Standards Test Beds for Greenhouse Gas (CO_2) Emissions

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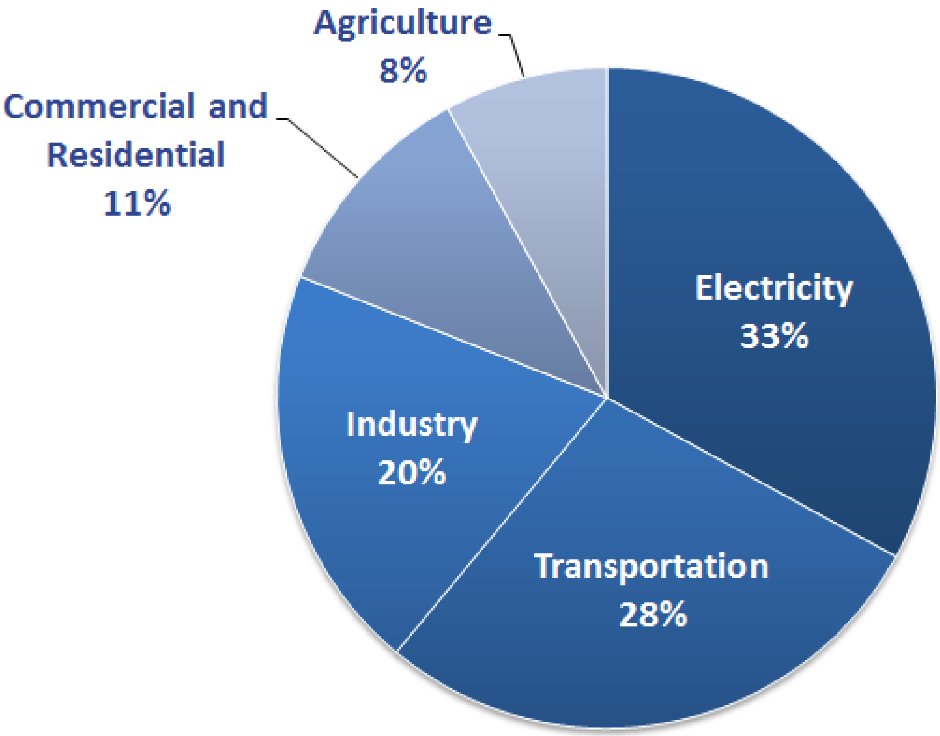
Greenhouse Gas & Climate Science Measurements
Program Review
01 August 2014

Preview:

- Research Objective
  - Stationary/Point Sources
- Measurement challenges:
  - Improving CO_2 emissions inventories
  - Improving stack gas flow measurements
  - Reconciling CO_2 emissions at the source
- Next Steps
- Take Away
  - NFRL is analogous to a stationary source
  - NFRL can be used to demonstrate best practices for achieving lower measurement uncertainty for CO_2 emissions

Stationary sources account for over 50% of GHG emissions.

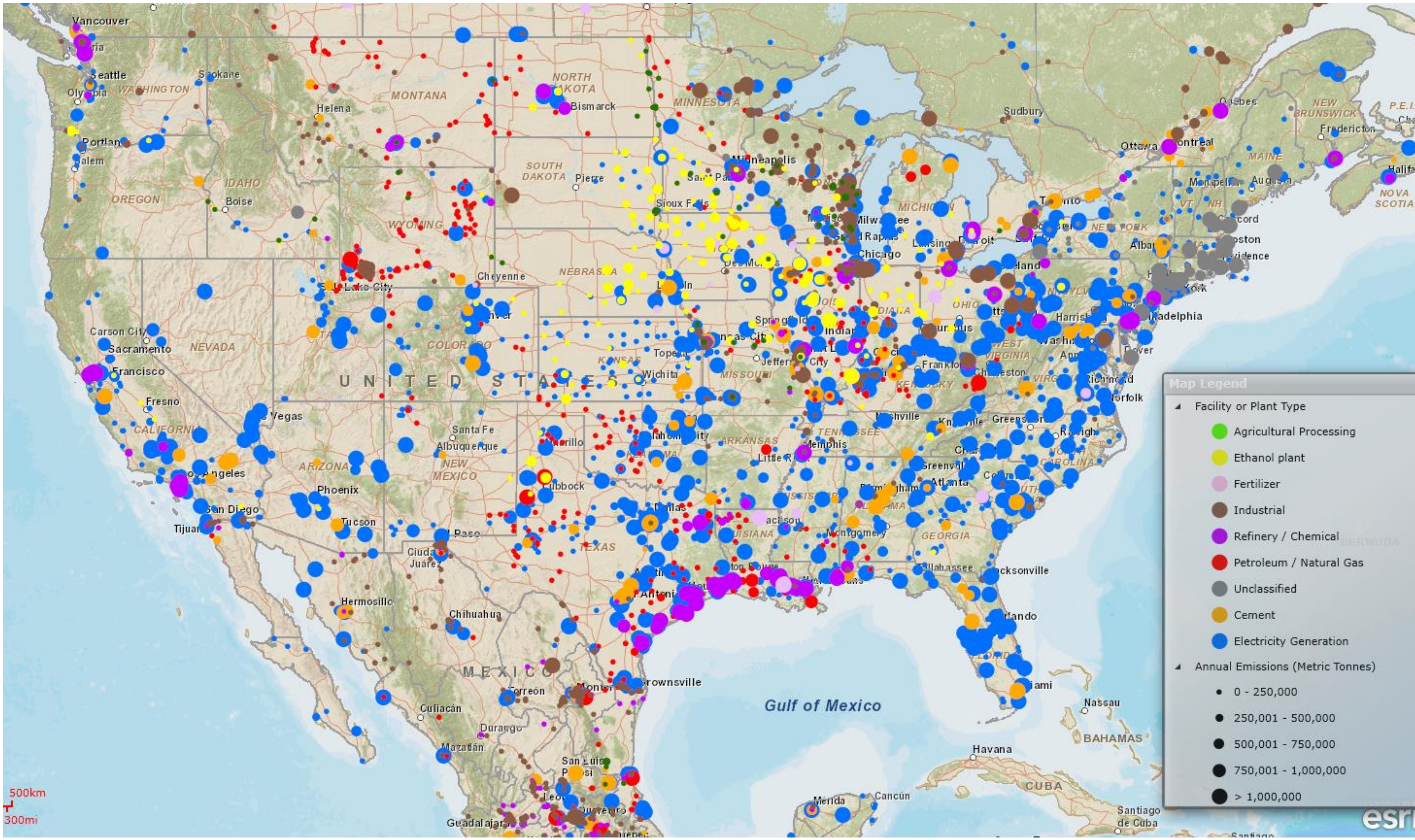


- 70% of electricity comes from fossil fuel combustion (coal and natural gas).

2011 Total Emissions = 6,702 Million Metric Tonnes of CO_2 Eq.
84% CO_2 emissions

Source: Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990 – 2011, EPA-430-R-13-001
http://www.epa.gov/climatechange/ghgemissions/sources.html

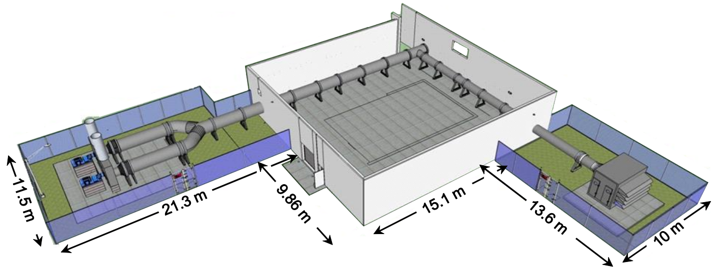
There are over 2000 stationary/point sources distributed throughout the United States.

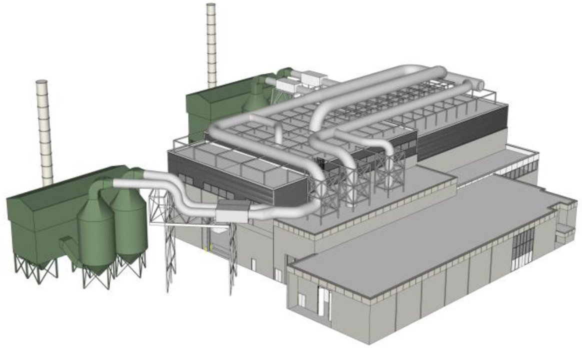


Source: North American Carbon Storage Atlas Partnership, http://gis.netl.doe.gov/NACAP/

Our objective is to enable better characterization of greenhouse gas emissions from stationary sources.

- Fossil-fuel burning stationary sources have a significant carbon footprint
- Sound scientific data is needed to determine if emissions targets are being met
- We plan to create well-characterized and highly accurate measurement test beds to address the challenges of CO_2 emissions measurements
  - The NIST Smokestack Simulator (NSS)
  - The National Fire Research Laboratory (NFRL)



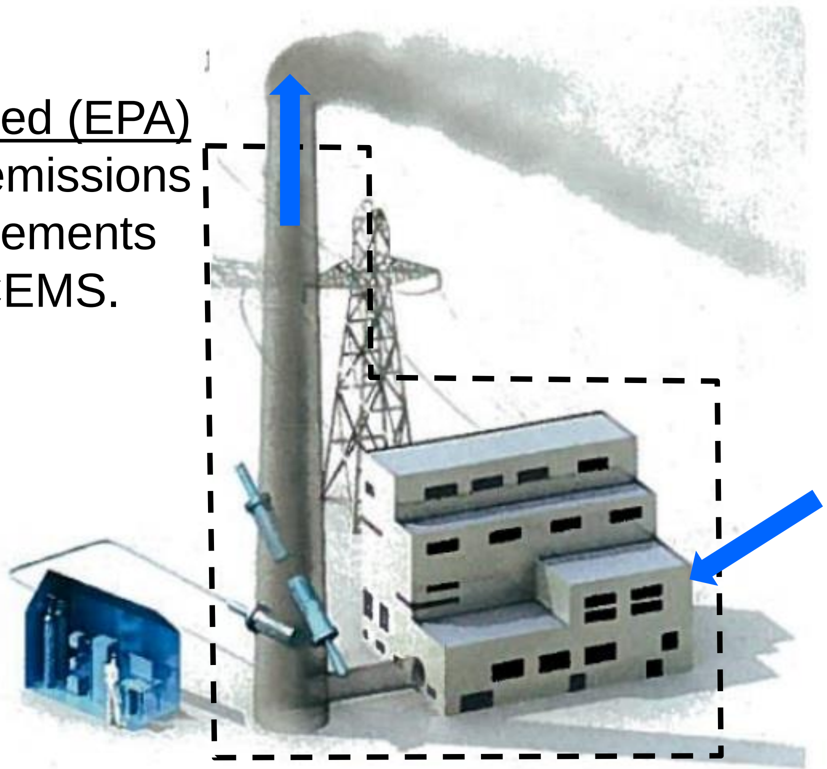


Measurement Challenge:
Improving CO_2 Emissions Inventories

It is possible to reconcile the CO_2 emissions at each stationary source.

Two accounting methods: Predicted Emissions = Measured Emissions

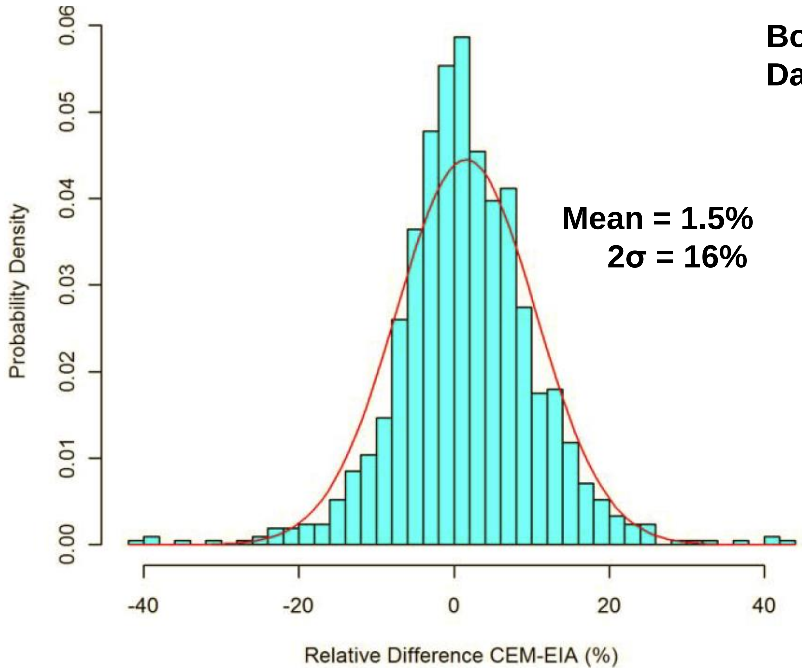
Measured (EPA)
Direct emissions measurements using CEMS.



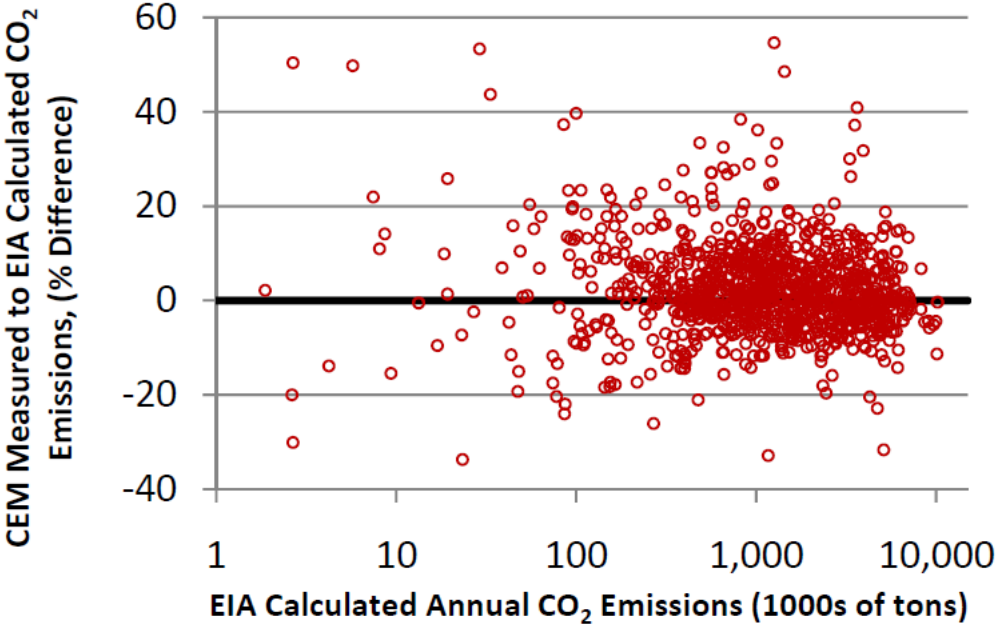
Predicted (EIA)
Computed from fuel consumption records and composition analysis.

Graphics courtesy of: N. Pearson, "The Carbon Numbers Game", Bloomberg Markets, v42, Jan 2011

Direct comparisons of the emissions databases reveal a wide distribution of the differences in CO_2 emissions.



Borthwick, et al., Examination of United States Carbon Dioxide Emission Databases, 2011.

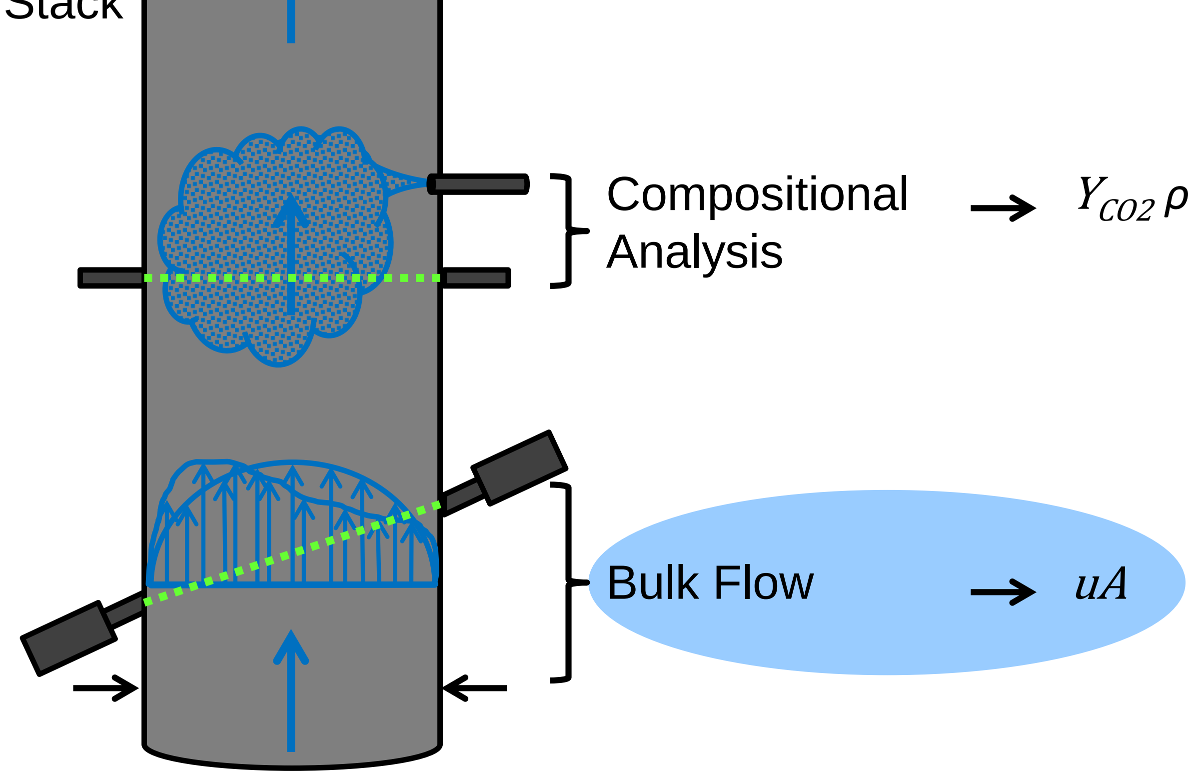


<u>Consistent w/similar studies:</u>
Ackerman & Sundquist, 2008
Quick, 2013

Measurement Challenge:
Improving Stack Gas Flow Measurements

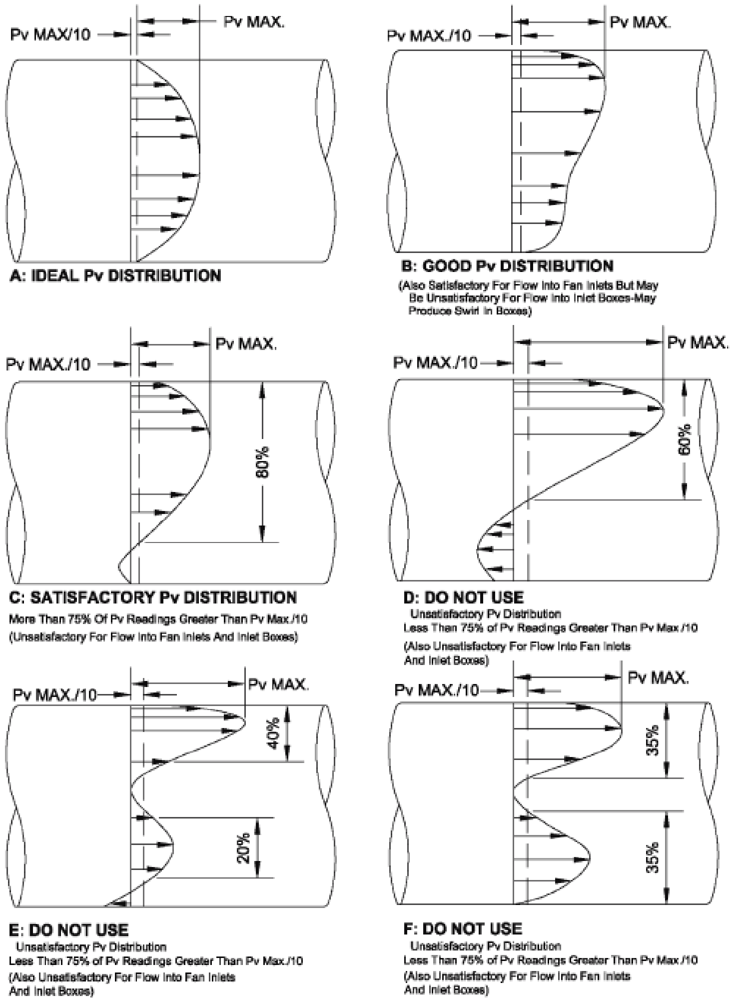
CEMS technology determines CO_2 emissions as the product of two measurements: CO_2 concentration and the bulk flow.

$$\dot{m}_{CO_2} = Y_{CO_2}\,\rho\,u\,A$$

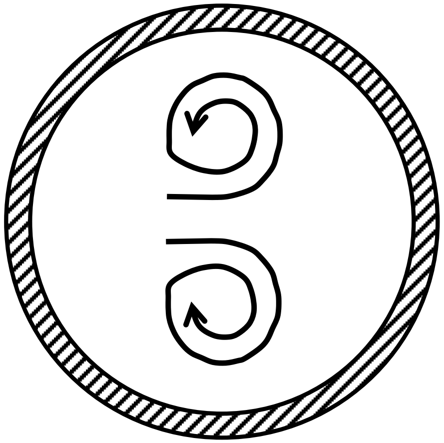


The “character” of the flow profile influences the accuracy of the flow measurement.

Asymmetry



Off-Axis Flow / Swirl

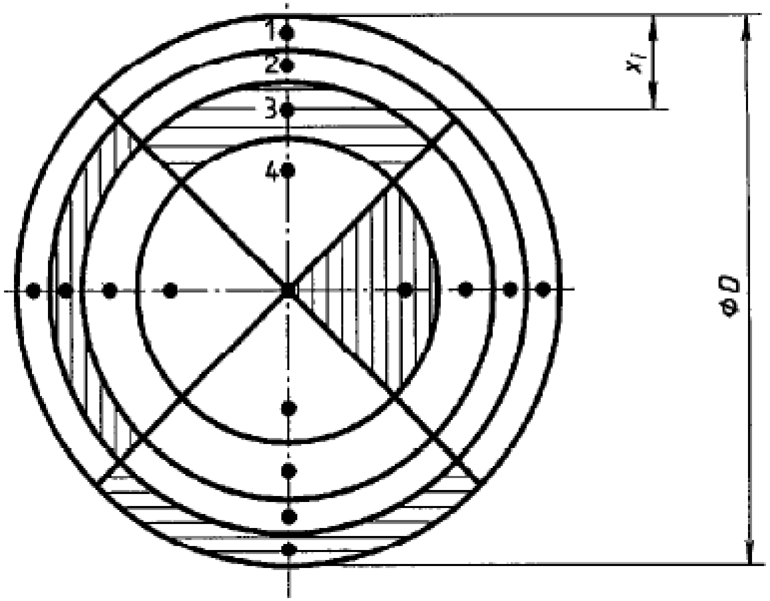


Source: ANSI/ASHRAE Standard 111-2008

EPA requires regular Relative Accuracy Test Audits (RATAs) of the CEMS on each stack.

Stack Testing Companies

Velocity Traverse



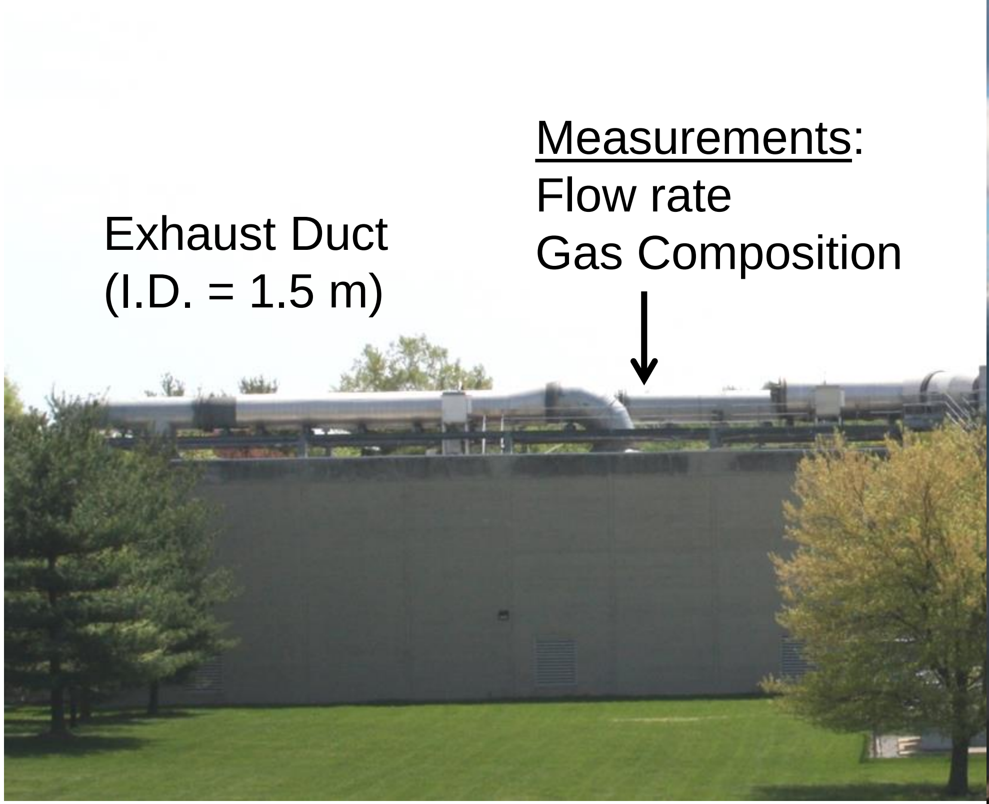
NOTE — The shaded portions are of equal area; *D* > 2 m.

Figure 6 — Sampling point positions in circular ducts — General rule

Source: ISO 10780:1994(E)

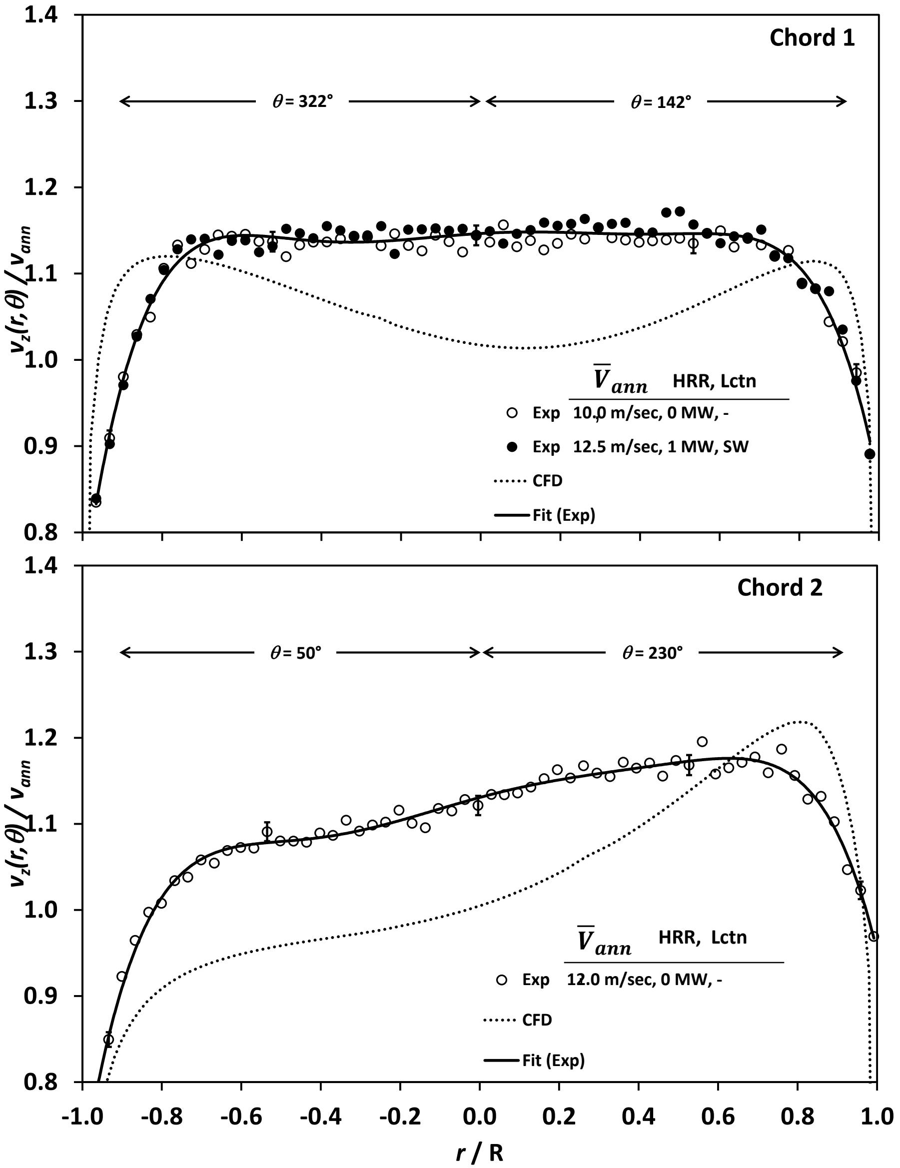
The Large Fire Research Laboratory is essentially a small-scale stationary source.

Large Fire Research Laboratory

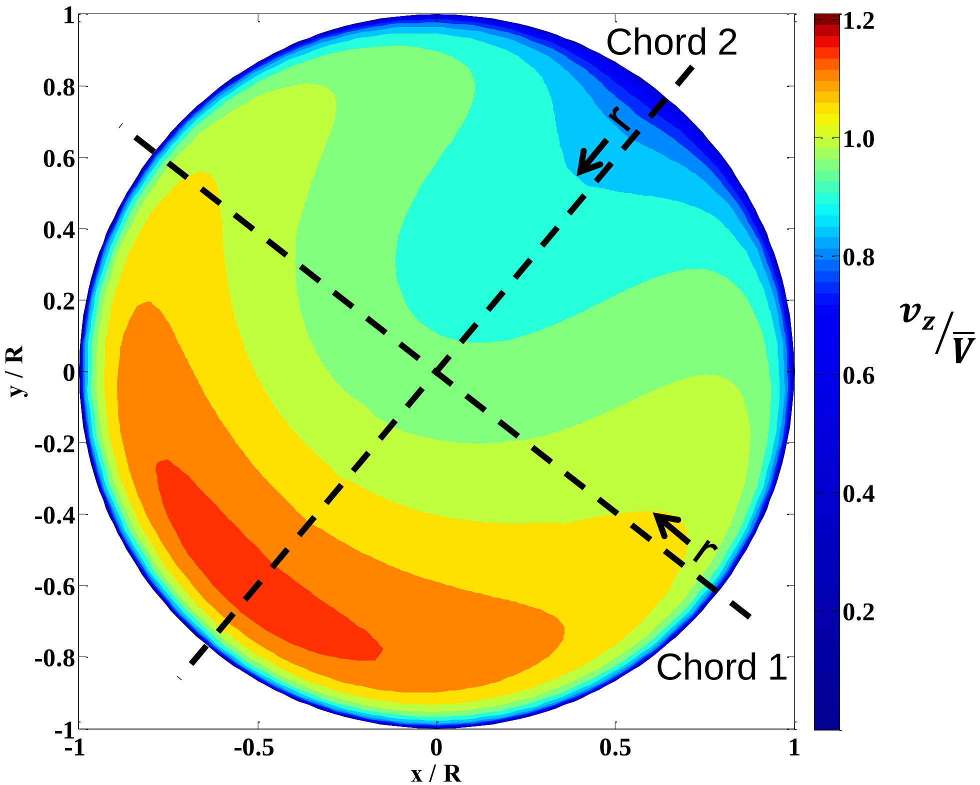


Following EPA procedures, we conducted our own flow RATA for the exhaust duct.

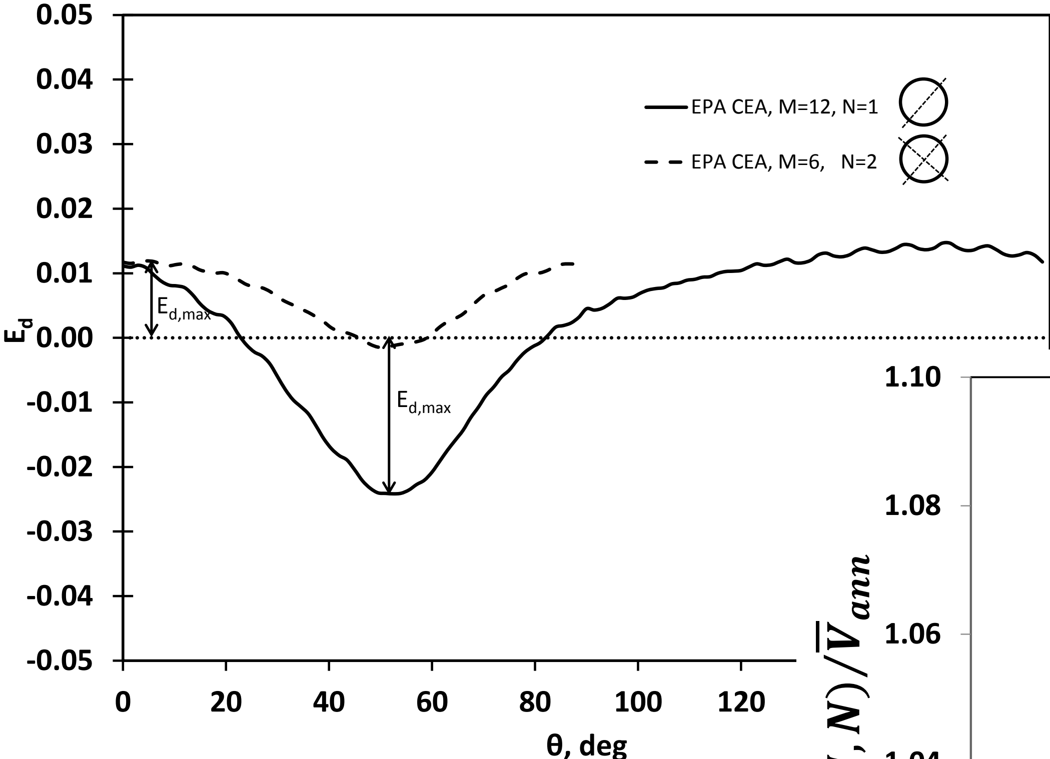
Experiments

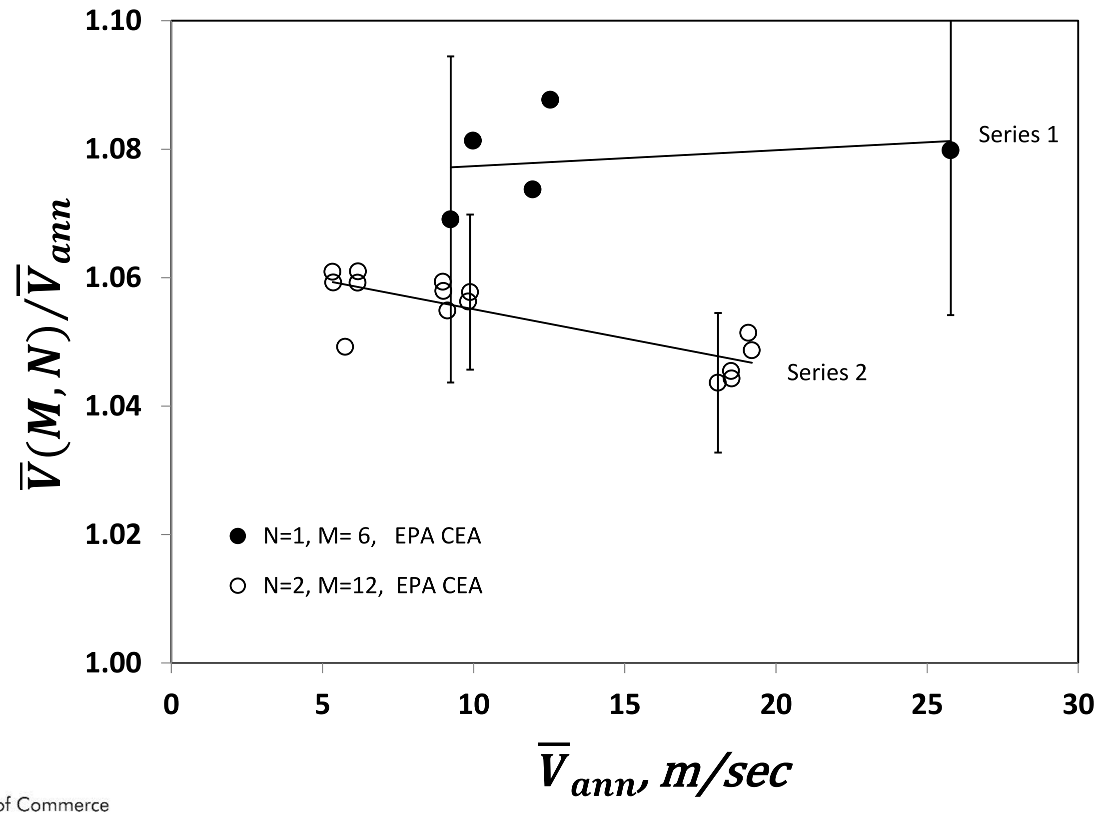


CFD Simulation



Demonstrated that lower measurement uncertainty is possible with careful measurements.





Bryant, et al., An Uncertainty Analysis of Mean Flow Velocity Measurements Used to Quantify Emissions from Stationary Sources, JAWMA, v64, 646-656, 2014.

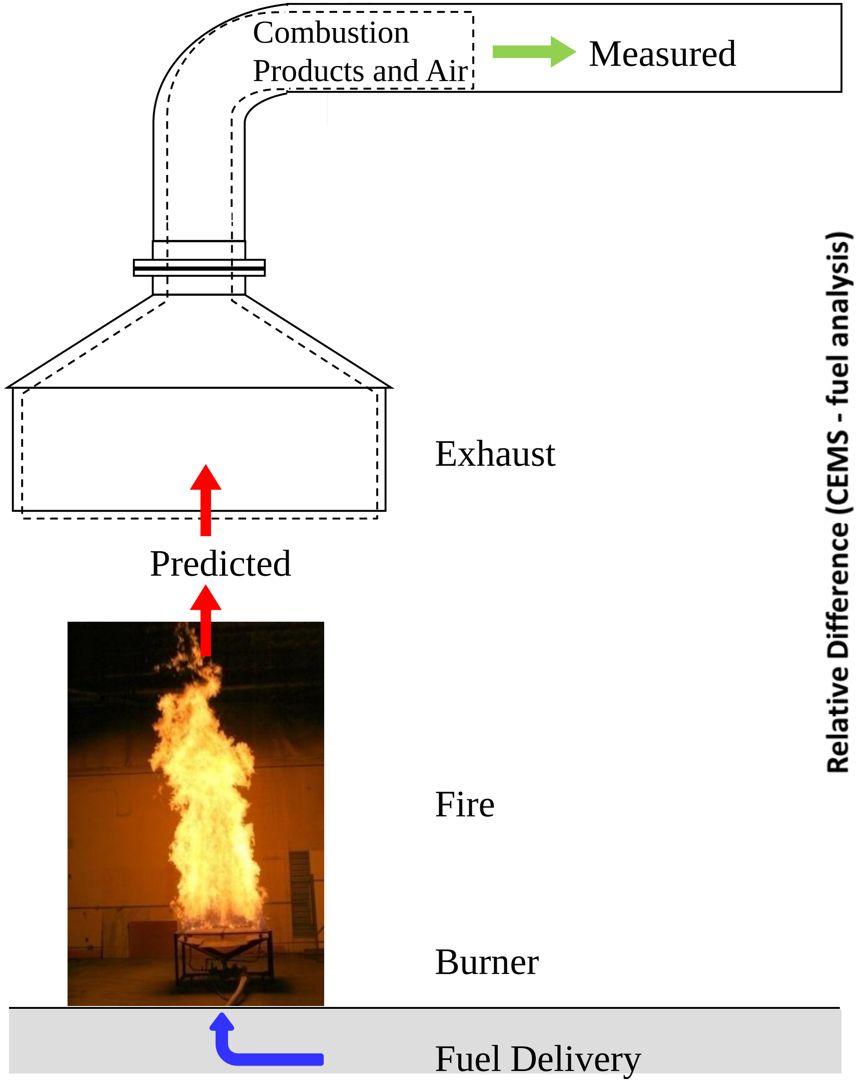
Measurement Challenge:
Reconciling CO_2 Emissions at the Source

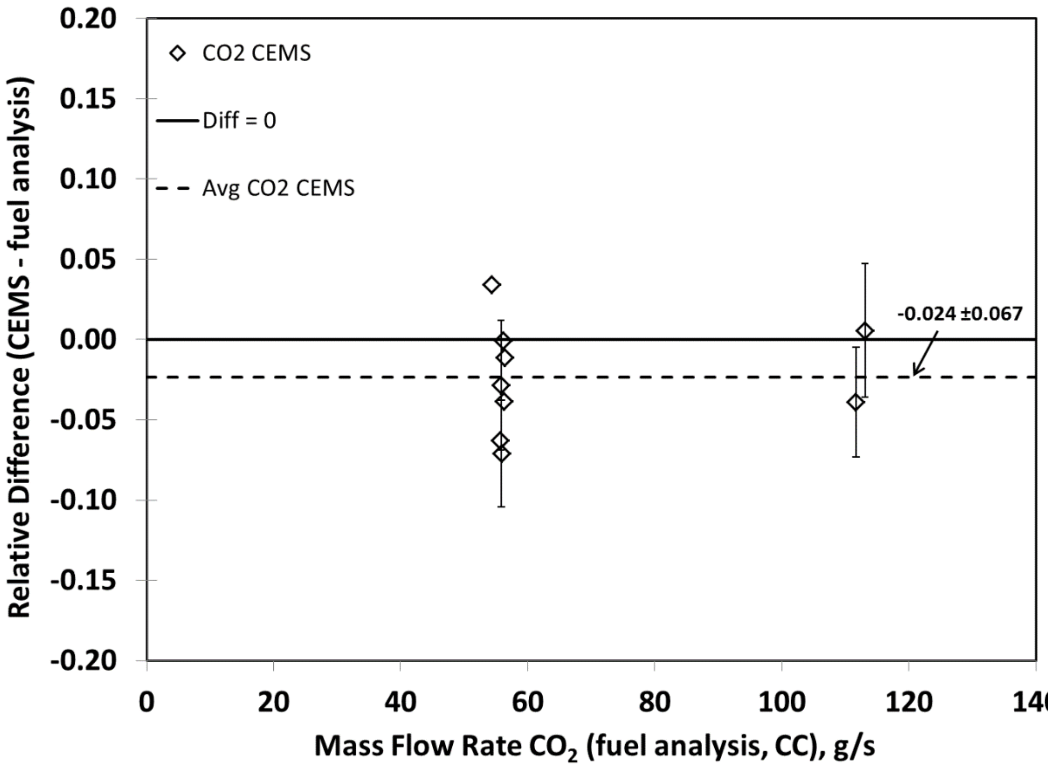
A well characterized natural gas delivery system and burner provides the capability to precisely generate large amounts of CO_2.

Natural Gas:

$$C_\alpha H_{2\alpha+2} + \frac{3\alpha+1}{2} O_2 \rightarrow \alpha CO_2 + (\alpha+1) H_2O$$

NFRL's measurement capabilities can be used to demonstrate a CO_2 mass balance at near industrial-scale.





CO_2 Mass In (Predicted) = CO_2 Mass Out (Measured)

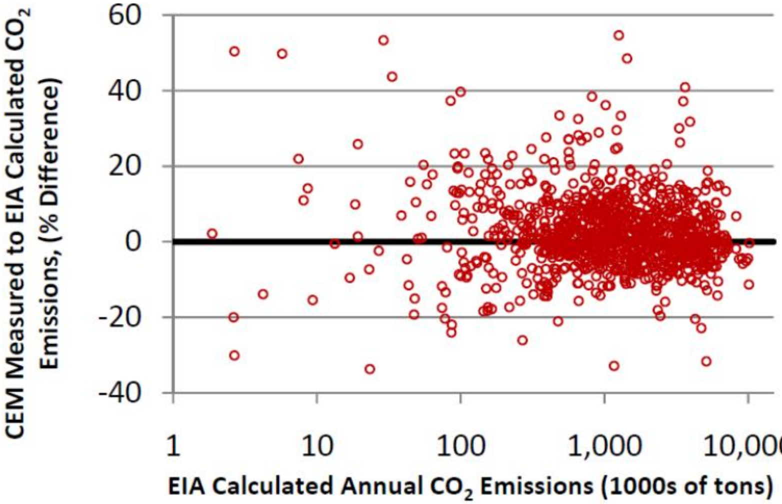
Next Steps

Establish the NFRL as a well-characterized and highly accurate test bed for CO_2 emissions measurements.

National Fire Research Laboratory

- Characterize the exhaust duct flows (flow RATAs)
- Establish a mass balance for CO_2 emissions for the facility
- Apply research results from the NIST Smokestack Simulator
- Provide test bed for new and existing stack mounted flow measurement technology

We plan to use the NFRL to demonstrate best practices to conduct CO_2 emissions measurements with uncertainty on the order of 1% to 2%.



Impacts

- Provides evidence of low uncertainty emissions measurements to stakeholders
  - Stationary Source Owners (EPRI)
  - Regulatory Agencies (EPA and State Environmental Agencies)
  - Testing Bodies (Source Evaluation Society)
- Accurate measurements of CO_2 emissions enables
  - Better assessments of greenhouse gas mitigation efforts
  - Future implementation of carbon controls (e.g., carbon tax, carbon credits)

Further Information

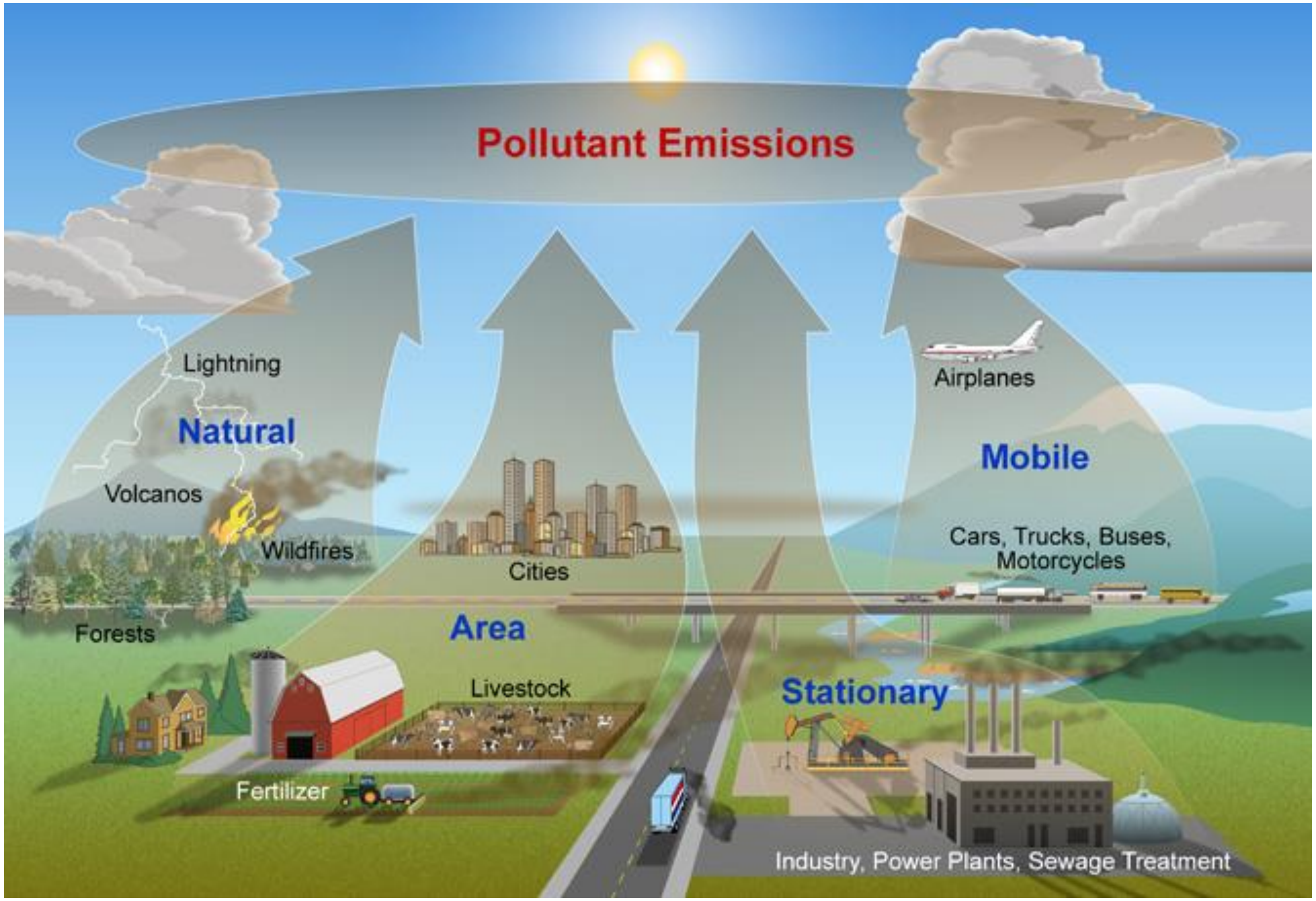
- Facilities:
  - http://www.nist.gov/el/fire_research/nfrl/index.cfm
  - http://www.nist.gov/pml/div685/grp02/smoke_stack_simulator.cfm

- Publications (http://www.nist.gov/publication-portal.cfm):

  - R. Bryant, O. Sanni, E. Moore, M. Bundy, and A. Johnson, An Uncertainty Analysis of Mean Flow Velocity Measurements Used to Quantify Emissions from Stationary Sources, Journal of the Air and Waste Management Association, v64 (6), pp 646-656, (2014),
  - R. Borthwick and M. Bundy, Quantification of a Precision Point Source for Generating Carbon Dioxide Emissions, EPRI CEM User Group Conference, 2011
  - R. Bryant, O. Sanni, E. Moore, R. Borthwick, M. Fernandez, I. Shinder, J. Yang, A. Johnson, Comparison of Gas Velocity Measurements in the Exhaust Duct of a Stationary Source, EPRI CEM User Group Conference, 2011
  - R. Borthwick, J. Whetstone, J. Yang, A. Possolo, Examination of United States Carbon Dioxide Emission Databases, EPRI CEM User Group Conference, 2011
  - A. Johnson, E. Harman, J. Boyd, Blow-Down Calibration of a Large 8 Path Ultrasonic Flow Meter under Quasi-Steady Flow Conditions, FLOMEKO, Paris, France, Sept. 2013
  - A. Johnson, J. Ricker, J. Boyd, Computational Fluid Dynamic (CFD) Investigation of NIST's Scale Model Smokestack Simulator, Measurement Science Conference, Anaheim, CA, March 19-23, 2012

Questions

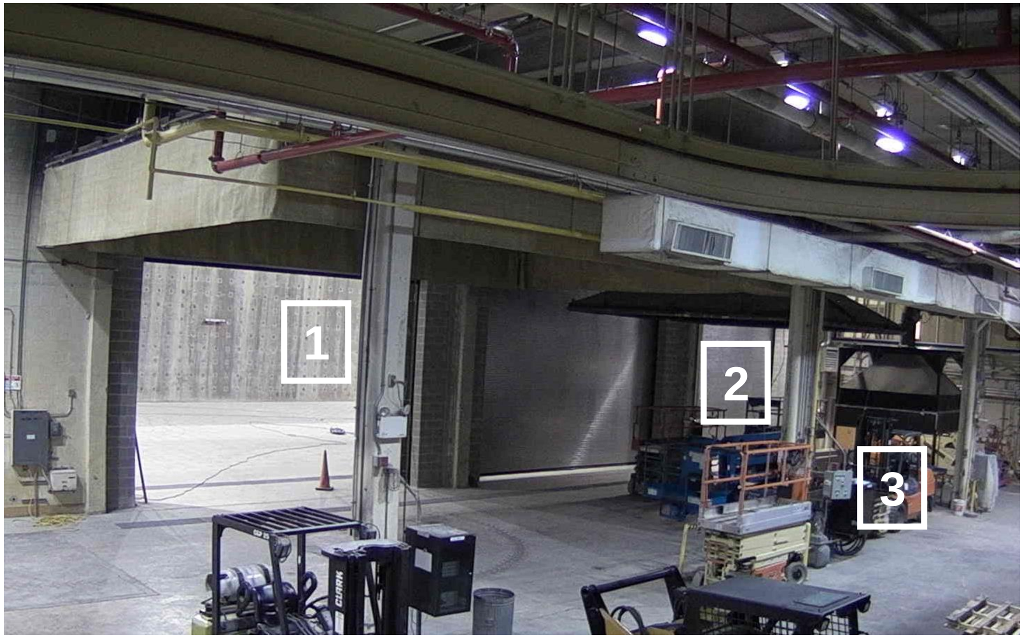
Stationary sources are facilities that burn fossil fuels to produce useful heat or energy.



Source: The National Parks Service, http://www.nature.nps.gov/air/aqbasics/sources.cfm

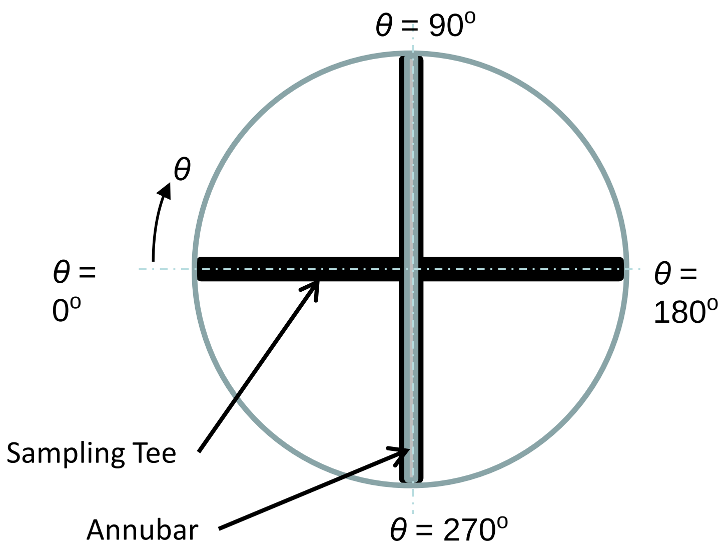
Capable of studying fires ranging from 50 kW to 20 MW; equipped with 4 exhaust hoods.

0.05 MW – 8 MW Fires



0.5 MW – 20 MW Fires

Averaging pitot tube (Annubar) is the flow measurement component of our continuous emissions monitoring system (CEMS).



- Annubar is the primary flow measurement for the exhaust duct
- Gas samples extracted at sampling tee for gas composition measurements (CO, CO_2, O_2, H_2O)

Photo Courtesy of Rosemount Inc.