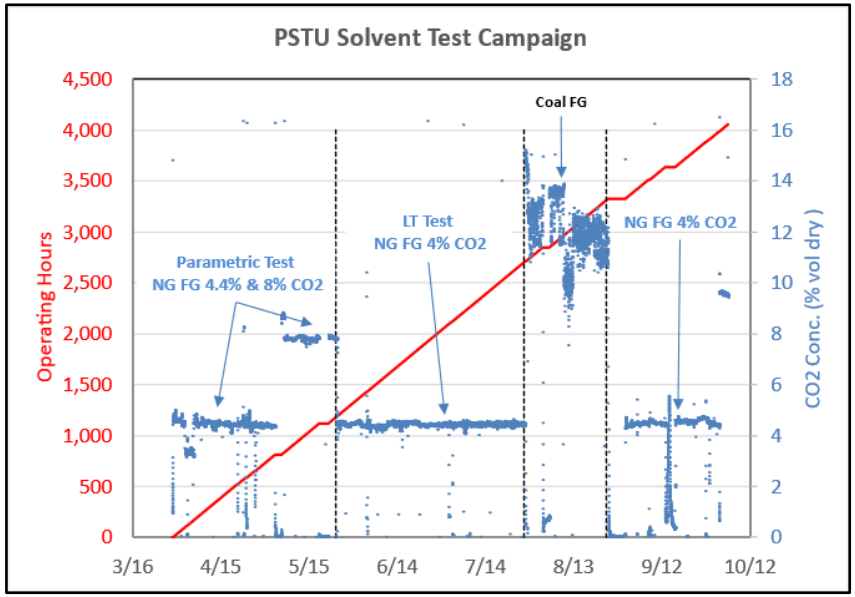
Operation Availability and Flexibility

Flue Gas Availability



62% more flue gas availability to support testing in 2021 since NG flue gas came online

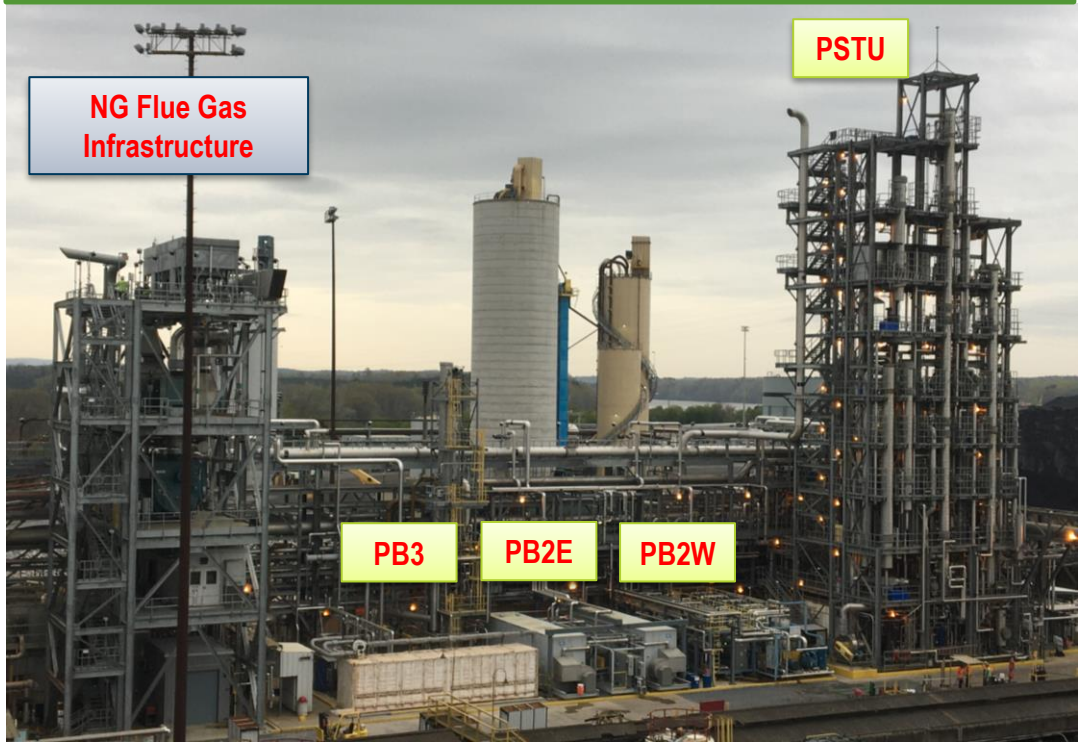
Test Flexibility – e.g. PSTU Test



Developer can switch between coal and NG flue gas during test campaign

Test Bays and Equipment

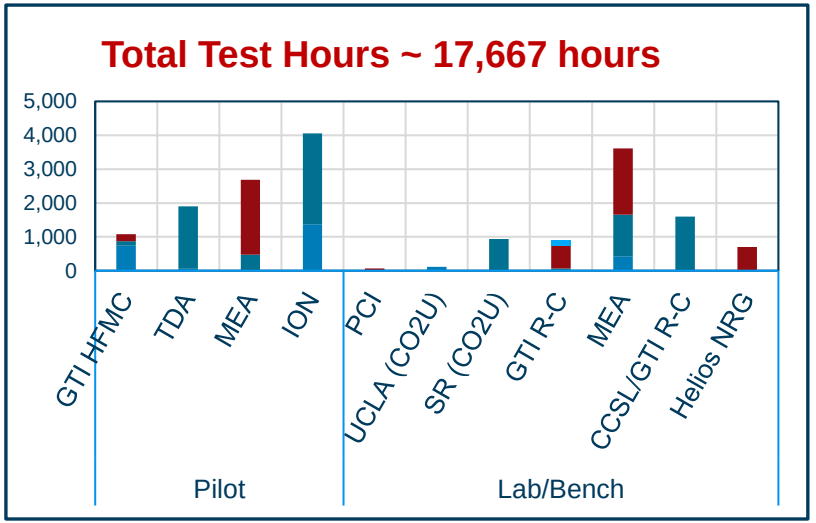
Pilot Scale



Lab/Bench Scale

Current Technology Testing Portfolio

	Test Campaign (2021 & 2022)	
Tech Areas	Pilot	Lab/Bench
Solvent/ Contactor	PSTU ION ☑ PSTU MEA (re-baseline) ☑ PSTU Susteon Catalyst PSTU UT PZAS GTI HFM Contactor ☑	SSTU MEA (re-baseline) ☑ SSTU GTI/CCSL ☑ GTI/CCSL ROTA-CAP
CO_2 Membrane		NETL OSU
Sorbent	TDA Sorbents ☑	PCI Sorbents
Others	Carbon America (Cryogenic)	
CO_2 Utilization		SR- Ethylene ☑ UCLA- Concrete ☑ Helios-NRG- Algae

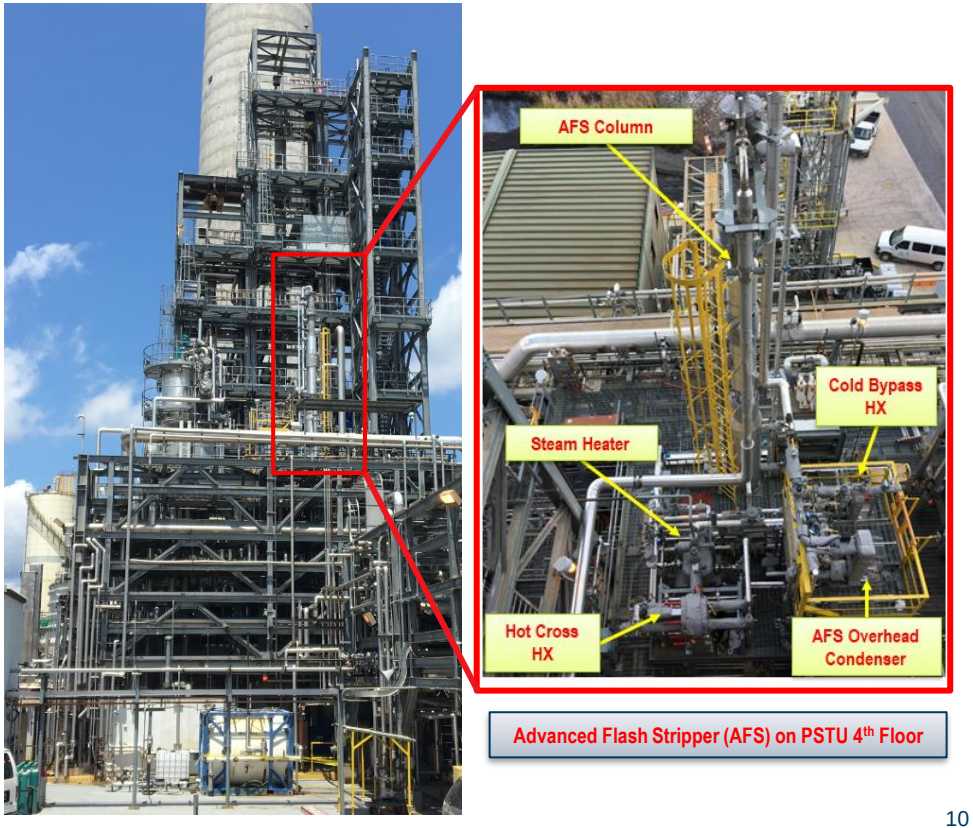


Color bars represent testing hours from different test campaigns.

☑ Test Completed Red - New Tests in 2022

PSTU- UT PZAS

- PZ w/Advanced Flash Stripper (PZAS)
  - Two test campaigns completed in 2018 & 2019
  - Current campaign funded by DOE (FE0031861), EU LAUNCH and private company
- Test Objectives
  - NGCC FG conditions: 4% CO_2,8% H_2O, 110 °C
  - Study solvent degradations, corrosion & mitigations
- PSTU/AFS Main Modifications
  - New FG heater for temperature control
  - 2-stage washes: water and acid
  - NO_2 removal from FG
  - N2 sparger to remove O_2 in solvent
  - Carbon filters for solvent containments removal
  - 7 new corrosion ports
- Status
  - Detail design completed; Construction in progress
  - Target Oct for commissioning

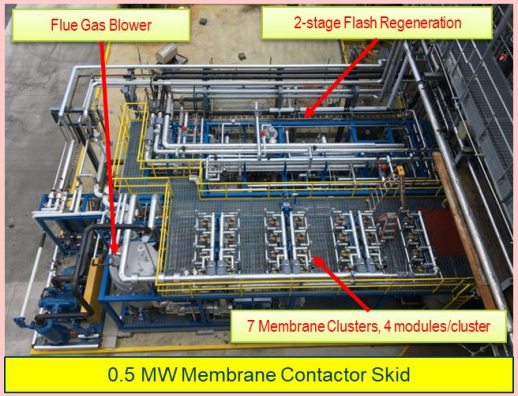


Advanced Flash Stripper (AFS) on PSTU 4th Floor

2022 Test Campaign- Solvent & Contactor

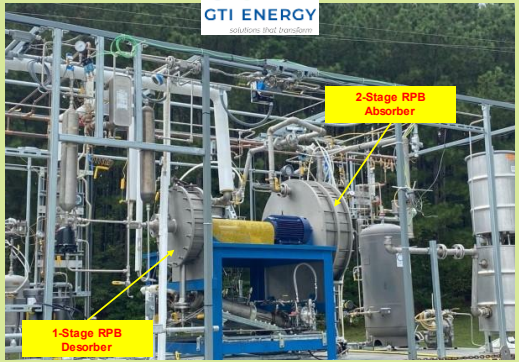
GTI HFM Contactor (FE0012829)

- High surface areas membrane contactor w/aMDEA
- Installed in Apr 2017
- Testing concluded in Mar 2022 for a total of 2,600 hours on both coal and NG FG
- Project decommissioned in May



GTI ROTA-CAP (FE0031630)

- CCSL intensified solvent → reduced energy & equipment size
- GTI rotating packed bed (RPB) absorber & regenerator → improve mass transfer
- CCSL solvent tested in SSTU (baseline) Aug-Nov, 2021
- Skids installed in Oct 2021
- Testing started in Oct 2021 and continues



Susteon Catalyst (Non-FOA)

- Patented ionic liquid catalyst in amine solvent to Improve kinetics & CO2 loading
- Similar catalyst is being tested with sorbents for DAC
- Test w/ MEA solvent in PSTU w/wo catalyst
- Testing started in Aug and continues

Pilot Solvent Test Unit (PSTU)

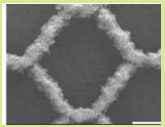
2022 Test Campaign- Sorbents

TDA (FE0012870)

- Alkalized alumina adsorbent- Low cost & heat of ads
- Near isothermal op at 150 °C
- Skids installed in Oct 2017
- Testing concluded in Oct 2021 for a total of ~2,900 hours on both coal and NG FG
- Project decommissioned in May 2022

PCI (SC0017221)

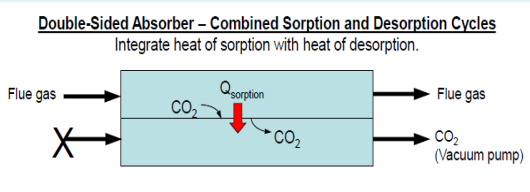
- Nano-sorbents on tailorable mesh substrate (Microlith®)
- High surface areas, heat & mass transfer rates
- Lower ΔP vs. pellet sorbent, and comparable ΔP vs. monoliths
- Tested at NCCC briefly in Mar 2020
- Skid installed in Mar and initial testing completed in Apr. More test is planned later this year



Nano-sorbents coated on Microlith mesh

Altex (SC0013823)

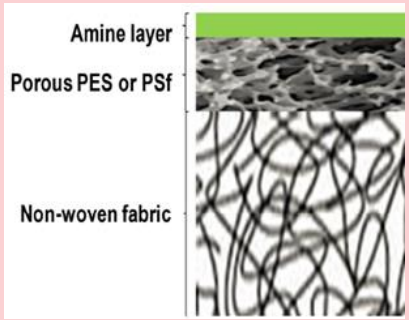
- Intensified Sorbent Process-sorbents coated on both sides of HX
- Low cost and compact Microchannel Heat Exchanger (MCHEX) wash-coated w/ PSU Molecular Basket Sorbents (MSB)
- Testing targets Jan 2023



2022 Test Campaign- Membrane

OSU (FE0031731)

- Facilitated transport membrane
- CO_2 transport via reaction with amine
- CO_2 selective amine polymer layer on polymer support
- Two test campaigns completed in 2015 & 2018
- Skid delivery targets for Aug/Sep
- Testing to start in Sep



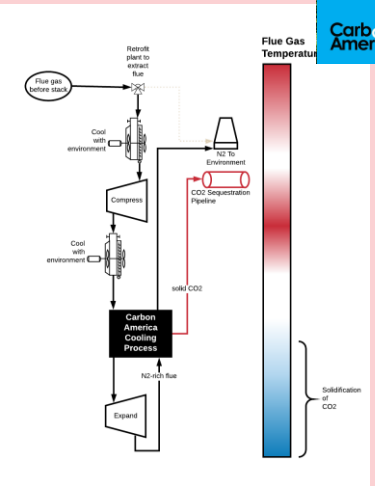
NETL

- Ongoing membrane material evaluation since 2015
- Test membranes in hollow fiber and flat sheet configurations
- Plan to restart testing in Sep

2022 Test Campaign- Other Capture & CO_2 Utilization

Carbon America (non-FOA)

- Phase changing cryogenic process - FrostCC
- FG compressed, cooled, and expanded to solidify and separate CO_2
- Skid delivery in Q4 2022
- Testing to start in Jan 2023



Helios NRG (FE0031713)

- Algae growth w/ CO_2 in FG
- Multi-stage continuous (MSC) process and closed system
- High water recycle
- Natural sunlight, top lit
- Skid installed in May
- Testing started in June and continues

Future Testing Outlook – 2023 & beyond

- Solvent (PSTU)
  - EPRI/PNNL/RTI
    - Water lean solvent by PNNL
    - Plastic packing in absorber
    - Moisture control in FG is critical
  - China Huaneng CERI (Clean Energy Research Institute)
- Membrane
  - GTI, MTR, SUNY Buffalo

- Sorbent
  - Altex
  - SUNY Buffalo
  - Cormetech
- CO_2 Utilization
  - UCLA concrete (2nd test)
  - Texas A&M algae
  - Helios-NRG (2nd test)
- DAC
  - Southern States Energy Board/AirCapture
  - Innosepra

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