

Testimony of

Eric K. Lin, Ph.D.
Director
Material Measurement Laboratory
National Institute of Standards and Technology
United States Department of Commerce

Before the

Committee on Science, Space, and Technology
Subcommittee on Environment
Subcommittee on Research and Technology

United States House of Representatives

*“Assessing Federal Programs for Measuring Greenhouse Gas Sources
and Sinks”*

June 23, 2022

Introduction

Chairwoman Stevens, Chairwoman Sherrill, Ranking Members Feenstra and Bice, and Members of the subcommittees, I am Dr. Eric Lin, Director of the Material Measurement Laboratory (MML) at the Department of Commerce's National Institute of Standards and Technology (NIST). Thank you for the opportunity to appear before you today to discuss NIST's role in greenhouse gas measurements. The NIST laboratory programs work at the frontiers of measurement science to ensure that the U.S. system of measurements is firmly grounded in sound scientific and technical principles. The NIST laboratories address complex measurement challenges ranging from the very small (nanoscale devices) to the very large (vehicles and cities), and from the physical (renewable energy sources and fossil fuel emissions) to the virtual (cybersecurity and cloud computing). As new technologies are developed and evolve, NIST's measurement research, standards, and services remain central to innovation, manufacturing, productivity, trade, and public safety.

NIST and Greenhouse Gas Measurements

NIST works with our federal partners through the Greenhouse Gas Monitoring & Measurement Interagency Working Group to coordinate existing capabilities and opportunities for enhancing measurement and quantification of greenhouse gas emissions and removals, with a goal of developing an operational greenhouse gas monitoring system that informs local to national-scale greenhouse gas emission mitigation efforts and assesses the effectiveness of greenhouse gas reduction policies. Coordination through this interagency working group is essential to maximize the impact of agency resources, enhance the Nation's ability to measure and monitor greenhouse gas emissions and removals, and accelerate the transition of relevant research capabilities to operational use.

As a global-scale example, NIST provides linkage for high-quality data that is traceable to the International System of Units (SI units; the international standard for measurement) to the National Oceanic and Atmospheric Administration (NOAA) as the World Meteorological Organization's Central Calibration Laboratory for greenhouse gas concentration measurements. NOAA disseminates standards to support ground, tower, and aircraft measurements of greenhouse gases (GHGs). These measurements are critical to keep track of sources (emissions into the atmosphere) and sinks (removal from the atmosphere) of GHGs around the world. The NOAA GHG network is also used to provide a direct link to remote measurements made by satellites such as NASA's Orbiting Carbon Observatories (OCOs). NIST works with NOAA to provide traceability of NOAA's primary greenhouse concentration standards to the International System of Units to strengthen global consistency of greenhouse gas measurements. NIST recently launched an ambitious project to develop a next-generation, continuous calibration system capable of extending SI traceability to both global satellite remote sensing and ground-based remote sensing platforms. If successful, this work will reduce the cost and complexity of satellite calibrations while improving accuracy and precision to 0.1 percent or better—a step on the path toward the World Meteorological Organization's ambitious goal of improving remote sensing of GHGs by a factor of 400.

On the ground, a portable frequency comb laser system developed as a research project by scientists and engineers from NIST and the University of Colorado Boulder detects minute methane emissions from oil and gas fields. The technology was commercialized by LongPath Technologies and is used by oil and gas producers to monitor their facilities for leaks. This project was originally funded by the Department of Energy's Advanced Research Projects Agency-Energy Methane Observation Networks with Innovative Technology to Obtain Reductions (MONITOR) program.

Among our federal partners, NIST is unique in its operation of dense observation networks for measuring greenhouse gases at the city level, and even down to the street and block. Our work complements that of our partner agencies with expertise in quantifying GHGs at the continental to regional scale.

NIST's work supports the Biden Administration's emphasis on transitioning demonstrated, key research capabilities to operational use, in order to generate and disseminate data and information on greenhouse gas emissions for use by mitigation policymakers and to inform local, regional and private-sector greenhouse gas mitigation efforts.

Support for Local Climate Action

The NIST mission is to promote U.S. innovation and industrial competitiveness by advancing measurement science, standards, and technology in ways that enhance economic security and improve our quality of life. It is fitting, therefore, that NIST's work supports the private sector and public-private partnerships working to mitigate climate change.

The Paris Agreement¹ recognized that locally implemented policies by cities and businesses are required to reduce greenhouse gas emissions. Occupying two to four percent of earth's land area, representing about 55 percent of domestic and global populations, and aggregating businesses, cities account for about 70 percent of greenhouse gas emissions.² Businesses play key roles at the local level as the main financiers, developers, implementers, and operators of specific mitigation, clean energy, and energy efficiency targets. Many national, state, local governments and businesses have stated yearly emissions reduction goals. Currently, U.S. cities are challenged to confidently determine whether those targets were being met. A recent NIST-funded study³ compared results from urban inventory protocol implementation in 48 U.S. cities with an atmospherically calibrated, U.S. emissions data product. The study showed differences ranging from about 60 percent over-reporting to about 140 percent under-reporting. This disparity illustrates the need for accurate and consistent methods of reporting. NIST is developing and

¹ <https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement>.

² IEA (2016), Energy Technology Perspectives 2016, OECD Publishing, Paris, https://doi.org/10.1787/energy_tech-2016-en.

³ Gurney, K.R. et al, "Under-reporting of greenhouse gas emissions in U.S. cities," *Nature Communications*, 12, Article number: 553 (2021). <http://dx.doi.org/10.1038/s41467-020-20871-0>

Schwartz, John, "U.S. Cities Are Vastly Undercounting Emissions, Researchers Find," *The New York Times*, Feb. 2, 2021. Accessed June 9, 2022: <https://www.nytimes.com/2021/02/02/climate/cities-greenhouse-gas-emissions.html>

demonstrating urban greenhouse gas emissions measurement methods to help improve existing goal tracking systems for states and local governments.

There is a need for equitable access to high-quality greenhouse gas monitoring systems to standardize the measurements—and, therefore, the data—that inform decision-making. NIST responds to that need with internationally recognized measurement capabilities and technical expertise to inform the development of new standards and has initiated efforts to establish technical international documentary standards.

The NIST Greenhouse Gas Measurements Program addresses the needs of businesses and governments at all levels, helping them measure, monitor, authenticate, and report greenhouse gas emissions in an accurate, transparent, and standardized manner. The methods developed by the program will help cities to demonstrate that their reductions are contributing to the Biden Administration's national greenhouse gas emissions reduction targets for the next 20 to 30 years.

An Innovative Measurement Framework

The NIST greenhouse gas measurement framework approach combines two independent methods to measure and map urban greenhouse gas emissions and removals, using one method to calibrate the other.

The top-down or atmospheric method measures and maps urban greenhouse gas emissions, in collaboration with the National Science Foundation and the National Center for Atmospheric Research, academia, and NOAA, by coupling highly accurate data from ground-based observing networks and airborne measurements of atmospheric greenhouse gas concentrations with numerical weather simulation and statistical optimization methods.

The bottom-up method uses advanced greenhouse gas accounting methods to provide fine-scale determination of urban greenhouse gas emissions locations. These maps account for fossil fuel emissions, biogenic sinks, and emissions associated with urban vegetation and agricultural and forested areas surrounding cities.

Urban Dome Testbeds

NIST established the Urban Greenhouse Gas Measurements Testbed System to demonstrate the feasibility and validity of this new measurement framework for cities. NIST operates testbeds in Indianapolis, the Los Angeles Air Basin, and the U.S. Northeast Corridor (beginning in the Washington, DC/Baltimore regions and extending to Boston over time). These testbeds encompass a range of meteorological, climatic, and emissions profiles meant to span U.S. urban topographic and meteorological conditions.

Recent measurements in the Indianapolis testbed demonstrated a better than 10 percent consistency between the top-down and bottom-up methods.⁴ Recent results in the Los Angeles and Northeast Corridor testbeds, using similar methods, detected and accurately quantified greenhouse gas reductions before and during the early months of the 2020 pandemic.

⁴ Lauvaux, T., et al., "Policy-relevant assessment of urban greenhouse gas emissions," *Environ. Sci. Technol.* 2020, 54, 16, 10237–10245: <https://doi.org/10.1021/acs.est.0c00343>.

Many governments and businesses have stated emissions reduction goals of 1 percent to 3 percent yearly. NIST's approach is to develop validated measurements and standards that are at least 10 times more accurate than the stated need, in this case 10 times less than 1 percent. The Urban Dome project measures and maps emissions at the street, block, or building level and at a time resolution of hours, days, weeks, seasons, and annual variations. Businesses and governments will then have the improved information they need for advancing timely and effective mitigation actions and science-based policy decisions.

NIST is working in partnership with government stakeholders at various levels and with the business, academic, and non-governmental organization communities to develop and provide mature, measurements-based scientific tools, methods, and data to estimate greenhouse gas emissions with high accuracy. These methods improve the means to track progress with the space and time resolutions required to guide evidence-based decision-making.

The validated tools, methods, and data disseminated will enable the identification of the most efficient and economically viable emission reduction opportunities in urban areas. Application of these tools before and after deployment of energy efficiency or alternative energy solutions can authenticate their effectiveness. Their application also has the potential for improved monitoring tools to enable validation and verification of the impacts of measures and policies that have historically been difficult to measure.

They also will provide a means of assessing the effectiveness of mitigation actions taken by other nations.

International Documentary Standards Development

The climate research community concerned with greenhouse gas measurements has advanced elements of measurement and emissions estimation capabilities to a level of maturity sufficient to support widespread usage. NIST has initiated a documentary standards effort aimed at advancing the implementation of mature, measurements-based, scientific tools and methods, together with associated data, based on the research community's best practices. New greenhouse gas technical documentary standards will support existing greenhouse gas emissions management standards promulgated by the International Organization for Standardization (ISO), specifically ISO 14064-1 to 3.⁵ NIST has initiated development of technical standards via the American National Standards Institute (ANSI) and ISO Technical Committee (TC) 207 – Environmental Management, Sub-committee (SC) 7 on Greenhouse Gas Management and Related Activities.

The effort will lead to the development of a series of technical measurement standards supporting transparency and accuracy for users globally. These technical standards—based on research community best practices currently nearing publication by the Integrated Global Greenhouse Gas Information System of the World Meteorological Organization's⁶ (WMO) Global Atmospheric Watch—are anticipated to improve data quality assurance of national

⁵ ISO TC 207, SC 7 Standards <https://www.iso.org/committee/546318/x/catalogue/>.

⁶ Integrated Global Greenhouse Gas Information System (IG³IS), An Integrated Global Greenhouse Gas Information System (IG3 IS) Science Implementation Plan, GAW Report No. 245, 2019: https://library.wmo.int/doc_num.php?explnum_id=10034.

greenhouse gas emissions reports from which all can judge progress toward national reduction targets.

A foundational element of worldwide atmospheric greenhouse gas observing strategies are the gas mixture concentration standards that are key to data accuracy in atmospheric greenhouse gas emissions estimation methods. Expanded development of certified measurement standards will be undertaken, in collaboration with the BIPM⁷ and the international metrology community, NOAA, the WMO, and the specialty gas industry, to ensure the consistency and accuracy of atmospheric greenhouse gas measurements globally.

Other areas in which collaboration with other agencies and partners can enhance GHG measurements and monitoring include:

Linking Surface Emissions Measurements to Satellite Observations

To address the complexities of integrating greenhouse gas concentration data with that observed from low Earth orbiting and geosynchronous Earth orbiting satellites, NIST will utilize its Urban Dome Testbeds. Successful linkage of atmospheric greenhouse gas concentration data obtained from testbed surface and aircraft networks to airborne and satellite remote sensing data can enhance comprehensive measurement and monitoring coverage domestically. Observations of atmospheric GHG concentrations through the entire atmospheric depth by satellite instruments linked to surface-determined emissions would enhance U.S. coverage using atmospheric methods. Completion of NIST's Northeast Corridor testbed in a region with multiple overpasses by U.S. satellites and those of other nations will extend U.S. measurement capacity over a range of emissions and socioeconomic conditions. Collaborating with the satellite and associated research communities to advance such measurements will provide the means to achieve domestic coverage and will provide an independent means of assessing bottom-up emissions data.

Fossil Fuel and Biogenic Emissions/Uptake Modeling for Bottom-Up Estimation

Urban climate change mitigation efforts are focused on reducing methane and fossil fuel CO₂ combustion emissions. However, vegetation and wetlands in cities complicate measurements of urban methane and CO₂ emissions and make it difficult to identify their sources. In addition, these biospheric processes add complexity to quantification of anthropogenic CO₂ emissions at the urban scale. Vegetative CO₂ emission can be as strong as fossil fuel emission, especially during the growing season. Similarly, methane emissions from biogenic sources like landfills and urban wetlands are significant contributors to urban emissions. To more confidently attribute urban and regional methane and CO₂ emissions to specific sources, the community needs advances in biospheric modeling.

NIST will expand its capabilities in both fossil fuel and biogenic emission modeling and partner with leading experts to improve modeling tool performance and assess results in NIST testbeds and those of others. NIST will strengthen its data science capabilities to harmonize currently disparate fossil fuel emissions estimation methodologies and advance modeling tools by establishing standards and guidelines. Expanded urban vegetation measurements will be used to improve modeling of vegetative processes and improve the calibration of satellite instruments.

⁷ The International Bureau of Weights and Measures (BIPM): <https://www.bipm.org/en/about-us/>.

Measurements and Models for Top-Down Methods

Measurement and modeling advances will also improve greenhouse gas emissions mapping and accuracy. For example, measuring atmospheric greenhouse gas concentration change with altitude due to dispersal and mixing in and above the atmospheric boundary layer will fill a measurement and modeling gap. By better describing vertical atmospheric concentration gradients, the accuracy of path averaged concentration data from satellite instruments will improve. These, coupled with advances in statistical inference methods, bottom-up emission analyses, and radiocarbon measurements will improve spatial resolution for local and urban applications.

Concentration Gradient Measurement: Atmospheric greenhouse gas concentrations change substantially from the surface to the top of the atmosphere and vary with local meteorological conditions. Satellites sense greenhouse gases through the entire atmospheric column and use analyses resulting in path averaged concentrations that employ initial gradient estimates from global models. Periodic instrumented aircraft flights sampling from the surface to near the atmospheric center provide data for these models. Surface observing networks sample the atmosphere from communication towers and building roofs at fixed altitudes and locations. Accurate means to relate the point measurements of surface networks to averaged values from aircraft and particularly satellites will improve emissions measurement accuracy. In concert with the next-generation, continuous calibration system mentioned above to extend SI traceability to both global satellite remote sensing and ground-based remote sensing platforms, NIST is developing methods to measure atmospheric greenhouse gas gradients from the surface to near the top of the atmosphere using a near-vertical beam⁸. Acceleration of this research will result in real-time gradient measurement capabilities that can be operationalized. Along with solar viewing spectrometers and Doppler Lidars located across the U.S. at overpass locations, path averaged data accuracy will be improved.

Radiocarbon Measurements: It is challenging to differentiate CO₂ emitted from fossil fuel combustion from CO₂ emitted by live vegetation as part of the growth process. Radiocarbon dating and modelling of biogenic processes are helpful, but the availability of data from these methods is currently severely limited due to sample measurement expense and scarcity. Recent NIST research has demonstrated bench-scale optical methods of absolute radiocarbon measurement that is much less costly than the current mainstay method, accelerator mass spectrometry. Advancing development and demonstration of these technologies will aid in transferring them to private sector providers of radiocarbon data, significantly expanding availability to the atmospheric greenhouse gas measurement community, as well as to other user sectors, such as those measuring carbon footprints.

Conclusion

Accurate and consistent greenhouse gas emissions data is essential for the success of climate actions and mitigation decisions as the United States and other nations around the world seek to achieve ambitious goals to reduce the impacts of climate change. Ensuring measurement

⁸ Wagner, GA and Plusquellic, DF, "Multi-frequency differential absorption LIDAR system for remote sensing of CO₂ and H₂O near 1.6 μm," Optics Express, Vol. 26, Issue 15, pp. 19420-19434 (2018). <https://doi.org/10.1364/OE.26.019420>

accuracy and consistency is a fundamental challenge on par with that of economic data. NIST continues to build on its world-leading scientific achievements to secure for the U.S. a position of international leadership in this vitally important global effort. NIST's statutory role as the U.S. National Metrology Institute, and its role to promote accurate national and international standards, are fully aligned with the Biden Administration's priority to achieve net-zero global emissions by 2050, and advance the means needed for all nations to provide scientifically based emissions data and reports to measure progress toward reducing the impacts of the climate crisis.

Thank you for the opportunity to testify today. I would be happy to answer any questions you may have.

Eric K. Lin

Director, Material Measurement Laboratory

Dr. Eric K. Lin serves as the Director of the Material Measurement Laboratory (MML) at the National Institute of Standards and Technology (NIST). MML has more than 900 staff members and visiting scientists and serves as the nation's reference laboratory for measurements in the chemical, biological and materials sciences. MML activities include fundamental research in the composition, structure and properties of industrial, biological, and environmental materials and processes, to the development and dissemination of certified reference materials, critically evaluated data and other measurement quality assurance programs. MML serves a broad range of industry sectors ranging from transportation to biotechnology, and provides research, measurement services and quality assurance tools for addressing problems of national importance ranging from developing tools to shorten the time-to-discovery of new materials, to the investigation of new sources of renewable energy, to improved diagnostics and therapies for health care.



Lin received a B.S.E. from Princeton University, and Masters and Ph.D. degrees in chemical engineering from Stanford University.