US-Norway Bilateral Meeting

Point Source Carbon Capture

Test Center Roles in Technology Development

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U.S. DEPARTMENT OF ENERGY | NETL NATIONAL ENERGY TECHNOLOGY LABORATORY

NATIONAL CARBON CAPTURE CENTER

National Carbon Capture Center Accomplishments and Scope

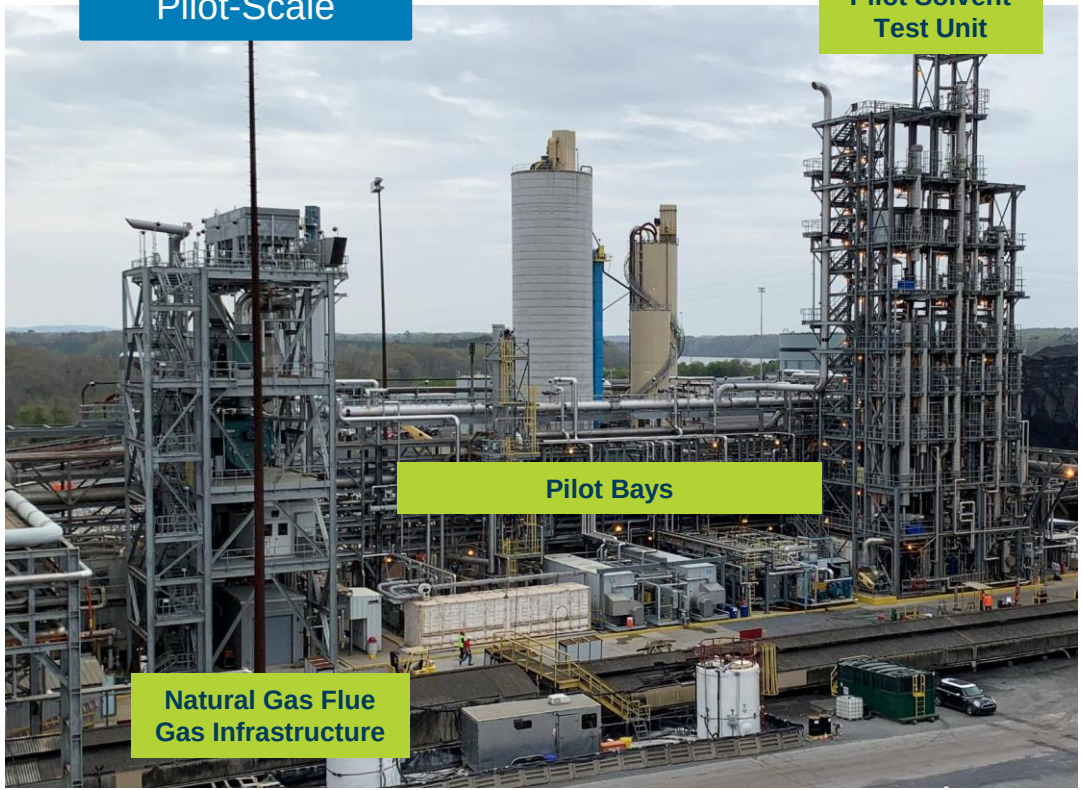
- 145,000+ hours of testing since 2009
- 70+ technologies / developers from 7 countries
- Continuous expansion – alternative regeneration, gas injection, analytical support
- Flexibility for testing at multiple scales & on-site scale-ups
- Accelerated technology development
  - 16+ technologies in queue to test
  - Multiple technologies progressed to FEED studies
  - 8 technologies scaled up (or ready) to 10+ MW
  - CO_2 concrete technology commercialized; returning to expand product development

Reduced CO_2 cost capture from fossil generation by more than 40%

October 2020 – 5-Year Agreement Renewal / $140 Million
Expanded scope to CO_2 capture for natural gas power, CO_2 utilization, direct air capture

Test Bays and Equipment

Pilot-Scale



Slipstream Solvent Test Unit

Bench-Scale Area

Lab-Scale Test Unit

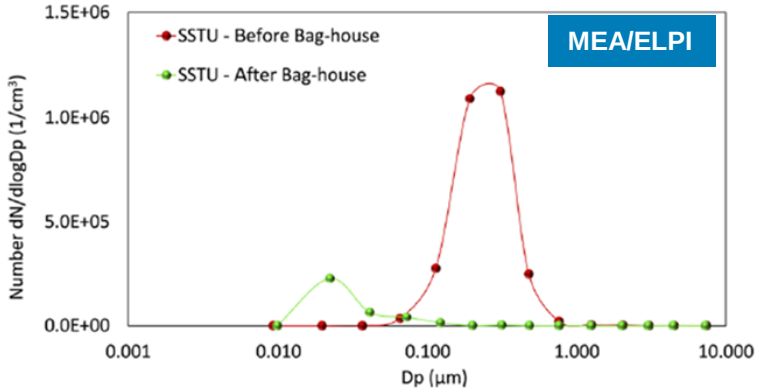
Monitoring, Reporting and Validation

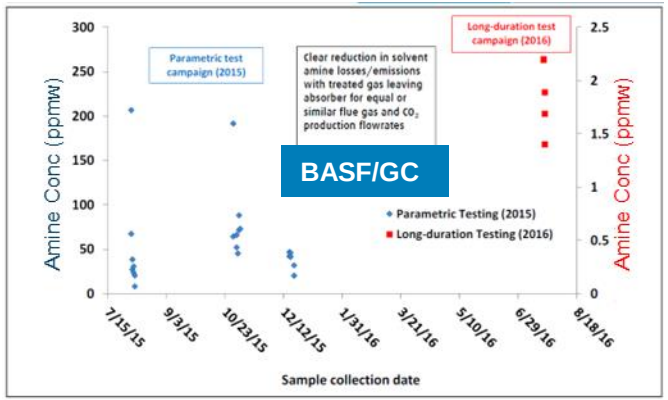
- **High-level lessons learned through testing**
  - Sample gas treatment is critically important (condensing chillers and Nafion dryers)
  - Understanding analyzer capability and limitation to ensure right instrument for the analysis
  - Flue gas source analysis and pre-treatment (contaminants can impact solvent degradation/emissions)
  - Need to further develop and understand operational mitigation strategies for emission reduction
  - Need to focus on long-term, continuous solvent emission and degradation analysis
  - Lack of data collection and data transparency can hinder understanding of emission profiles
  - Opportunity exists to standardize testing to allow more consistent interpretation of data

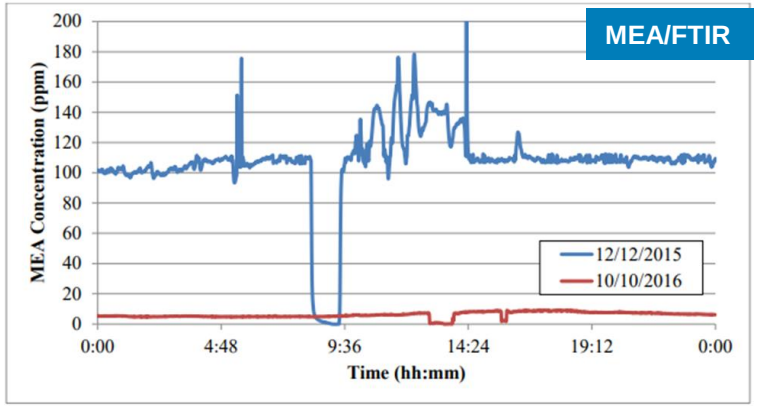
Emission-Related Analyses

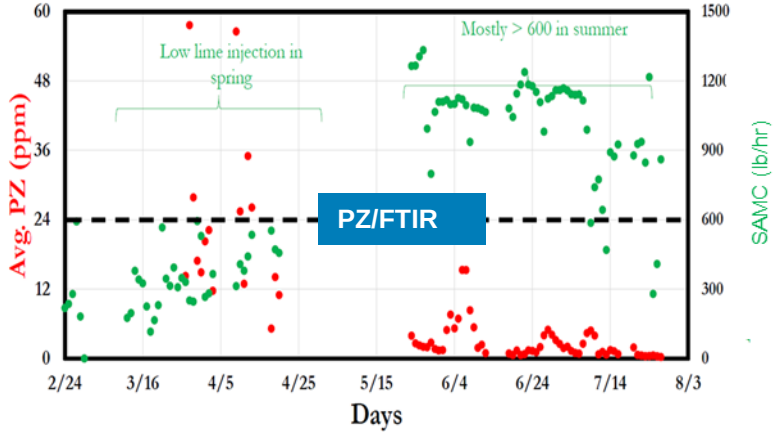
- **In-house capability**
  - Sample gas treatment (condensing chillers and Nafion dryers)
  - UV analyzers for NO_2 and SO_2
  - FTIR for amines, NH_3, etc.
  - ELPI$^+$ for particles concentrations and size distribution
  - Gas sampling train for offline degradation products
- **In collaboration with technology developers**
  - FTIR, PDI, UV-Vis, Ecotech low-NO_2 analyzer, AMI low O_2 analyzer (UT Austin)
  - SMPS and APS from TSI Inc. (Linde/BASF, EPRI & WUSL) for particles distribution
  - CB&I CEM mobile trailer (Linde/BASF)
  - PTR-TOF MS for degradation products (UT Austin & University of Oslo)

Example – Impact of Aerosol (SO_3)









NCCC Next Steps and Future Considerations

- ITCN technical focus is emissions characterization and reduction
  - Plan to collect best practices on emissions measurement protocols from all member test centers
- Explore advanced analyzer/instrument for solvent degradation/emission analysis
  - PTR-TOF MS
  - Total Nitrosamines (TONO) by Stanford University
  - Raman Spectroscopy
  - Optical Sensor
- Consider design of flexible multi-stage flue gas washing for emission reductions (e.g., dry bed, trickle bed, water, acid wash)
- Explore use of SSTU for long-term solvent degradation and reclamation study
- Perform emission measurement for all technologies testing at NCCC, as needed
  - Continuous monitoring of source flue gas for changes
  - Measurements in both liquid and gas phases (key locations) for comprehensive understanding

Acknowledgment

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Questions?

Backup Slides

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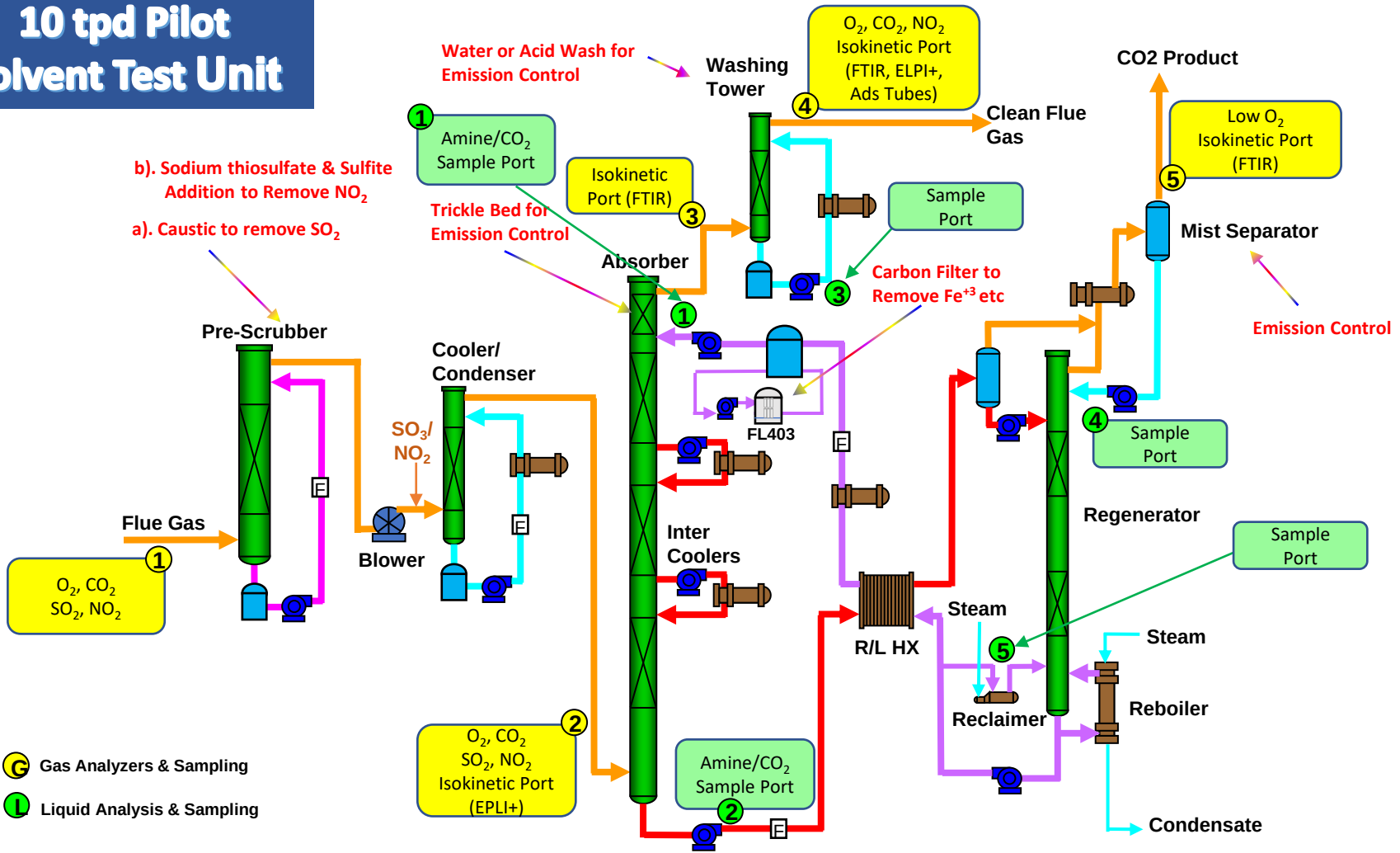
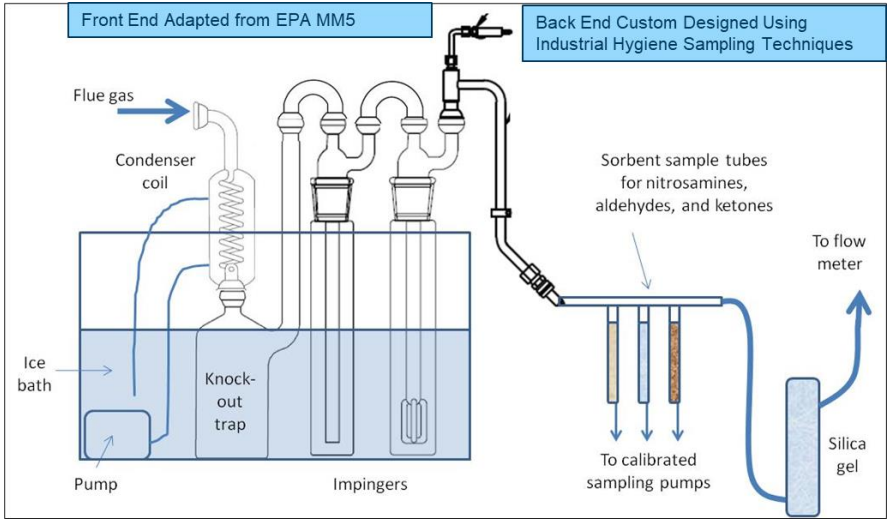
10 tpd Pilot Solvent Test Unit



Example - MEA Degradation Products Sampling and Results



MEA ~ 1100 operation hours

Analyte	WT Outlet Concentration, ppmv (1)	
	Wash Tower	Regenerator
MEA	135	0.061
Formaldehyde	0.32	2.09
Acetaldehyde	0.69	2.04
Ammonia	140	3.5
Ethyl amine	0.036	ND
Acetone	0.18	0.033
Acetonitrile	0.039	0.023
Acetic acid	0.021	0.020
Propionic acid	0.23	0.26
N-Nitrosodimethylamine (2)	0.000225	0.0000058
N-Nitrosodiethanolamine (2)	0.00106	ND

(1) Expressed as ppmv in the gas phase
(2) Present only in vapor samples
ND = Not Detected