


The NETL DAC Center: Design and Capabilities

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Introduction: NETL received up to \$25M in infrastructure funding under FY22 appropriations to design and construct a Direct Air Capture (DAC) Center that will support the nation's decarbonization goals. The DAC Center will be utilized to support DOE and stakeholder research, development, demonstration, and deployment projects to accelerate the development and commercialization of technologies that remove CO₂ directly from the atmosphere. The facility will support fully integrated technology testing between TRL 3 and TRL 6 with a suite of systems including laboratory scale material performance testing systems, bench scale module performance testing systems, and environmental chambers for the testing of pilot scale prototype units. The research will focus on process design and data collection, specifically demonstrating process reliability, sorbent and solvent lifetimes, energy consumption, capture efficiency, and other parameters needed to determine economic viability. Universities, research institutions, and businesses developing DAC technologies can leverage the facility to test their technologies, avoiding the need of these institutions to develop and invest in similar capabilities.

Multiple Testing Scales

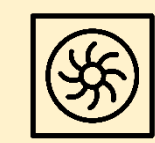
From the Laboratory to the Plant...




Material Scale
Novel Material Assessments
(~0.1 kg CO₂/day)



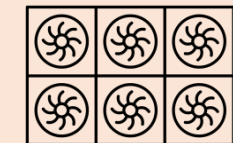
Operational



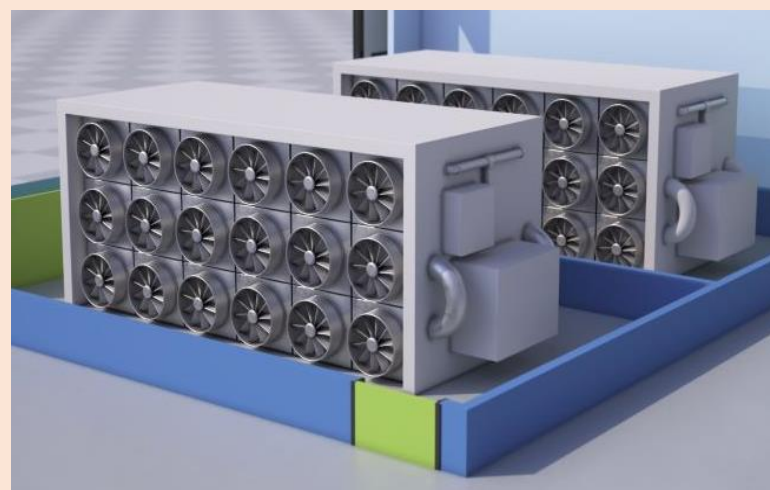
Module Scale
Form Factor Evaluation
(~10 kg CO₂/day)



2024



Prototype Scale
Developer-built Unit Testing
(~100 kg CO₂/day)

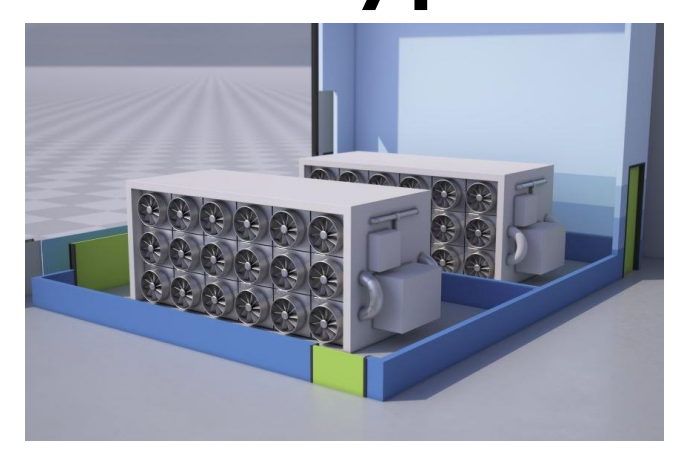


2025

Summary of Capabilities

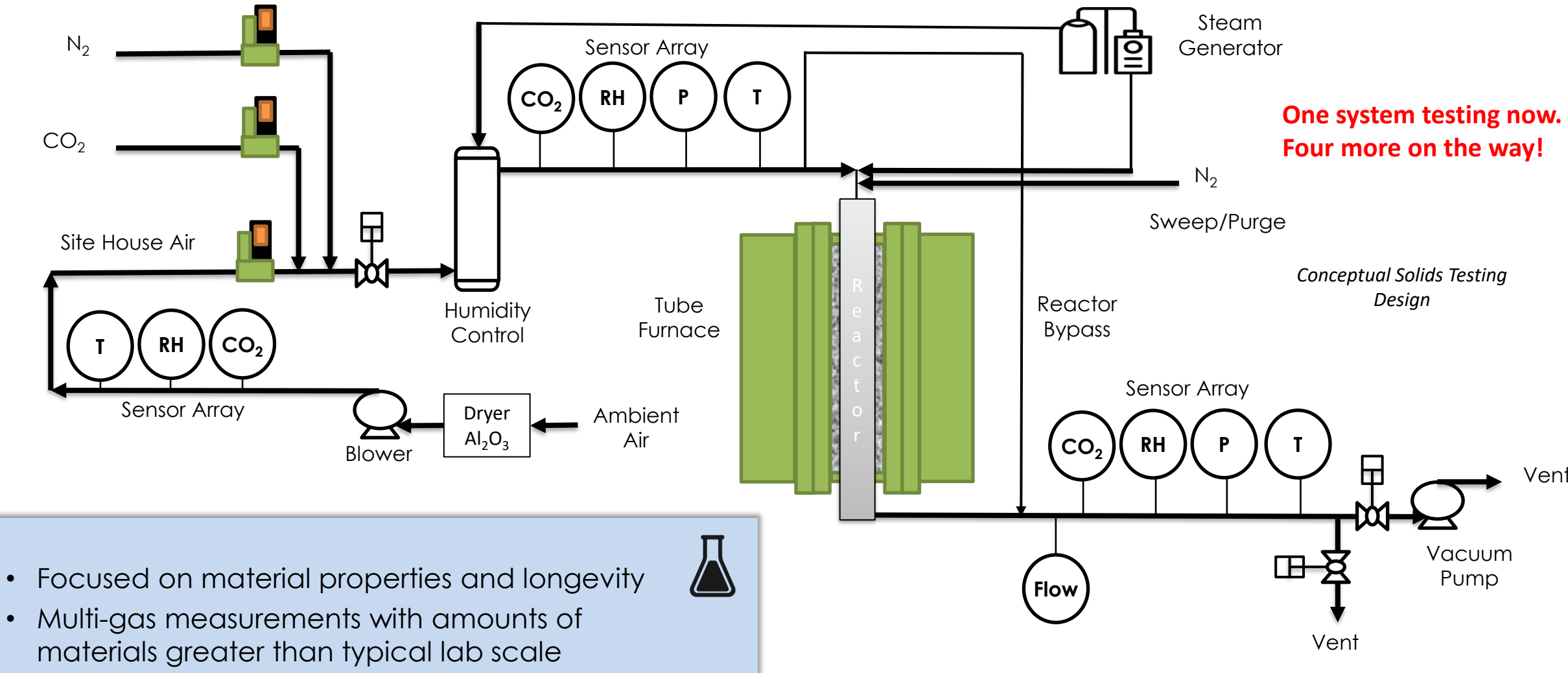
| Parameter | 2 in DAC 1.1 (1 Unit) | 2 in DAC 1.2 (3 Units) | 2 in DAC 2.0 (1 Unit) | 12 in DAC 1.0 (1 Unit) | DAC Skid Enclosure (2 Units) |
|-------------------------------|----------------------------|----------------------------|----------------------------|-------------------------------|---|
| Air Flow | 500 slpm | 500 slpm | 500 slpm | 400 scfm | 3000 scfm |
| Air Source | Site House Air | Site House Air | Site House Air | Ambient in Lab | Ambient in Enclosure |
| CO ₂ | 100-800 ppm | 100-600 ppm | 100-600 ppm | 420-600 ppm | Ambient (~420 ppm) |
| H ₂ O | 2-75% RH | 2-75% RH | 2-75% RH | ~50-70% RH | As noted below: |
| Capture Temp | 21C (Min) | 21C (Min) | -20C (Min) | 25C (Min) | Mode T (F) RH (%) |
| | | | | | Normal 60-80 50-60 |
| | | | | | Cold/Dry 10-59 10-49 |
| | | | | | Cold/Wet 10-59 50-98 |
| | | | | | Hot/Dry 81-110 10-29 |
| | | | | | Hot/Wet 81-110 30-98 |
| Reactor Dimensions | 1.88 in ID 18 in length | 1.88 in ID 18 in length | 1.88 in ID 18 in length | 12 in x 12 in 12 in length | 20 ft Shipping Container 8 ft (w) x 20 ft (d) x 8.5 ft (h) |
| Regeneration Mode | | | | | |
| Temp Swing | up to 150C | up to 150C | up to 150C | up to 150C | up to 150C |
| Inert Sweep (N ₂) | 250 slpm | 200 slpm | 200 slpm | ~1 scfm | up to 38 scfm |
| Steam Sweep | 14.7 psia sat | 14.7 psia sat | 14.7 psia sat | 14.7 psia sat | 14.7 psia sat |
| Vacuum | 2 psia | 2 psia | 2 psia | 2 psia | 1 psia |

Pilot Scale Prototype Testing Units



- Focused on testing of small pilot scale prototype DAC units
- Able to accommodate a wide variety of technology types
- Testing under conditions representative of many climates
- Automated for extended, multi-cycle testing
- Instrumented for measurement of all parameters needed for assessment of field deployment at NCCC or a DAC hub

Laboratory Scale Materials Testing Units

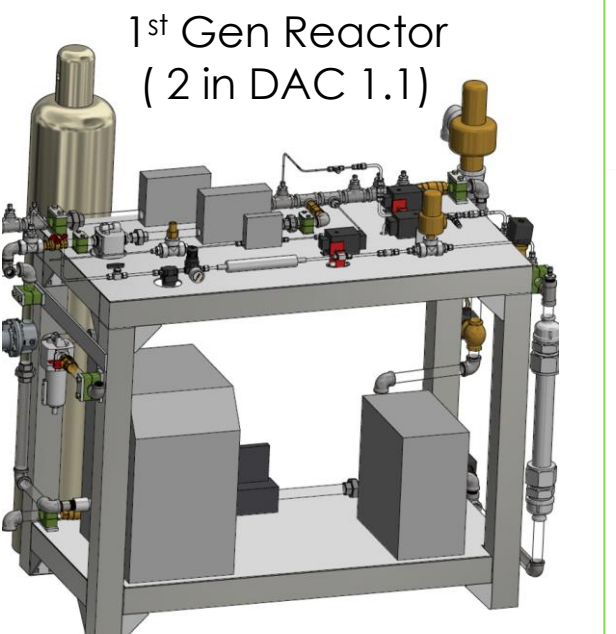


- Focused on material properties and longevity
- Multi-gas measurements with amounts of materials greater than typical lab scale
- Able to accommodate all common materials (granular, fiber, structured)
- Automated for extended, multi-cycle testing

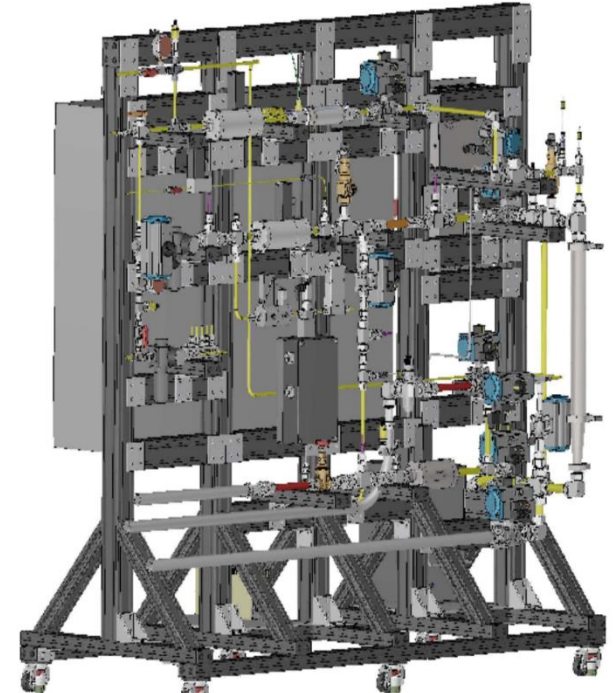
One system testing now. Four more on the way!

Laboratory Scale Materials Testing Units

1st Gen Reactor (2 in DAC 1.1)



2nd Gen Reactor (2 in DAC 1.2)



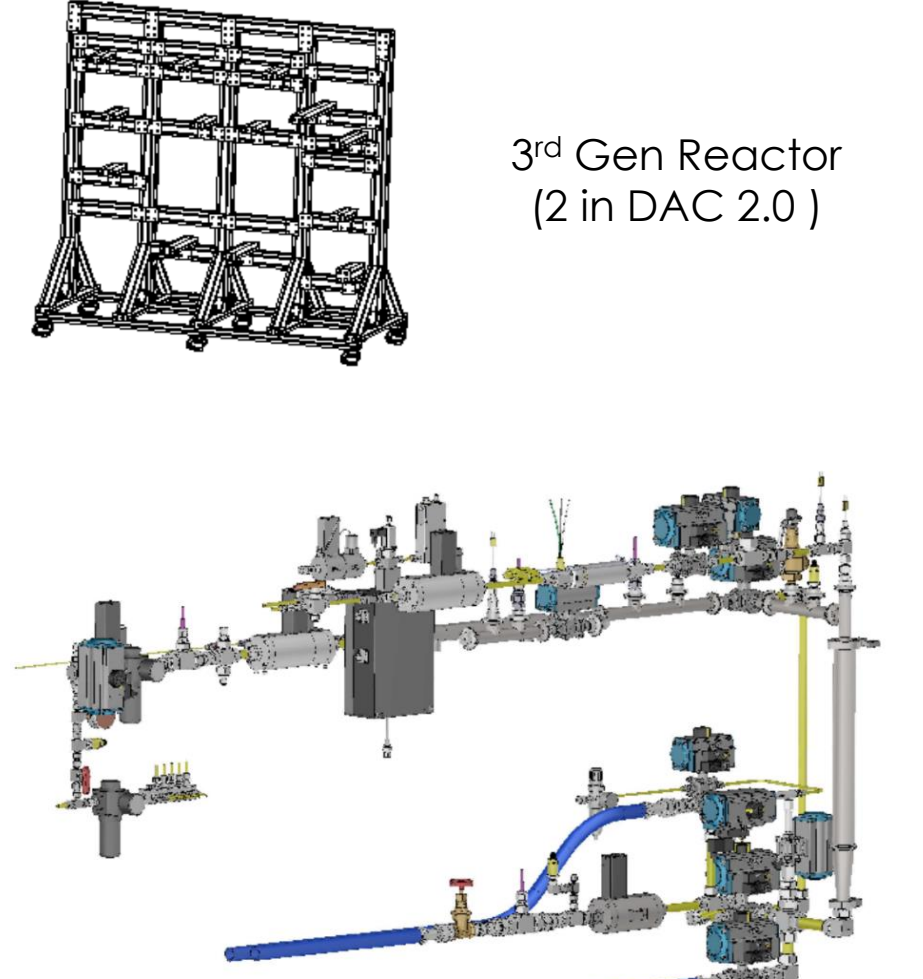
Three systems on the way!

Enhancements:

- Improved reactor design
 - Mobile (on wheels)
 - Modular (vertical layout; reduced footprint)
 - Better gas sealing (tube fittings, minimize NPT)
- Improved humidity/steam generator
- Filter on CO₂ sensors
- Venturi vacuum pumps with downstream CO₂ & RH sensors
- Improved MFCs & MFM
- Purge N₂ having MFC & line heater
- High temp RH sensors

Laboratory Scale Materials Testing Units

3rd Gen Reactor (2 in DAC 2.0)

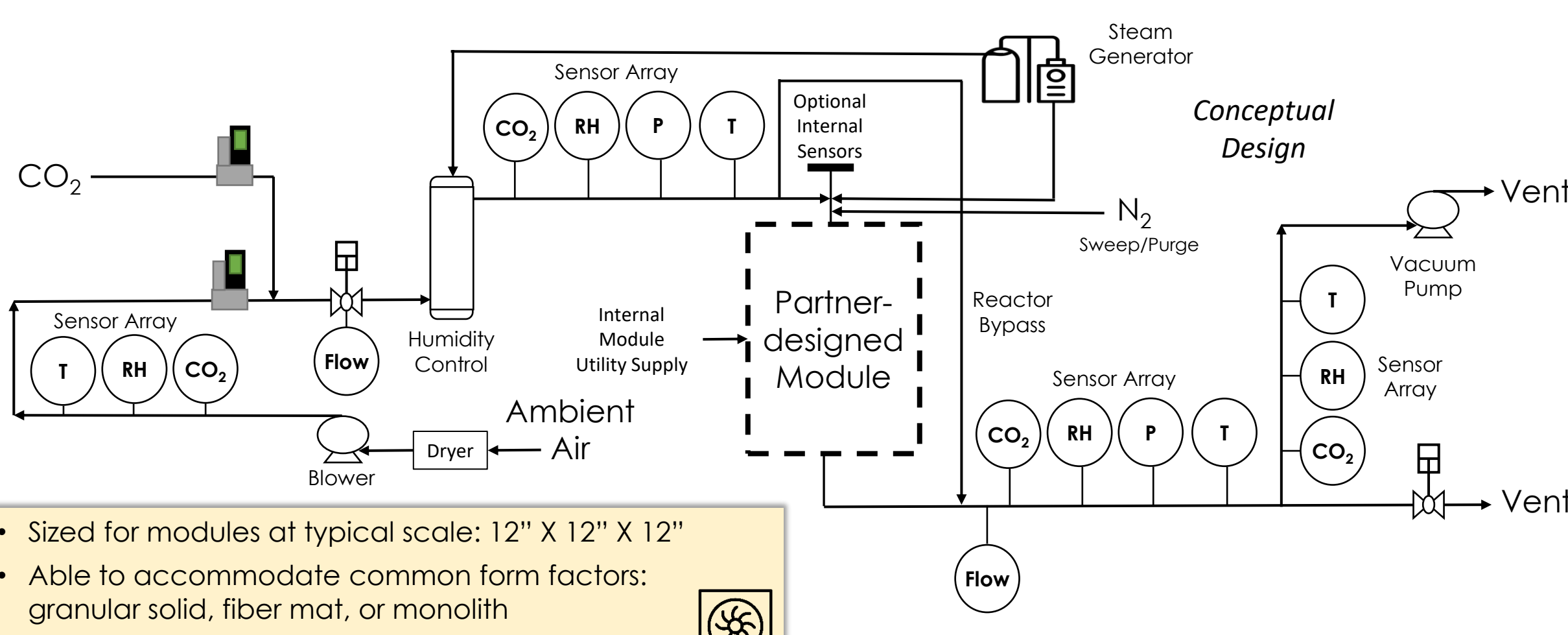


One system on the way!

Enhancements:

- All 2 in DAC 1.2 features on same mobile/modular stand
- Sub-ambient and elevated temp capability
 - Jacketed reactor and feed gas lines
 - Recirculating glycol-based heater/chiller bath
- Sampling pumps (needed for vacuum) on CO₂ sensors
- Perma pure gas dryer after line filters leading to CO₂ sensors.
- PTR-TOF-MS (analysis for VOC degradation products)

Bench Scale Module Testing Units

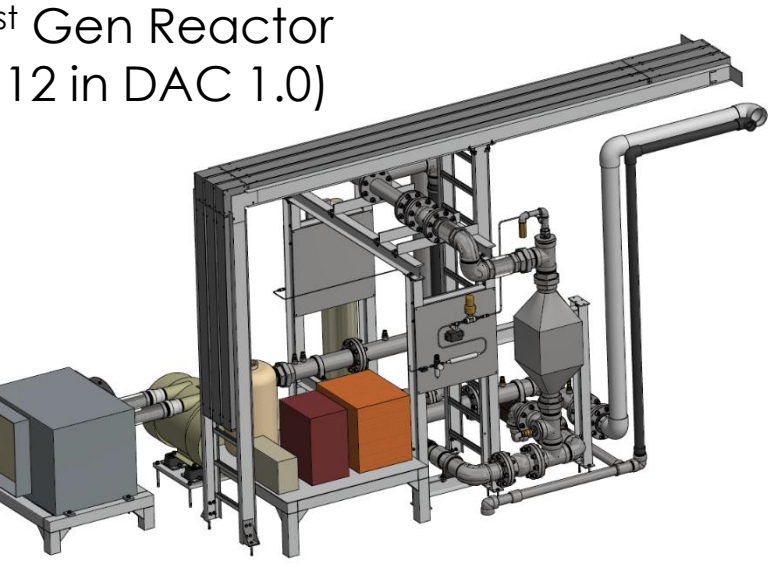


- Sized for modules at typical scale: 12" X 12" X 12"
- Able to accommodate common form factors: granular solid, fiber mat, or monolith
- Instrumented to provide measurements of all parameters needed for prototyping models
- Designed to allow non-standard regeneration

In shakedown. Testing begins in Fall!

Bench Scale Module Testing Units

1st Gen Reactor (12 in DAC 1.0)



1st Gen Reactor (12" x 12" x 12")

Pros:

- Able to accommodate common form factors:
 - granular solid, fiber mat, or monolith

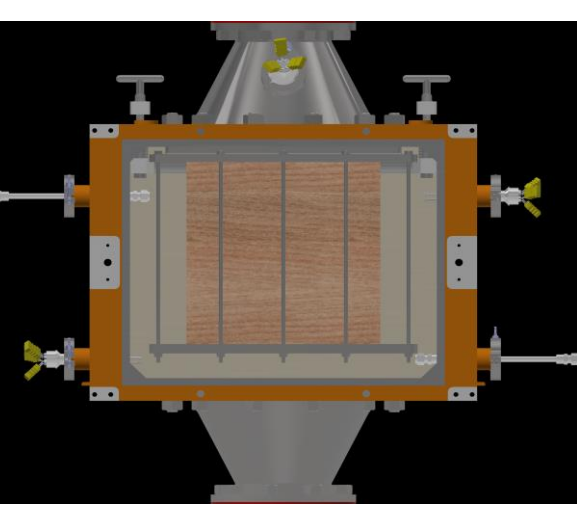
Cons:

- Cumbersome sample loading
 - assembly/disassembly of large flanges required
- No internal heat exchange
- Not rated for vacuum regeneration
- Potential for gas bypass between basket and chamber wall

Sample Basket

Bench Scale Module Testing Units

2nd Gen Reactor (Kurt J. Lesker Co)



Enhancements:

- Front access door (ease of sample loading)
- Internal heat exchanger coils surrounding sample perimeter
 - Steam/water/chilled glycol
- Rated for vacuum regeneration
- Improved gas sealing to mitigate gas bypass of bed
- Able to accommodate common form factors: granular solid, fiber mat, or monolith
- Instrumented to provide measurements of all parameters needed for prototyping models

Sample Holder Assembly

Disclaimer: This project was funded by the United States Department of Energy, National Energy Technology Laboratory, in part, through a site support contract. Neither the United States Government nor any agency thereof, nor any of their employees, nor the support contractor, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.