National Carbon Capture Center Technology Testing Update (FE0022596)

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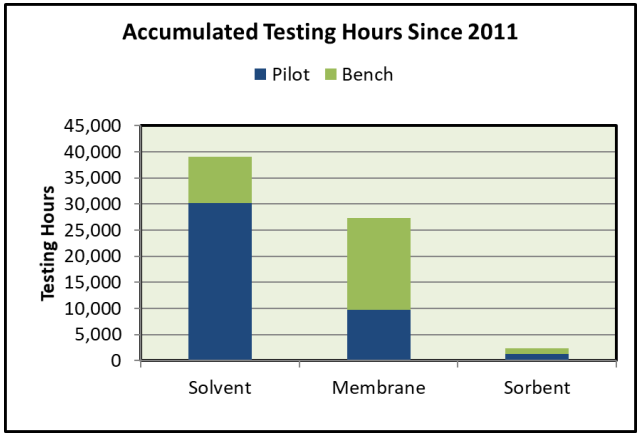
Nation Carbon Capture Center (NCCC)

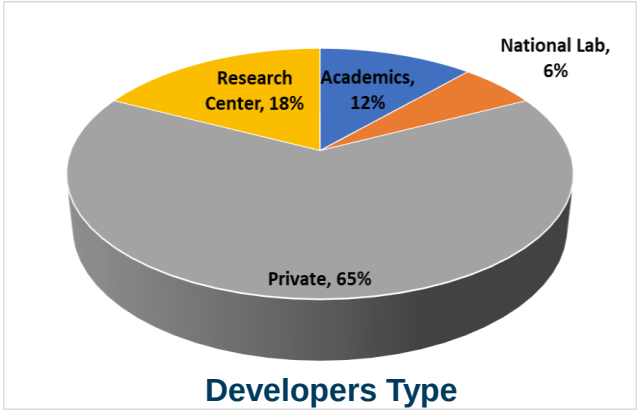
- A centralized test facility providing comprehensive support for technology testing and evaluation
  - Process, engineering, operational, analytical, troubleshooting and maintenance
- Goal: accelerating technology development, scale-up, cost reduction and commercialization
  - CO_2 capture, utilization 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 BP6)
  - Total $348MM (DOE $253.4MM / Non-DOE $94.6MM)

NCCC by Numbers (2011-2021)

- 68,000+ hours of performance data collected
  - Post-combustion capture and CO_2 utilization
- 46 technologies from 33 developers tested or planned
  - Solvent, membrane, sorbent & hybrid-based capture technologies
  - Chemical, fuel, concrete and algae-based utilization technologies
  - 65% are private companies
- 8 technologies scaled up (or ready) to 10+ MW
  - Aker, Carbon Clean Solutions, ION Clean Energy, Linde, MTR, RTI, Shell Cansolv and UT Austin
- International testing collaboration: 7 countries
  - Canada, China, Germany, India, Japan, Norway, UK





NCCC – Technical Program

CO_2 Capture

- Capture from coal-fired power plant since 2009
- Added capture from NG-derived flue gas in 2020
- Solvent, 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 needed
- Look to collaborate w/ national labs, universities and other research institutions

DAC: Direct Air Capture

NCCC – Facility Infrastructure

Plant Gaston: Host Site

- Coal flue gas
  - 35,000 lb/hr slipstream from U5 (890 MW supercritical)
  - Exhaust gas returns to Gaston
- MP/LP steam, water (demin, potable, filter-treated), IA and power
- Wastewater returns to Gaston for treatment and disposal

NCCC

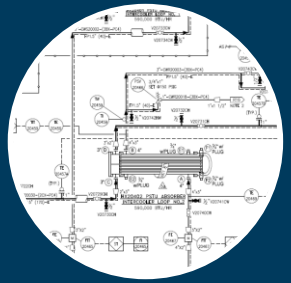
- Test equipment, test bays and infrastructure
- NG flue gas from package boiler (new 2021)
  - 40,000 lb/hr flue gas
  - Exhaust stack
- LP steam, N_2 and cooling water

Located Inside APCo's E.C. Gaston Steam Plant

Project Development and Implementation

Safety First

Contract
- Screening
- NDA/TCA
- Onboarding

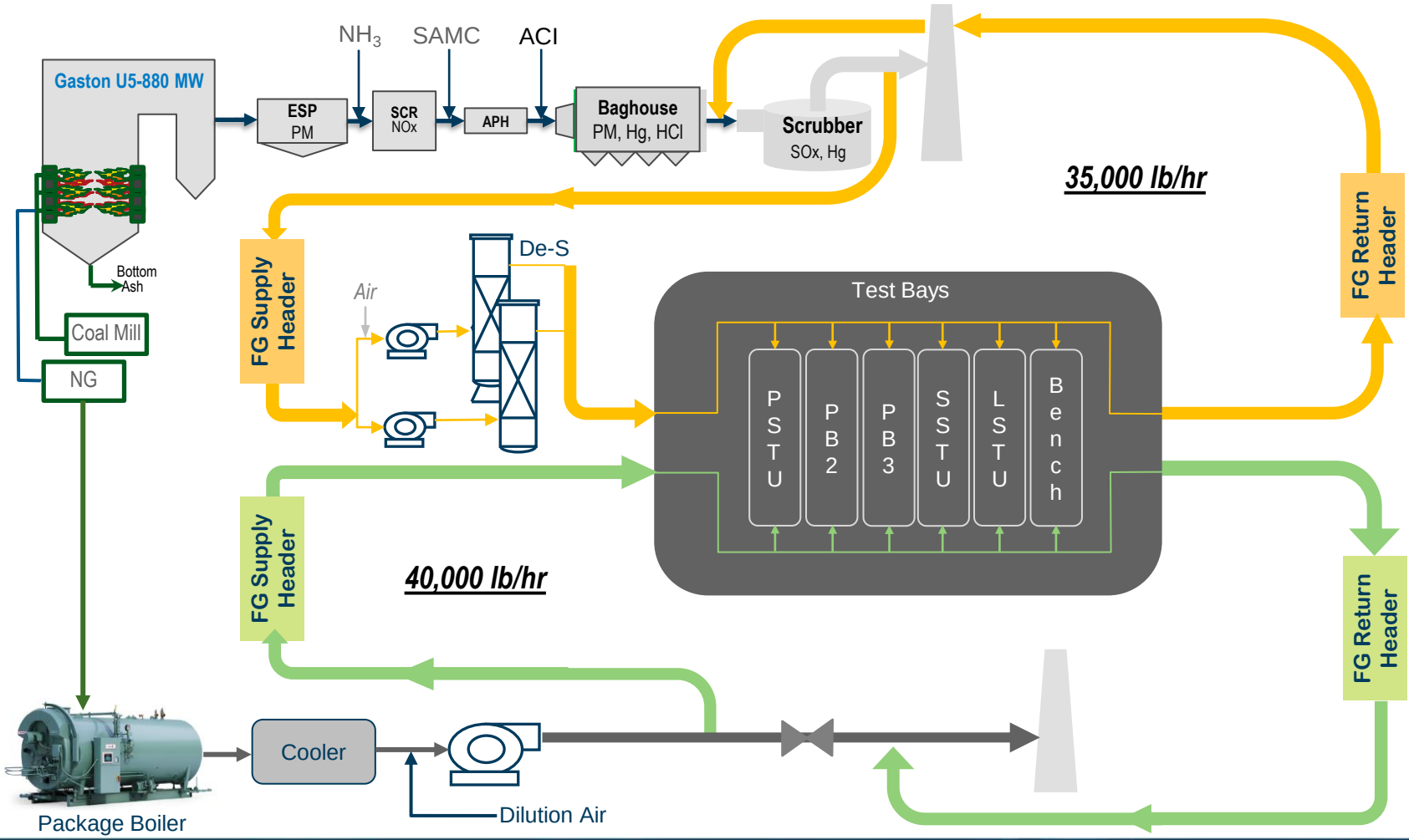


Project Scope
- Process
- Modification
- Integration

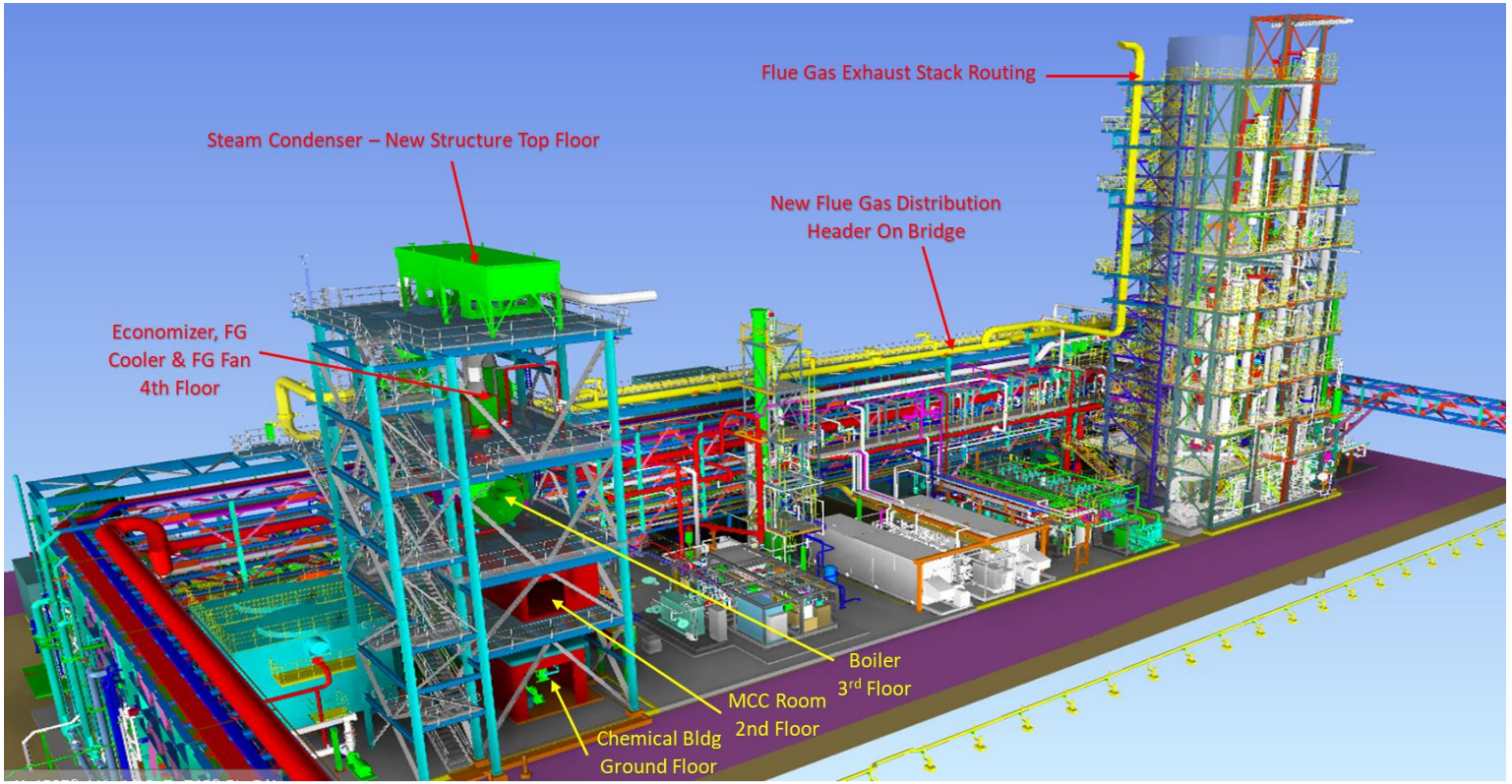
Design
- Mechanical
- Instrument
- Control
- Electrical
- Civil

Construction
- Foundation
- Flue Gas
- Utilities
- Installation
- Interconnection

O&M
- Operate
- Test Support
- Analysis
- Troubleshoot
- Repair

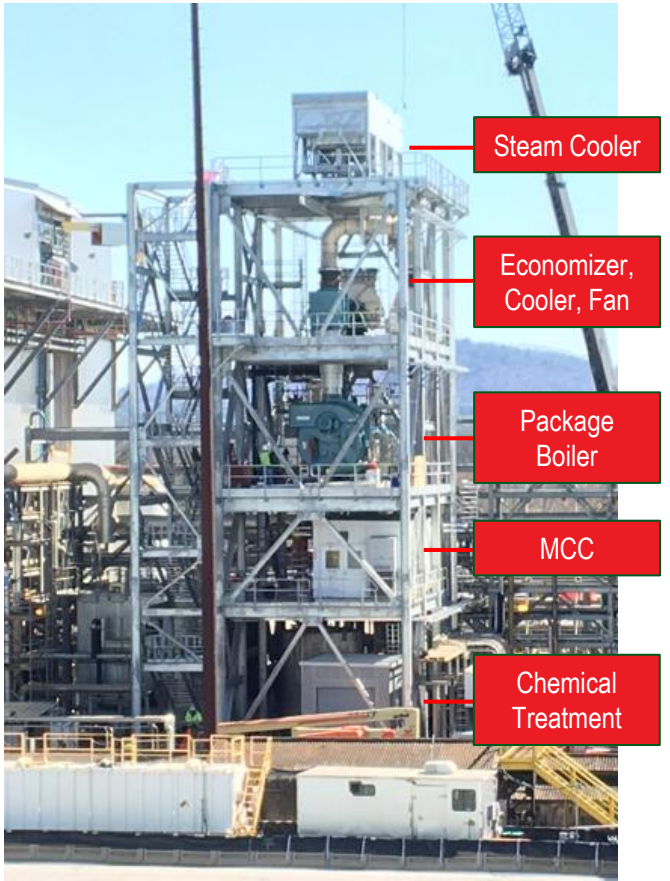

Gaston U5-880 MW
NH_3
SAMC
ACI
ESP
PM
SCR
NOx
APH
Baghouse
PM, Hg, HCl
Scrubber
SOx, Hg
35,000 lb/hr
FG Return Header
Coal FG Config 2011-
Bottom Ash
Coal Mill
NG
FG Supply Header
Air
De-S
Test Bays
PSTU
PB2
PB3
SSTU
LSTU
Bench
40,000 lb/hr
FG Supply Header
FG Return Header
NG FG Config 2021-
Cooler
Dilution Air
Package Boiler

Model View of NG Flue Gas Infrastructure

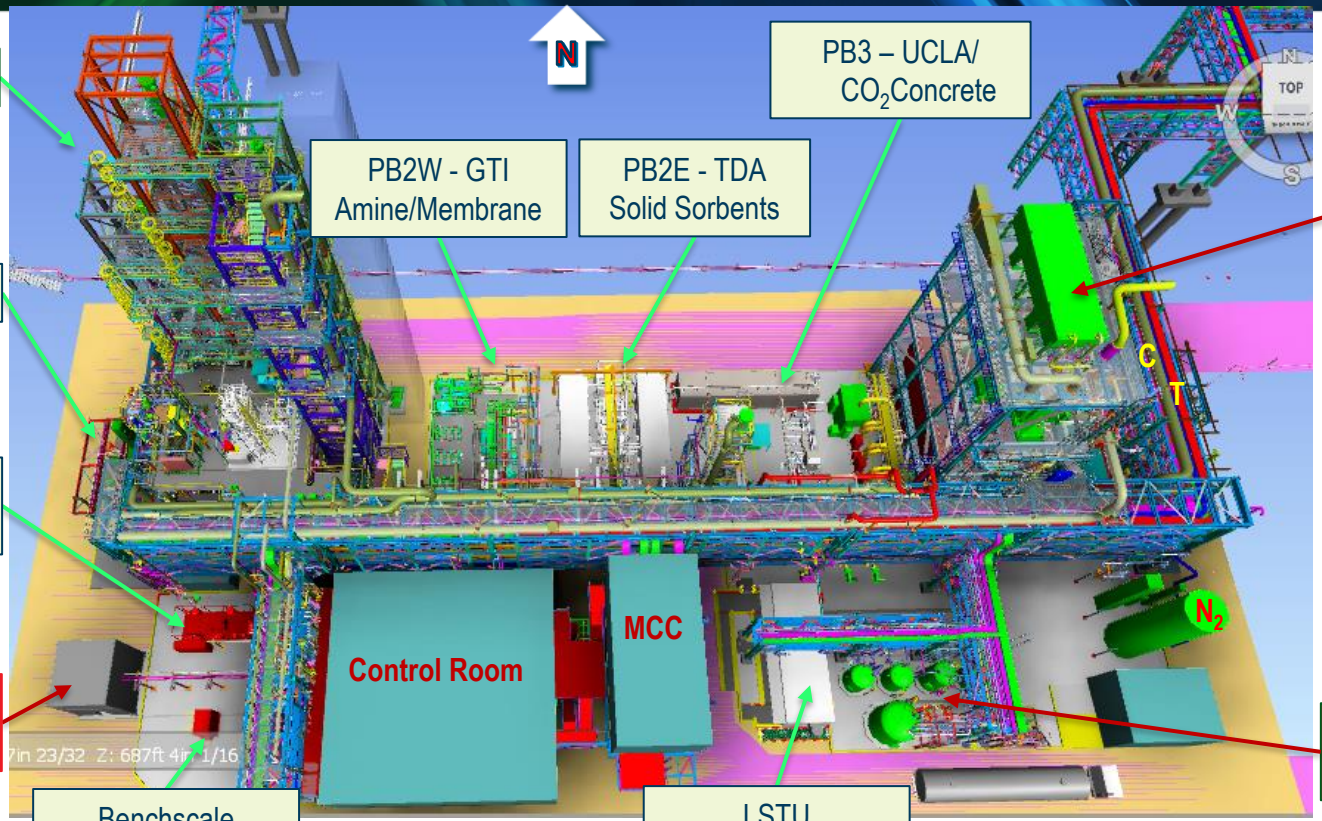


NG Flue Gas Infrastructure Project

- Project
  - Jan 2018: Started conceptual design
  - Apr 2019: Began construction
  - Nov 2020: Completed construction (after pandemic delay)
  - Mar 2021: Placed system In service to support technology testing
- Flue Gas Conditions
  - Boiler flue gas CO_2 ~ 8.5 vol%
  - Air dilution to simulate flue gas from NGCC (CO_2 ~ 4 vol%)
- Operation
  - Independent from plant Gaston U5 (coal)
  - Each test bay controls type of flue gas to receive
  - Swap between coal and NG flue gas with minimum interruption

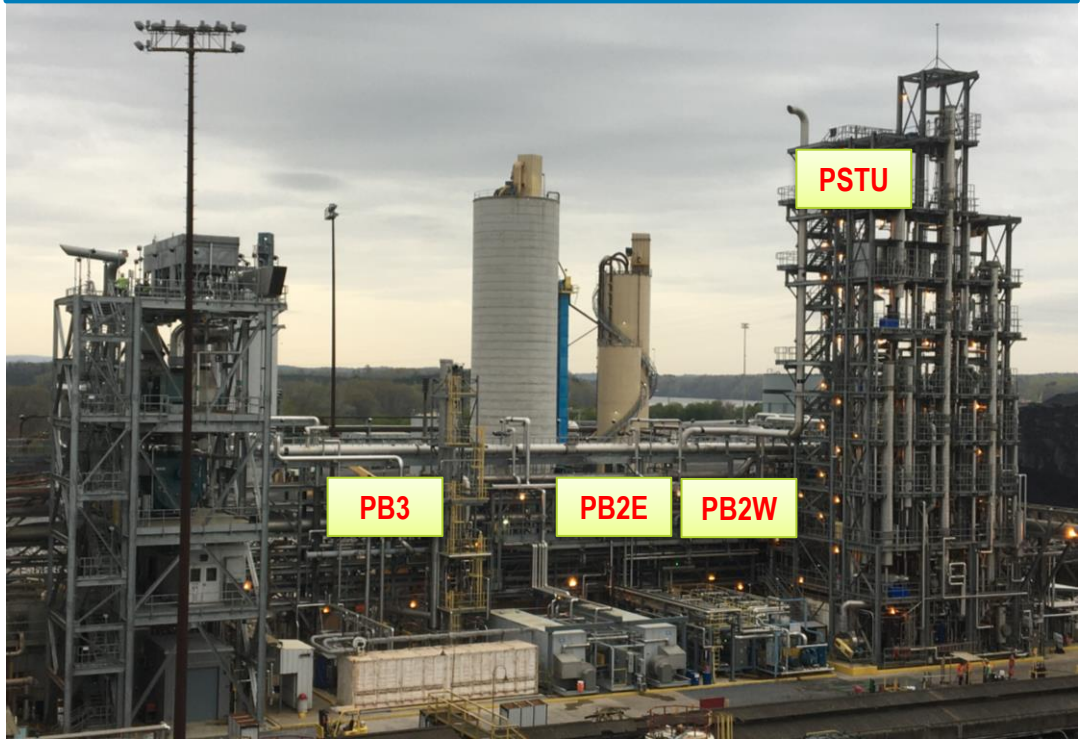


Model View of Current Test Bays Layout



Test Bays and Equipment

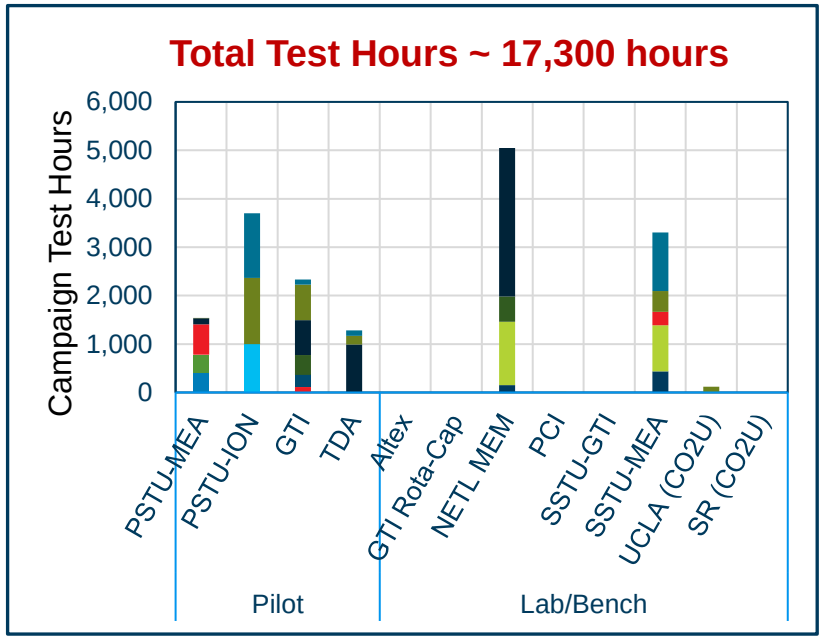
Pilot Scale



Lab/Bench Scale

Current Technology Testing Portfolio

	Test Campaign (2021)	
Tech Areas	Pilot	Lab/Bench
Solvent/ Contactor	PSTU ION PSTU MEA (re-baseline) GTI HFM Contactor	SSTU MEA (re-baseline) SSTU GTI/CCSL GTI Rota-Cap
CO_2 Membrane		NETL
Sorbent	TDA Sorbents	Altex Sorbents PCI Sorbents
CO_2 Utilization		SR- Ethylene UCLA- Concrete ☑



☑ Test Completed Red - New Tests in 2021

2021 Test Campaign- Solvent & Contactor

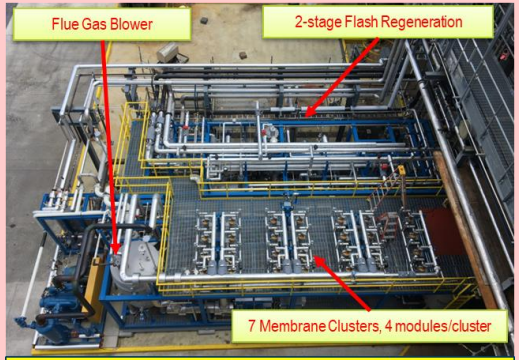
ION Solvent (FE0031727)

- Amine-based (ICE-31)
- Excellent chemical stability in the presence of O_2
- Excellent specific reboiler duty
- Validate model in ProTreat®
- Test started in Mar 2021 and is ongoing

Pilot Solvent Test Unit (PSTU)

GTI HFM Contactor (FE0012829)

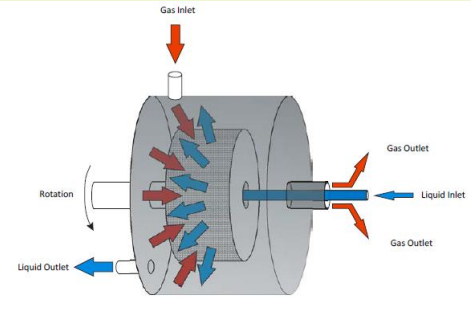
- High surface area HFM contactor
- Installed in 2017 & operated 2,330 Hours on coal flue gas
- Skids modified based on field test experiences
- Membrane performance declines upon cycling - investigation continues
- Testing w/ NG flue gas completed in July 2021. Data is being analyzed.



0.5 MW Membrane Contactor Skid

GTI Rota-Cap (FE0031630)

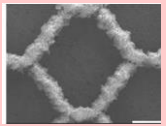
- CCSL intensified solvent (APBS-2) → reduce E & equipment size
- GTI rotating packed bed (RPB) absorber & regenerator → improve mass transfer → volume reduction
- Skids fabricated and test is ongoing at GTI
- Skid delivery targets in Sep 2021



2021 Test Campaign- Sorbents

PCI (SC0017221)

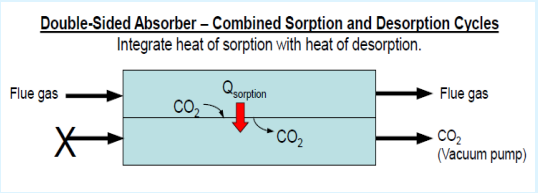
- Nano-sorbents on tailorable mesh substrate (Microlith®)
- High surface area, heat & mass transfer rates
- Lower ΔP vs. pellet sorbent, and comparable ΔP vs. monoliths
- Tested at NCCC briefly in Mar 2020
- Return in Oct 2021 for additional testing



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)
- Skid delivery targets Oct 2021



TDA (FE0012870)

- Alkalized alumina adsorbent- Low cost & heat of ads
- Near isothermal op at 150 °C
- Installed in 2017 & operated 1,280 hours
- Achieved >90% CO_2 capture @ >95% CO_2 purity
- Sorbents reprocessed in 2018 and replaced in May 2021
- Test resumed in July 2021

2021 Test Campaign- CO_2 Utilization

UCLA (FE0031718)

- CO_2 mineralization for concrete production
- X-PRIZE winner
- 3/2 – 3/25, 2021 test completed using both coal and NG flue gas
- Produced 5,000+ blocks
- Achieved >75% CO_2 utilization
- Blocks met industrial standard
- Will return in 2022 for more test (FE0031915)

$$Ca(OH)_2 + CO2 \rightarrow CaCO3 + H2O$$

SR (FE0031713)

- Thermocatalytic process - 150 ^oC, lower op T than steam cracking
- Use nano-engineered catalyst
- High ethylene selectivity and productivity
- Ethane/SO_2 gas injection system installed and commissioned
- Commissioning started in July 2021

$$C_2H_6 + CO_2 = C_2H_4 + CO + H_2O$$

Confirmed Future Technology Tests

Program	Technology	Pilot Scale	Lab/Bench Scale
CO2 Capture	Solvent/Contactor	CERI (non-DOE) UT PZAS EPRI/PNNL	
	CO_2 Membrane		GTI MTR OSU SUNY Buffalo
	Sorbent		SUNY Buffalo
	Others		Carbon America (cryo)
CO_2 Utilization	Algae		Helios-NRG
	Concrete		UCLA (2nd Project)
DAC	Sorbent		SSEB/Global Thermostat

Acknowledgements

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