COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
SUBCOMMITTEE ON RESEARCH AND TECHNOLOGY
SUBCOMMITTEE ON ENVIRONMENT
U.S. HOUSE OF REPRESENTATIVES

HEARING CHARTER

Assessing Federal Programs for Measuring Greenhouse Gas Sources and Sinks

Thursday, June 23, 2022
10:00 a.m.
2318 Rayburn House Office Building and Online via Zoom

Purpose

The purpose of this hearing to explore Federal programs focused on monitoring, measuring, and verifying sources and sinks of greenhouse gas emissions (GHGs). The Committee will examine data and measurement challenges as well as research gaps related to improving GHG monitoring, measurement, and verification. Finally, the Committee will discuss the measurement tools, methods, and standards that can enable industries and governments to have the information they need to manage emissions effectively and where Congress should focus efforts to improve GHG monitoring, measurement, and verification.

Witnesses

- **Dr. Eric K. Lin**, Director, Material Measurement Laboratory, National Institute of Standards and Technology
- **Dr. Ariel Stein**, Acting Director, Global Monitoring Laboratory and Director, Air Resources Laboratory, National Oceanic and Atmospheric Administration
- **Dr. Karen M. St. Germain**, Earth Science Division Director, Science Mission Directorate, National Aeronautics and Space Administration
- **Dr. Bryan Hubbell**, National Program Director for Air, Climate, and Energy, Office of Research and Development, United States Environmental Protection Agency

Overarching Questions

- What are the ongoing research and development (R&D) efforts related to GHG monitoring, measuring, and verification within and outside of the Federal Government?
- What are the current gaps in GHG monitoring, measuring, and verification research?
- What are opportunities for further federal investment in GHG monitoring, measuring, and verification efforts?
- What is the role of collaboration and coordination within the Federal Government and with non-federal entities in advancing GHG monitoring, measuring, and verification?

Background

Greenhouse gases (GHG) are gases which trap heat in the atmosphere and are a driving force of climate change. These gases can be emitted through anthropogenic and natural sources, and include carbon dioxide, methane, nitrous oxide, and other fluorinated gases. Of these gases, carbon dioxide is the most prevalent, making up 79% of 2020 U.S. emissions. GHGs are emitted from the combustion of fossil fuels, livestock and agricultural practices, manufacturing processes, and industrial activities. [1]

Greenhouse gas emissions are measured via several technologies, including observational tower, aircraft, and satellite measurements.[2] GHG measurements are broadly undertaken in two ways. One is through a ground source, or bottom-up approach, where the data is collected near the source of the emitter. Alternatively, a top-down approach collects data on a broad atmospheric level. This data can be utilized to determine an emitter, although the data is not collected directly from the emissions source.[3] Different measurement strategies are employed by federal agencies to collect various types of GHG data, further discussed in each agency section below.

The measurements of greenhouse gases can be used for a number of different activities and the method, scale, and type of measurement can affect how those measurements are used. Measurements that are conducted at a larger scale, such as atmospheric measurements or measurements at a regional level, can be used to constrain GHG emissions at the level of nation states. In turn, this information can be used to test and evaluate greenhouse gas inventories. This information can also be used to support compliance with international agreements and frameworks regarding greenhouse gas emissions. Measurements that are conducted at a smaller scale, such as measuring the emissions of individual wellheads, can be used to drive mitigation efforts such as fixing leaks or informing regulatory work. There can be overlap between these two types of measurements and they often are used in complementary ways.

The Global Warming Potential (GWP) compares the global warming impact of different gases.[4] Carbon dioxide is used as the reference for GWP and thus, has a GWP of 1.[5] Methane, nitrous oxides, and fluorinated gases all have significant GWP's, with fluorinated gases being the most substantial. GWP provides a common unit of measurement, which is essential for compiling national GHG inventories and comparison between emissions.[6]

Due to the harmful impacts of anthropogenic GHG emissions, there have been agreements at the international level to help curtail and regulate GHG emissions. The United States Nationally Determined Contribution (NDC) as part of the Paris Agreement, the most recent international agreement, sets an economy-wide target of reducing its net GHG emissions by 50-52 percent below 2005 levels in 2030.[7] The U.S. uses the *Inventory of U.S. Greenhouse Gas Emissions and Sinks*, produced by the EPA, as the quantifiable information.[8] The quantifiable information is used as the

[1] https://www.epa.gov/ghgemissions/overview-greenhouse-gases
[2] https://www.nist.gov/greenhouse-gas-measurements
[3] https://www.fs.fed.us/pnw/pubs/pnw_gtr906.pdf
[4]https://www.epa.gov/ghgemissions/understanding-global-warming-potentials
[5] Ibid.
[6] Ibid.
[7] https://unfccc.int/sites/default/files/NDC/2022-06/United%20States%20NDC%20April%2021%202021%20Final.pdf
[8] Ibid.

starting point, or baseline, and as part of the accounting mechanism for the U.S. NDC.[9]

Federal GHG Research and Development Activities[10]

Environmental Protection Agency (EPA)
The Environmental Protection Agency's Office of Research and Development (ORD) provides scientific and technical information on GHG measurements with a research focus on improving source emissions measurements for sources with uncertain or little GHG emissions data. ORD research supports EPA's regulatory and voluntary emissions reductions programs with ORD working closely with the Office of Air and Radiation (EPA OAR). EPA focuses on a bottom-up approach, analyzing ground-level sources of GHG emission. EPA OAR utilizes the data provided by ORD to contribute toward the *Inventory of U.S. Greenhouse Gas Emissions and Sinks*.[11] ORD collaborates with a variety of stakeholders including industry, state and local regulators, and communities as part of their Next Generation Emissions Measurement (NGEM) research team. These research approaches include novel mobile and remotely operated sensor technologies for GHG detections.[12] The EPA's *Greenhouse Gas Reporting Program* (GHGRP) collects further GHG emissions data from industries including power plants, refineries, waste companies, and chemical manufacturers. It requires that large GHG emissions sources report their GHG emissions data, and approximately 8,000 facilities report data which is compiled and released as an annual report.[13] EPA also has strong collaborations with other federal agencies to improve the understanding of GHG emissions from sources with uncertainties by closing the gap between bottom-up and top-down emissions estimates.

National Institutes of Standards and Technology (NIST)
The NIST Greenhouse Gas Measurement Program works to develop tools and standards for accurately measuring GHG emissions. A key component of this work is the measurement science research done at NIST. NIST has developed a greenhouse gas measurement framework to measure and map urban GHG emissions, using independent top-down and bottom-up measurements to calibrate each other. The top-down measurements are captured in coordination with NSF, NOAA, and the National Center for Atmospheric Research (NCAR) using ground-based observing networks and airborne measurements of atmospheric greenhouse gas concentrations. The bottom-up measurements are advanced greenhouse gas accounting methods focused on urban locations. To test this framework, NIST established Urban Test Beds throughout the United States in 2010. The agency currently operates three testbeds in the United States: one in Indianapolis, IN; one in the Los Angeles Air Basin; and one in Northeast Corridor, which starts in the Washington, DC/Baltimore regions.[14] The Northeast Corridor test bed will be extended up to Boston. These testbeds allow NIST to develop and evaluate the performance of advanced GHG measurement capabilities. NIST's observation networks allow for measurements at a finer scale, at the city level and sometimes down to the street level. This complements the observation done at larger scales by other federal agencies. NIST measurement science research can be used by a variety of

[9] https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks
[10] Note: Several federal agencies are involved in GHG R&D activities, including many outside of the Science Committee's jurisdiction. The information in this charter should not be considered an exhaustive list of all federal GHG R&D efforts.
[11] https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks
[12] https://www.epa.gov/air-research/next-generation-emission-measurement-ngem-research-fugitive-air-pollution
[13] https://www.epa.gov/ghgreporting
[14] https://www.nist.gov/greenhouse-gas-measurements/urban-test-beds

stakeholders including other federal agencies, state and local governments, and the private sector. By improving the accuracy of GHG emissions measurement and monitoring, this work will help stakeholders identify the best ways to reduce their GHG emissions.

In addition to the measurement science research, NIST's expertise in international standards is an important aspect of their GHG measurement work.[15] NIST has initiated the development of technical standards that will help support accuracy and transparency in GHG emissions measurements. NIST is also supporting the development of certified measurement standards, in collaboration with a number of partners, to ensure the consistency and accuracy of global GHG measurements. NIST also provides linkage traceable to the International System of Units to NOAA as the World Meteorological Organization's (WMO) Central Calibration Laboratory for GHG concentration measurements.

National Oceanic and Atmospheric Administration (NOAA)
The National Oceanic and Atmospheric Administration primarily conducts GHG emissions research activities through its Office of Oceanic and Atmospheric Research (NOAA OAR). NOAA's research laboratories conduct an integrated program of research, technology development, and services to improve the understanding of Earth's atmosphere, oceans, and inland waters, and to describe and predict changes occurring to them.[16] Within NOAA OAR, the Global Monitoring Laboratory (GML) provides high-precision measurements of the abundance and distribution of long-lived GHGs that are used to calculate global average concentrations.[17]

GML produces the Annual Greenhouse Gas Index (AGGI), which is a measure of the climate-warming influence of long-lived trace gases in the atmosphere and how that influence has changed since the onset of the industrial revolution.[18] Air samples are collected through the NOAA Global Greenhouse Gas Reference Network (GGRN), which provides samples from up to 80 global background air sites.[19] The GGRN also provides measurements of the atmospheric distribution and trends of the three main long-term drivers of climate change: carbon dioxide, methane, and nitrous oxide.[20] GML also performs reference measurements and research, maintains calibration scales and provides calibration services, top-down emission quantification, and satellite and model data evaluation. GML has observation facilities at the South Pole, the Artic Circle, American Samoa, and Mauna Loa. NOAA's Mauna Loa Atmospheric Baseline Observatory has collected carbon dioxide emissions since 1958 and has been essential in tracking global emissions. In 2021, carbon dioxide at Mauna Loa eclipsed 420 parts per million for the first time in human history.[21]

NOAA's Office of National Environmental Satellite Data and Information Service (NESDIS) collects raw data, including GHG emissions, from its constellation of weather and environment-monitoring satellites.[22] As part of NESDIS' data mission, the National Centers for Environmental Information (NCEI) host and provide access to comprehensive oceanic, atmospheric, and

[15] https://www.nist.gov/greenhouse-gas-measurements/international-activities
[16] https://gml.noaa.gov/
[17] Ibid.
[18] https://gml.noaa.gov/aggi/aggi.html
[19] Ibid.
[20] https://gml.noaa.gov/ccgg/ggrn.php
[21] https://keelingcurve.ucsd.edu/2022/05/31/2114/
[22] https://www.nesdis.noaa.gov/about/what-we-do

geophysical data.[23] NCEI manages the world's largest archive of climate and palaeoclimatological data, which was essential in providing the GHG emissions measurements prior to the inception of modern instrumental measurements.[24]

National Aeronautics and Space Administration (NASA)

NASA conducts GHG research activities through its Earth Science Division and the management of space-based, airborne, and ground-based measurement platforms. This work focuses on observation, measurement, and foundational science. The Orbiting Carbon Observatory 2 (OCO-2) is a remote sensing satellite that collects daily space-based global measurements of atmospheric carbon dioxide from a polar Earth orbit. These measurements allow for the characterization of sources and sinks on regional scales.[25] The Orbiting Carbon Observatory 3 (OCO-3), externally mounted on the International Space Station, consists of an identical instrument as OCO-2, that measures variations through the day in the release and uptake of carbon dioxide by plants and trees in mid-latitude urban areas and major tropical rainforests. These measurements help explain global variations in atmospheric carbon dioxide levels.[26] NASA's Carbon Monitoring System, which was initiated in 2010, sponsors project opportunities for research focused on developing carbon monitoring, reporting, and verification systems.[27] NASA is also planning future work to support GHG research activities. In May 2021, NASA announced the Earth System Observatory, a planned set of Earth-focused missions based on top-priority observations recommended by the decadal survey to provide information to guide efforts related to climate change, disaster mitigation, fighting forest fires, and improving real-time agricultural processes. This project is in the formulation phase.[28] NASA is also planning the Geostationary Carbon Cycle Observatory (GeoCarb), which would place an instrument on a satellite in geostationary orbit. GeoCarb, which is due to launch by the end of 2024, will collect 10 million daily observations of the concentrations of carbon dioxide, methane, carbon monoxide and solar-induced fluorescence (SIF)over North and South America.[29] In addition to the space-based and airborne observations, NASA also sponsors ground-based networks, such as the Advanced Global Atmospheric Gases Experiment (AGAGE). AGAGE is a network of 15 ground sensors supported by NASA, NOAA, and agencies in Europe and Asia that have measured greenhouse gases and other trace gases, like the types that contribute to ozone depletion, since 1978.[30] The Earth Science Division also engages in technology development work to make sensors smaller, cheaper, and easier to deploy.

Department of Energy (DOE)

DOE's Advanced Research Projects Agency-Energy's (ARPA-E) Methane Observation Networks with Innovative Technology to Obtain Reductions (MONITOR) program, which started in 2014, provided funding for the development of low-cost technologies to accurately locate and measure methane emissions associated with natural gas production.[31] Within DOE's Office of Fossil Energy

[23] https://www.ncei.noaa.gov/about
[24] For more information on palaeoclimatological practices, principles, and perspectives see here: https://www.ncei.noaa.gov/products/paleoclimatology/paleo-perspectives
[25] https://www.nasa.gov/mission_pages/oco2/overview
[26] https://ocov3.jpl.nasa.gov/mission/
[27] https://carbon.nasa.gov/pdfs/CMS_Phase-2_Report.pdf
[28] https://www.nasa.gov/press-release/new-nasa-earth-system-observatory-to-help-address-mitigate-climate-change
[29] https://eospso.nasa.gov/missions/geostationary-carbon-cycle-observatory-evm-2
[30] https://agage.mit.edu/about/our-mission
[31] https://arpa-e.energy.gov/technologies/programs/monitor

and Carbon Management, the Methane Mitigation Technologies Division works to eliminate non-trivial methane emissions from the oil and gas supply chain by 2030.[32] The National Energy Technology Laboratory at DOE supports research to address mitigation and quantification of methane emissions from fossil energy supply chains.[33] DOE's Methane Reduction Infrastructure Initiative provides technical assistance to Federal agencies, states, and tribes to assist with the clean-up of orphaned wells.[34]

Interagency Coordination

In January 2022, the White House announced the formation of a Greenhouse Gas Monitoring and Measurement Interagency Working Group. The IWG will help identify and develop tools and data systems to measure, monitor, report and verify carbon dioxide, methane, and other GHG emissions and removals. The IWG will work to develop a national GHG system to measure, monitor, report, and verify GHG emissions that will facilitate the dissemination of GHG data to end users. The IWG is co-led by the White House Office of Science and Technology Policy (OSTP), the Office of Management and Budget (OMB), and the White House Climate Policy Office.[35]

A number of other Federal agencies outside the Committee's jurisdiction also engage in GHG measurement research activities. The U.S. Department of Agriculture's Agricultural Research Service, the U.S. Geological Survey, the Department of Transportation, and the Federal Aviation Administration all contribute to this work though they are not the subject of this hearing.

Research Gaps and Opportunities

There are several areas of research underway to address some of the outstanding questions related to greenhouse gas measurement. One focus of research to improve GHG measurement and observation involves work to make sensors smaller, more accurate and more cost-effective. Work to improve the accuracy of sensors used for observations must also balance the cost and size of these instruments to ensure they can be used effectively. Additional research gaps include reducing data contamination between GHG sources and sinks, especially from sources difficult to pinpoint such as shipping and aviation.[36] Further, there are opportunities for increasing research related to reducing the emission gap, or the gap between recorded and reported GHG emissions. Streamlining best practices for researching natural carbon sinks like forests and bodies of water is another area for improvement. Improved standards can improve reporting of GHG emissions in the context of international agreements and provide a pathway for reduced emissions.[37]In increased collaboration and data sharing between federal agencies and the private sector could also help improve the quality of measurements. Pilot programs such as the collaboration between NOAA and Boeing to evaluate GHGs on commercial jets are an example of such collaboration.[38]

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[32] https://www.energy.gov/fecm/mission

[33]https://www.energy.gov/sites/default/files/202206/June%208%2C%202022%20HSST%20NETL%20Dr.%20Anderson%20Testimony%20on%20Methane%20Research%20Hearing.pdf

[34] https://www.whitehouse.gov/briefing-room/statements-releases/2022/01/31/fact-sheet-biden-administration-tackles-super-polluting-methane-emissions/

[35] https://www.whitehouse.gov/briefing-room/statements-releases/2022/01/31/fact-sheet-biden-administration-tackles-super-polluting-methane-emissions/

[36] https://www.washingtonpost.com/climate-environment/interactive/2021/greenhouse-gas-emissions-pledges-data/

[37] https://www.unep.org/resources/emissions-gap-report-2021

[38] https://research.noaa.gov/article/ArtMID/587/ArticleID/2763/NOAA-Boeing-team-up-to-test-greenhouse-gas-measuring-technology