Workshop on Measurement, Monitoring and Controlling Potential Environmental Impacts from the Installation of Point Source Capture

National Carbon Capture Center & Southern Company Energy Center

Birmingham, AL - June 7-8, 2023

The United States Energy Association (USEA), in cooperation with the U.S. Department of Energy's Office of Fossil Energy and Carbon Management (DOE-FECM), organized a workshop on Measurement, Monitoring and Controlling Potential Environmental Impacts from the Installation of Point Source Capture that was held at the Southern Company Energy Center in Birmingham, AL on June 8, 2023. The workshop was preceded by a site visit to the National Carbon Capture Center (NCCC) in the afternoon of June 7, 2023. Please note, FACA – Federal Advisory Committee Act does not apply to this meeting as the purpose of this meeting is to obtain information or viewpoints from individual attendees as opposed to advice, opinions or recommendations from the group acting in a collective mode. [1]

i. Background

As we begin to build large carbon capture systems facilitated by the BIL and IRA funding, we must understand the impacts of these systems on both the environment and local communities.

On March 3, 2023, the White House Office of Science and Technology Policy, together with the Council on Environmental Quality and the Climate Policy Office convened a roundtable of domestic and international experts to discuss the air quality impacts associated with carbon capture and to identify research needs. Highlights of the discussion and recommendations are listed below:

(i) Adding a solvent-based carbon capture to existing facilities could result in improved air quality from a criteria pollutant perspective (e.g., sulfur dioxides). However, there is the potential for solvents to degrade resulting in degradation products such as

[1] When is Federal Advisory Committee Act (FACA) Applicable? http://www.gsa.gov/faca

nitrosamines and aldehydes, and for amine emissions to form aerosols in the atmosphere, which may further degrade into other pollutants via photochemical reactions in the atmosphere.

(ii) Although the potential exists and research needs were identified, it is important to underscore that these emissions can be managed and avoided. The potential will vary depending on the configuration of the solvent-based carbon capture unit and the location. For example, amine aerosols are minimized on a facility that already has a baghouse or wet electrostatic precipitator (wet ESP) to control for particulate matter.

(iii) Emissions of nitrogen containing compounds (e.g., nitrosamines) can be minimized by fitting the solvent-based carbon capture plant with highly efficient engineering control systems (e.g., 2-stage water wash, acid wash).

(iv) Carbon capture technologies based on adsorption (physical sorbents), or cryogenic separation do not create any secondary air emissions.

The Department of Energy has already taken steps to collect data regarding the non-CO_2 air quality impacts associated with large-scale carbon capture pilots. Ensuring there is transparency regarding this data and shared lessons based on experiences in operation of these facilities is critical to furthering our understanding of how carbon capture can impact the environment.

ii. Objectives and Agenda

As a follow-up to the White House Office of Science and Technology Policy round table, DOE and USEA convened this workshop to gather information on the following topics:

- What needs to be measured from large-scale Carbon Capture pilots or CCS demonstration projects;
- Which analytical methods should be used for measurement;
- What mitigation methods or emission control technologies are currently available and what should be installed on the large-scale Carbon Capture pilots or CCS demonstration projects; and
- What additional R&D needs to be funded to accelerate large scale deployment of carbon capture systems in the future.

The workshop was attended by 65 participants with a broad expertise, including (i) carbon capture developers (e.g., solvents, sorbents, membrane, cryogenic based technologies) for both Point Source Carbon Capture and Direct Air Capture, (ii) engineering, procurement, and construction companies, (iii) host sites owners from both power generation and industrial sectors, (iv) nonprofit organizations, (v) trade associations, (vi) subject matter experts from national labs, national and international universities, (vii) national and international test centers (National Carbon Capture Center (NCCC), SINTEF, Technology Center Mongstad (TCM) Norway), (viii) government agencies (DOE-FECM, DOE-NETL, EPA), and (ix) the Executive Office of the

President (Office of Science and Technology Policy and Council on Environmental Quality). The list of participants can be found in **Appendix A**.

The agenda included introductory remarks from Dr. Jennifer Wilcox (DOE-FECM), and Dr. Sally Benson (Office of Science and Technology Policy, Executive Office of the President) followed by panel discussions, individual presentations, and breakout sessions addressing the following main focus areas of the workshop (**Figure 1**):

1. Define baseline of air pollution measurements and engineering controls from the current carbon capture pilots and demonstrations;
2. Discuss CCS environmental impacts as a function of input parameters (e.g., flue gas composition, duty cycle, fuel type), and engineering control options for mitigation strategies;
3. Summarize CCS impacts on life cycle analysis (water usage, waste management) – based on DOE-funded Front-End Engineering and Design studies (FEEDs);
4. Identify R&D Gaps on emission measurements, engineering controls, and atmospheric dispersion and photochemical models; and
5. Define specifications for the design of air pollution measurements and engineering controls for pilots/demos.

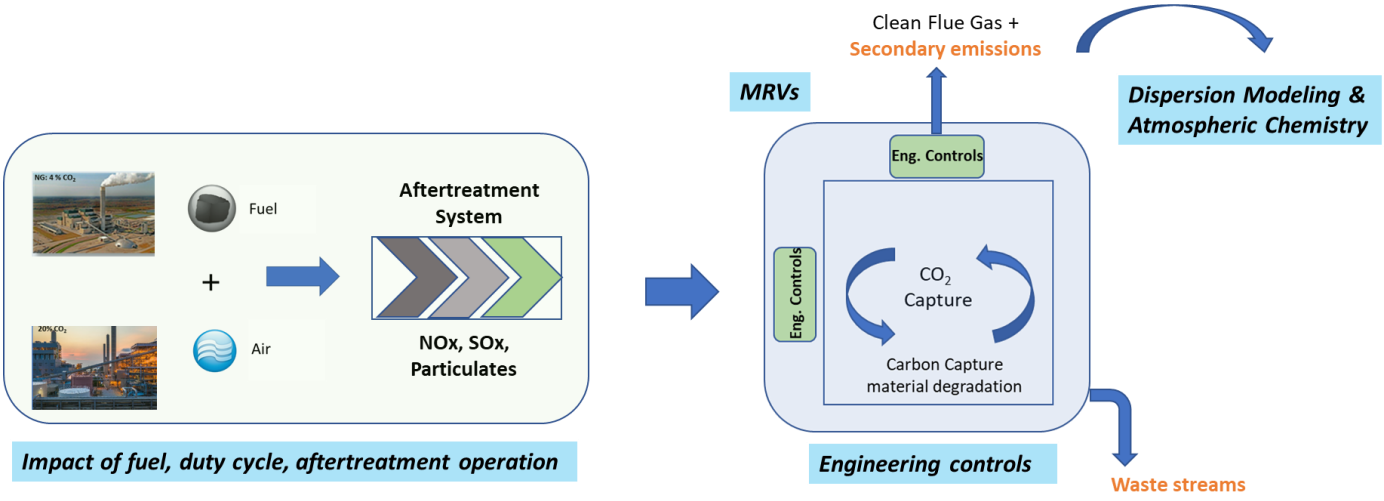

Figure 1: Topic areas addressed during the workshop.

The agenda can be found in **Appendix B** and links to the presentations are posted on the workshop website.[2]

[2] Workshop on Measurement, Monitoring and Controlling Potential Environmental Impacts from the Installation of Point Source Capture | USEA | United States Energy Association.

Following all the presentations, the participants were split in four break-out sessions and had the opportunity to provide individual inputs on the main topic areas discussed during the workshop. The remainder of the report highlights observations and discussions that were captured in the presentations and the breakout sessions. Summary of the break-out sessions can be found in **Appendix 2.**

iii. Workshop Findings

There are several carbon capture technologies available in the market. The workshop included presentations on cryogenic, physisorption-, adsorption- based capture and oxy-combustion. Workshop participants highlighted that these systems were unlikely to form secondary air emissions that solvent-based systems might. Findings from Focus Areas 1-3 are included below:

Focus Area 1: Impact of site selection, fuel, duty cycle, and emissions after treatment operation.

i. ***Site Selection.*** A workshop finding was that careful attention should be paid to site selection and host plant capabilities. For coal electric generation facilities, capture systems should be installed on host sites that have the highest level of air pollution control implemented. Specifically, the coal electric generation facilities installing carbon capture systems must have: Flue Gas Desulfurization (FGD), Selective Catalytic Reduction (SCR), baghouse, mercury control and sulfur trioxide control. For the natural gas electric generation facilities (e.g., Natural Gas Combined Cycle (NGCC) systems, and possibly Natural Gas Simple Cycle), the host sites should have SCR, as the use of SCR will minimize NO_x entering the amine scrubbing unit. Depending on fuel source, industrial facilities may need additional PM controls including fabric filters and/or wet Electrostatic Precipitator (ESP) to reduce aerosol formation.

ii. ***Solvent Selection.*** To this end, discussion focused on solvent/amine selection and how appropriate selection and pre-screening are important. Specifically, selecting amines that (i) do not form nitrosamines, (ii) have lower volatility, and (iii) are highly resistant toward oxidation, and/or other types of degradation processes, is recommended.

iii. ***Fuel Source Effects.*** Electric generation and industrial facilities are using a variety of fuels (e.g., coal, NG, biomass, municipal waste) that have a strong impact on the flue gas composition. For example, Svante discussed their pilot plant campaign that was conducted at a cement plant with a variable flue gas composition due to various fuel sources. In order to deal with this challenge, Svante instituted a characterization program

ahead of installing their capture unit so that they could design a guard bed control technology to clean the flue gas upstream to their sorbent-based technology.[3]

iv. ***Duty Cycle Effects.*** Flue gas composition is strongly dependent on the duty cycle regime operated by the host site facilities. Southern Company presented data on combustion turbines that are uncontrolled for CO_2. This data showed that during start-up operations non-CO_2 emissions can increase. The data highlights that start-up duration and emissions are both unit specific and variable, and can be impacted by the type of unit, environmental controls installed, equipment size, and process and permit requirements. It was suggested that DOE pursue additional R&D around this topic, and to run units at non-steady state during parametric testing phases of the pilot and demonstration projects to determine the impact on emissions from this operational variability.[4]

v. ***Insights from the Focus Area 1 breakout session***:

Workshop participants suggested that DOE develop:

(a) *Publicly accessible databases for high quality data and information* based on the DOE funded pilots and demos that are tailored to a variety of stakeholders. The databases could include: (i) accurate composition of flue gas entering the capture unit, (ii) methods for minimizing operational variability, (iii) standardized information on pre-treatment methods, (iv) standardized reports for the composition of exhaust leaving the capture unit stack, and (v) methods to quantify non-CO_2 air emission benefits and impacts to public health and the environment.

(b) *Standardized procedures for flue gas compositional monitoring* from the host site and the capture plant, which can be evaluated across projects. Workshop attendees discussed the role of Environmental Protection Agency as the regulatory entity responsible for addressing and setting emissions limits related to air pollution.

B. Focus Area 2: Engineering Controls

Many engineering solutions through equipment and operational methods are available to address potential emissions resulting from the installation of solvent-based carbon capture systems.

i. ***Engineering Solutions.*** Minimizing amine emissions is important as it can limit or eliminate the secondary formation of nitrosamines by atmospheric reactions. This can be achieved by installing pre- and post-absorber engineering controls. Specifically, pre-

[3] https://usea.org/sites/default/files/event-/Svante%20Technology%20-%20%20Final.pdf
[4] https://usea.org/sites/default/files/event-/Lunsford%20-%20Startup%20Shutdown%20Emissions%20considerations%202023%2006%2005.pdf

scrubbers can reduce significantly SO_2 in the flue gas. The addition of thiosulfate can also remove NO_2. Furthermore, the use of a fabric filter with added alkali, a Brownian Diffusion Unit (BDU), or a wet ESP may reduce or eliminate sub-micron particulates entering the absorber unit. Water wash systems installed down-stream of the absorber were discussed to be effective at removing amine emissions. Furthermore, the use of an acidic solution in the wash systems (i.e., acid-wash) can eliminate ammonia and remove most nitrosamines.

WORKSHOP INSIGHTS

Installing highly effective pre-absorber (e.g., wet ESP, BDU or equivalent) and post-absorber (e.g., advanced wash systems) engineering solutions onto carbon capture pilot and CCS demonstration projects will serve multiple purposes including: (i) preventing the release of non-CO_2 constituents into the environment, and (ii) allowing DOE and others to understand the efficacy of these systems when installed at commercial scale.

ii. ***Operational controls*** were discussed to further minimize non-CO_2 emissions, and/or carbon capture material degradation including:

a. *Aldehyde management*: Manage condensate bleed or treat water wash or reflux.
b. *Oxidation mitigation through*:
(i) carbon treating, N_2 sparging, selective catalysts; (ii) reduced residence time of the working solution at high temperature, (iii) removal of soluble iron salts (e.g., $Fe^{2+/3+}$) from working solutions, (iv) continuous reclaiming, and/or (v) reduction of NO_2 from flue gas.
c. *Aerosol mitigation*:
(i) increase temperature at the top of the absorber, (ii) add second stage in the water wash to increase residence time, and/or (iii) use less hydrophobic amine.

iii. ***Insights from the Focus Area 2 breakout session***:

a. Suggestions included implementing mandates for emissions controls, utilizing existing testing sites, selecting suitable sites with flue gas pre-treatment, and creating North Star metrics.
b. Suggested action items for DOE and other government agencies include: (i) structure funding opportunity announcements (FOAs) such that funding decisions are contingent on site selection and proper environmental controls, (ii) issue a request for information (RFI) to solicit R&D needs on the topic, (iii) develop a roadmap report on the topic, (iv) establish a cross-disciplinary group within DOE to address this topic, and (v) develop guidelines and standards to apply to federally-funded projects.

C. Focus Area 3: Measurement, Reporting, and Verification (MRV) Methods and Air Dispersion Models

A significant component of the workshop discussions focused on appropriate measurement devices to be used at facilities that are installing carbon capture systems.

i. Technology Center Mongstad (TCM) was highlighted as an operation that has excellent analytical equipment capabilities and that uses several different methods to measure the same constituents. **Figure 2** shows the equipment that is located on the Amine Plant at TCM.

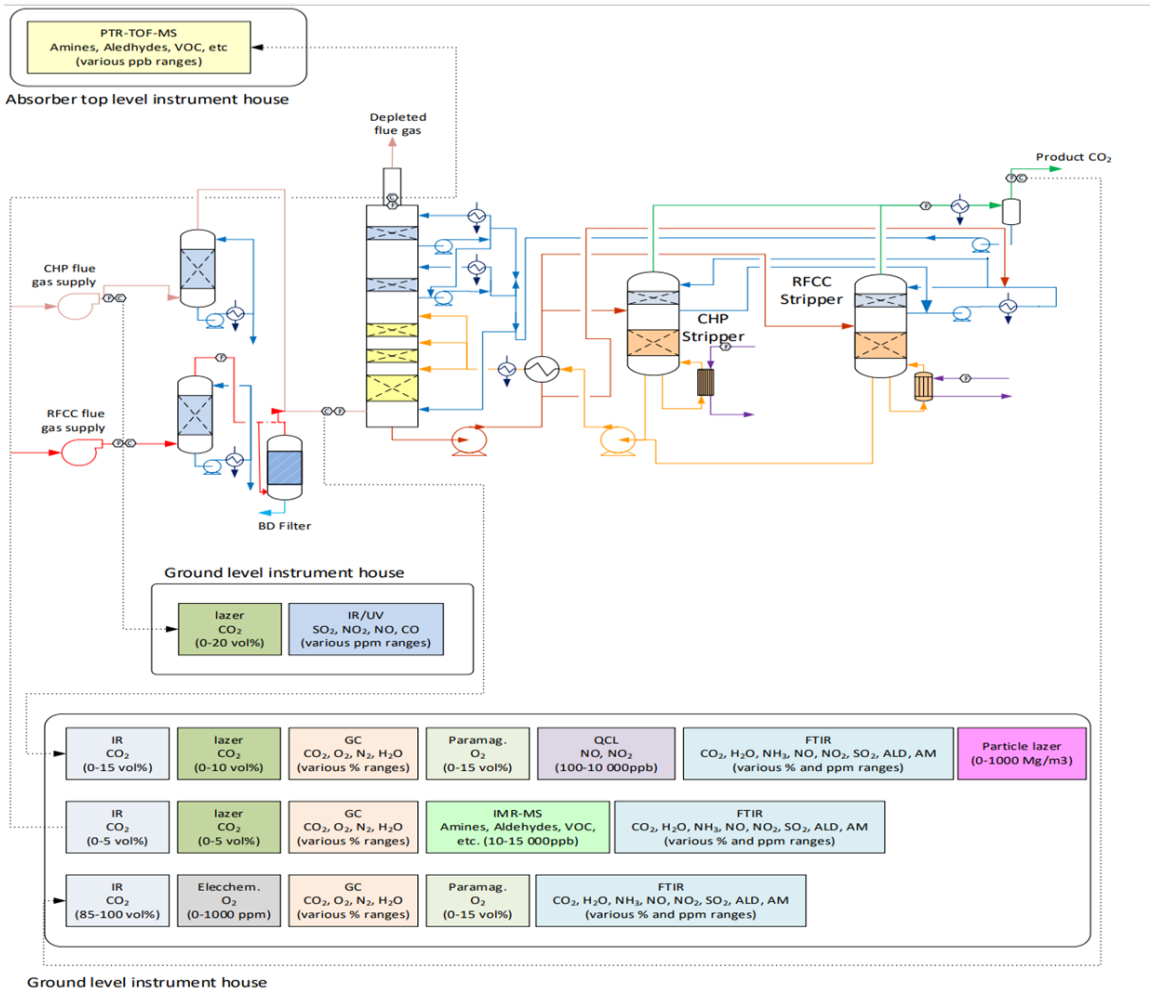

Figure 2: Emission testing installed at the Amine Plant (Technology Center Mongstad)[5]

ii. It was suggested that DOE require project developers to design the emission control and monitoring systems for upcoming carbon capture pilots and CCS demonstration projects

[5] https://usea.org/sites/default/files/event-/Rouzbeh%20Jafari-DOE%20Workshop-Emission%20Control%20BDU.pdf

to enable a comprehensive understanding of emissions from various systems. Most projects use a continuous measurement device, Fourier-transform infrared (FTIR) spectroscopy that measures amine and ammonia levels greater than 1 part per million (ppm). However, it was noted that it may be necessary to go below this detection limit and to utilize a testing procedure with greater sensitivity at all testing locations. Specifically, Proton Transfer Reaction–Time of Flight-Mass Spectroscopy was discussed as an analytical equipment that can identify nitrosamine and aldehyde emissions at ppb levels.

iii. SINTEF has been developing an Absorber Continuous Emissions (ACEMs) Monitor System which allows for continuous and online measurements of amines and solvent degradation products.[6] DOE is working with SINTEF to gain understanding of the capabilities of this unit and is seeking opportunities to partner with SINTEF in incorporating a Beta unit at the National Carbon Capture Center, and other DOE-funded pilots and demonstration projects.

iv. During the workshop, there was discussion regarding the impact of installing carbon capture systems in the U.S on air quality in the context of current regulations. PM2.5 was flagged as being a constituent that may increase if there are increased ammonia or amine emissions observed from the capture system. PM2.5 therefore has the potential to be out-of-compliance with current air quality standards and must be closely monitored. Additionally, it was noted that on January 6, 2023, EPA announced a Notice of Proposed Rulemaking (NPRM) to revise the National Ambient Air Quality Standard for PM2.5.[7] Any additional PM2.5 generated by the installation and operation of capture systems, specifically amine based solvent systems, should be considered in the context of this proposed decision.

v. Air dispersion modeling was discussed and is currently being conducted by EPRI, Technology Centre Mongstad (TCM)[8] and Fossil Energy and Carbon Management collaboratively with the University of Maryland. It was suggested that DOE continue working closely with TCM to understand how to implement this type of modeling on both carbon capture large pilots and the CCS demonstrations. The need for atmospheric chemistry dispersion modeling and experiments to quantify risk of PM2.5, aldehydes and nitrosamines was identified as a R&D priority at the workshop.

vi. Acetaldehyde and formaldehyde were also discussed as both are listed by EPA as Hazardous Air Pollutants (HAPs). It was noted during the workshop that certain amines when installed at full scale will likely exceed the major source HAP thresholds thereby

[6] https://usea.org/sites/default/files/event-/da%20Silva%20-%20SINTEF%20experience%20on%20CO2%20capture%20plant%20emissions%208%20June%202023%20v2.pdf
[7] Proposed Decision for the Reconsideration of the National Ambient Air Quality Standards for Particulate Matter (PM) | US EPA
[8] https://usea.org/sites/default/files/event-/Rouzbeh%20Jafari-DOE%20Workshop-Dispersion%20Model.pdf

triggering New Source Review. It was clear throughout the workshop that additional data surrounding the quantity of these emissions from capture systems would be useful and therefore, these systems should be designed with the measurement of these components in mind.

vii. During the break-out session (Focus Area 3), participants suggested that for each new carbon capture material that is a part of DOE's carbon capture pilots or CCS demonstration projects, DOE should specify R&D tasks to identify and quantify solvent degradation byproducts, to study mechanism of formation of byproducts, and atmospheric chemistry/dispersion impacts in the process. Participants also recommended R&D funding to develop analytical detection methods (e.g., liquid phase, gas phase) for solvent degradation products to ensure meaningful data can be collected and can be utilized to support monitoring and modeling validation.

iii. Summary of the Workshop Recommendations

Tables 1 summarizes the actions items as identified during the workshop.

Table 1: Summary of suggested action items

TOPIC	Action Items
R&D	✓ Develop advanced water-wash systems ✓ Develop mitigation processes for aldehydes ✓ Develop continuous solvent reclamation processes ✓ Validate the safety of solvent emissions ✓ Develop engineering control systems tailored for specific industrial applications ✓ Develop air dispersion models tailored for specific carbon capture material chemistry
Project Implementation: Carbon Capture Pilots and CCS Demos	✓ Install online FTIR and other advanced/more sensitive analytical equipment (e.g., Proton Transfer Reaction TOF- MS) ✓ Install mandatory pre-CCS and post-CCS advanced engineering controls ✓ Measure co-benefits ✓ Implement standardized procedures for flue gas compositional monitoring ✓ Implement 3rd party emissions testing
Communications	✓ Disseminate R&D results including emission monitoring from Carbon Capture Pilots and CCS Demonstration projects by developing publicly accessible databases ✓ Distill information for non-scientific communities

Appendix A: List of attendees and affiliations

Last Name	First Name	Organization
Baxter	Larry	Brigham Young University
Benitez	Jose	US Department of Energy-FECM
Benson*	Sally	Office Science, Technology and Policy
Bhown*	Abhoyjit	EPRI
Bosch	Dan	National Rural Electric Cooperative Association (NRECA)
Brickett	Lynn	Keylogic
Carroll	John	Southern Company Services- NC3
Cooney	Gregory	US Department of Energy-FECM
Corser	Michele	Southern Company Services- NC3
Danyi	Erick	BP
Elliott	Bill	Bechtel
Federici*	Justin	Exxon
Flagg	Danielle	Sargent & Lundy
Gibbins	Jon	University of Sheffield
Grogan-McCulloch	Lisa	US Department of Energy-FECM
Hancu	Dan	US Department of Energy-FECM
Hill	Lee Ann	PSE Healthy Energy
Hill	Krista	U.S. Department of Energy-NETL
Hlasko	Andrew	US Department of Energy-FECM
Hoffmann	Jeffrey	US Department of Energy-FECM
Homsy	Sally	NETL Support Contractor
Honda	Gregory	US EPA
Jafari	Rouzbeh	TCM
Kammer	Ryan	Great Plains Institute
Kapila	Rudra	Third Way
Kniep	Jay	Membrane Technology and Research, Inc.
Knipping*	Eladio	EPRI
Koka	Jona	EDF
Lambrecht	Robert	Southern Company Services- NC3
Lee	Mendy	Southern Company Services- NC3
Leung	Sarah	White House CEQ
Littlefield	Michelle	USEA
Liu	Jinzhong	Svante
Longstreth	Benjamin	Clean Air Task Force
Luebke	David	U.S. Department of Energy-NETL
Lunsford	Landon	Southern Company Services- NC3
Maas	Cole	Mitsubishi Heavy Industries America
Matuszewski	Michael	AristoSys
McCahill	Jenny	Carbon Engineering Ltd.
Merkel	Tim	MTR
Meuleman	Erik	ION Clean Energy

Moore	Michael	US Energy Association
Morton	Frank	Southern Company Services- NC3
Munson	Ron	NETL
Nikolic	Heather	University of Kentucky
Northington	John	Southern Company Services- NC3
O'Brien	Kevin	Illinois Sustainable Technology Center
Rentz	Rebecca	Occidental Petroleum Corporation
Ring	Allison	University of Maryland
Robinson	Julie	Southern Company Services- NC3
Rochelle	Gary	University of Texas at Austin
Shah	Minish	Linde Inc.
Shamitko-Klingensmith	Nicole	U.S. Department of Energy-NETL
Shaw*	Stephanie	EPRI
Silva	Eirik Falck da	SINTEF
Setophaga	Bob	Kiewit
Stevens	Alan	Svante Inc
Stolark	Jessie	Carbon Capture Coalition
Tanthana	Jak	RTI International
Thompson	Jesse	University of Kentucky
Tran	Minh	Svante
Uhrig	Laura	Southern Company Services- NC3
Vitse	Frederic	Graymont
Wilcox *	Jennifer	US Department of Energy-FECM
Wu	Tony	Southern Company Services- NC3

*** Virtual presentation/attendance**

Appendix B: Workshop Agenda

Workshop on Measurement, Monitoring and Controlling Potential Environmental Impacts from the Installation of Point Source Capture

National Carbon Capture Center &
Southern Company Energy Center
Birmingham, AL
June 7-8, 2023

Wednesday, June 7

1:30 PM	**National Carbon Capture Center Tour**

Thursday, June 8

7:30 – 8:00 AM	**Registration Open**
8:00 – 8:15 AM	**Introduction**
8:15 – 8:45 AM	**Keynote** Dr. Jennifer Wilcox, U.S. Department of Energy, Office of Fossil Energy & Carbon Management (DOE-FECM) (Virtual) Dr. Sally Benson, Office of Science and Technology Policy, Executive Office of the President (Virtual)
8:45 – 9:00 AM	**Objectives and Deliverables** Dan Hancu, DOE-FECM
9:00 – 9:30 AM	**State of the Knowledge: Emission Measurements and Mitigation Methods for Amine Chemistry**

Gary Rochelle, University of Texas – Austin (UT – Austin)

9:30 – 10:30 AM **Panel 1: Baseline measurements & procedures: Past Pilots & Demos**
Moderator: Andrew HLasko, DOE-FECM

1. Demos:
Jenny McCahill, Carbon Engineering
Cole Maas, Mitsubishi Heavy Industries

2. Large Pilots
Jak Tanthana, RTI
Larry Baxter, Brigham Young University

10:30 – 10:45 AM **Break**

10:45 – 12:00 PM **Panel 2: Current Small/Large Pilots**
Moderator: Ron Munson, National Energy Technology Laboratory (NETL)
Matthew Stevenson, Svante
Erik Meuleman, ION Clean Energy
Minish Shah, Linde
Heather Nikolic, University of Kentucky

12:00 – 1:00 PM **Lunch**

1:00 – 2:00 PM **Panel 3: Analytical Methods to Measure Emissions**
Moderator: Michelle Corser, Southern Company Services
Eirik Falck da Silva, SINTEF
Tony Wu, Southern Company Services
Gary Rochelle, UT – Austin
David Luebke, NETL

2:00 – 2:45 PM **Environmental Control Methods & Normal, Abnormal, and Emergency Operations**
Moderator: Lynn Brickett, Keylogic
Landon Lunsford, Southern Company Services
Rouzbeh Jafari, Technology Center Mongstad (TCM)
Jak Tanthana, RTI
Minish Shah, Linde

2:45 – 3:00 PM **Break**

3:00 – 3:20 PM **Analytical Method to Measure Total Amine Emissions**
William "Bill" Mitch, Stanford (virtual)

3:20 – 3:50 PM	**Atmospheric Dispersion Plume Modelling –** Moderator: Jose Benitez, DOE-FECM Eladio Knipping, EPRI / Prakash Karamchandani, Ramboll (virtual) Rouzbeh Jafari, TCM
3:50 – 4:20 PM	**Environmental Impact of Capture Technology: A Review of DOE-Sponsored FEED Studies** Sally Homsy, Keylogic
4:20 – 4:50 PM	**Environmental Health Considerations** Lee Ann Hill, PSE Healthy Energy
4:50 – 5:50 PM	**Breakout Sessions**
5:50 – 6:00 PM	**Wrap-up**

Appendix C: Summary of the Breakout Sessions

Breakout Session #1 – Flue Gas Impurities and Pre-Treatment: Impact of Operational and Feedstock Variability

The need for high quality data and information that is made available to all stakeholders was the main topic discussed during Breakout Session #1. During implementation of a carbon capture technology project, there will be a variety of stakeholders, each with different needs. For instance, operator's informational needs may include accurate composition of flue gas entering the capture unit, methods for minimizing operational variability, and standardized information on pre-treatment methods. These informational needs likely would not align with the needs of the stakeholders in the community, who seek information on the composition of exhaust leaving the carbon capture unit stack and the effects it could potentially have on human health, wildlife, and the environment. Currently, a repository for such information does not exist; existing information is disparate across academic sources, reports, and journal articles. The development of standardized procedures for flue gas compositional monitoring from the host site and carbon capture facility will be critical to ensure that the resulting emissions data is accurate, reliable, and can be easily evaluated across projects. This information can also be used as reference when developing emissions regulations for emerging carbon capture technologies across the different types of power generation and industrial facilities. Workshop attendees discussed the role of Environmental Protection Agency as the regulatory entity responsible for addressing and setting emissions limits related to air pollution and communicating these emission limits.

Breakout Session #2 – Emissions Control and Mitigations

Group 2 participants discussed visions and priority action items for mitigating and controlling emissions from carbon capture facilities. The visions included 1) being realistic and ambitious, 2) identifying unknowns, 3) creating standards for facility emissions, 4) publicly communicating pollution reductions, 5) using engineering solutions and instrumentation to achieve results, and 6) understanding the costs of the mitigation methods. Participants saw several key opportunities such as using water or acid washes to reduce emissions and aerosols, engaging with other industries, identifying specific R&D needs and site permitting requirements, performing speciation research, and constructing plants that would be turnkey ready for an acid wash and drop-in solvents if needed. The group selected three key priorities: 1) acid wash and aerosol control, 2) site selection, and 3) prioritizing R&D needs. Suggestions included implementing mandates for emissions controls, utilizing existing testing sites, selecting suitable sites with flue gas pre-treatment, and creating North Star metrics. Several suggested action items fell within the US Government or DOE's responsibility, such as including research areas of interest (AOIs) in new FOAs, making funding decisions contingent on site selection and proper environmental controls, creating a request for information (RFI) to solicit R&D needs, drafting a R&D roadmap report,

establishing a cross-disciplinary group within DOE to address this topic, and developing guidelines and standards to apply to federally funded projects.

Breakout Session #3 – Emissions MRV and Atmospheric Dispersion Modeling

Discussion on Emissions MRV and Atmospheric Modeling was segregated into the following parts: problem identification, data generation, modeling, and establishing standards. The first opportunity focused on identifying topics or areas within solvent-based processes that previously may have been unstudied. Funding for the nascent study of solvent degradation byproducts, the mechanism of formation, and lifecycle analysis in the process should be considered with each new solvent. Funding is also required to develop monitoring capabilities to ensure that meaningful data can be collected to support monitoring and modeling validation. DOE supported model development is required to promote predictive capabilities for the atmospheric fate of emissions in the context of reaction, degradation, and dispersion. Model development should also be supported to properly inform, develop, and enforce DOE-developed standards for emissions monitoring and tracking.

Breakout Session #4 – Development and Application of Guidelines or Standards that can be Applied to Federally-funded Projects

Discussion during the Breakout Session #5 was centered around the addition of language to Federally-funded projects to ensure that projects do not become stranded assets due to excessive emissions. Specifically, it was suggested that language ensure that projects are contractually able to change solvents, and that an additional acid wash can be accommodated if needed. The group focused on the importance of having Federally-funded projects outline clear methodologies for emissions measurement, modeling, testing and dissemination of findings to the public. The need for standardization of testing methods, and clearer definition of the scope of testing and modeling required were highlighted. While DOE and other government entities were highlighted as responsible for setting the standards to protect their investment, DOE's solicitation of community input was recommended. It was also proposed that Federally-funded projects should submit to regular third-party emissions testing in collaboration with DOE, and the resulting test data should be transparently shared with the public.