

Testimony of
Patrick D. Gallagher, Ph.D.
Deputy Director

National Institute of Standards and Technology
United States Department of Commerce

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“Monitoring, Measurement and Verification of
Greenhouse Gas Emissions II: The Role of Federal
and Academic Research and Monitoring Programs”

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Good morning Chairman Gordon, Ranking Member Hall and Members of the Committee. Thank you for the opportunity to appear before you today to discuss the National Institute of Standards and Technology's (NIST's) role and interactions with other Federal agencies in the measurement, monitoring, and verification of greenhouse gas emissions. The NIST Laboratories, with core competencies in measurement science, traceability, fundamental data, and standards development and dissemination, have a long history of supporting the measurements needed for climate change research and greenhouse gas emission monitoring carried out by other federal agencies, including the Environmental Protection Agency (EPA), the National Aeronautics and Space Administration (NASA), and the National Oceanic and Atmospheric Administration (NOAA), all of which are represented here today.

Overview of NIST's Role

Today, I will discuss how NIST works to identify the necessary measurement requirements needed to accurately assess not only baseline inventories of greenhouse gases important to understanding climate change but also for supporting the implementation of greenhouse gas mitigation policies. Climate change measurements require high accuracy, excellent comparability, and exceptional stability to meet the stringent requirements for detecting changes in the Earth's climate over long time scales. Rigorous traceability of measurements to the International System of Units (SI) is essential for meeting these requirements and for providing a firm scientific basis for policy decisions. NIST's role in working with the climate change research community to help meet traceability requirements is well recognized and has been highlighted, for example, in the strategic plan for the U.S. Climate Change Science Program:

“... Instrument calibration, characterization, and stability become paramount considerations. Instruments must be tied to national and international standards such as those provided by the National Institute of Standards and Technology (NIST)...”

The NIST laboratory programs support those in other Federal agencies involved in climate change monitoring activities, which include NASA, NOAA, and EPA represented here today as well as DOE, USGS, USDA, and NSF. The NIST laboratories provide the measurement science, measurement traceability, production and dissemination of fundamental data, and standards development and dissemination (both artifact and documentary) to support other government agencies and their satellite, air, and surface¹-based measurement programs by ensuring the accuracy, comparability, and stability of their data.

By federal statute NIST is the National Measurement Institute (NMI) of the United States responsible for national standards of measurement and for their compatibility, within the SI framework, with the standards of other nations. To achieve international compatibility in measurement, NIST works with its counterpart NMIs in other countries. These government-established entities exist in nearly every industrialized nation. NIST's advancement, maintenance, and dissemination of base SI units (length, mass, time,

¹ Surface denotes both land and ocean.

electric current, temperature, amount of substance, and luminous intensity) and a growing number of derived units underpin private-sector investments in measurement technology and standards. The measurement foundation laid by NIST provides the necessary means for assessing the quality of measurements made daily during the design, production, inspection, and sale of goods and services. They provide benchmark references for so-called second and third-tier suppliers of measurement services, including private-sector test and calibration laboratories, manufacturers of measurement tools and control systems, and the businesses that rely on these services and tools.

The international community, through the 23rd General Conference on Weights and Measures, has acknowledged the importance of SI traceable measurements to monitor climate change (2007)² through:

- the expansion in the number of international and national initiatives to address the challenges and implications of climate change for the world,
- working arrangements between the International Committee for Weights and Measures (CIPM) and the United Nation's World Meteorological Organization (WMO),
- the increasing importance of optical radiation measurements and physico-chemical measurements of air, ground-based as well as air-borne, and physico-chemical measurements of ocean water, which support research into the understanding of the causes and impacts of climate change, and
- the importance of basing long-term measurements which relate to climate change on the stable references of the SI.

Through international agreements, measurement results traceable to different NMIs can be accepted across international borders, thereby improving transaction efficiency and eliminating potential regulatory burdens and technical barriers to international trade.

NIST's Measurement Science and Standards Role in Assessing Climate Change

Predicting the Earth's future climate and monitoring the effects of climate change depend upon highly accurate, comparable, and stable measurements that are often made by a variety of organizations, instruments, and nations over decades or longer time scales and need to be integrated. Thus, traceability of a range of measurements to international standards with known uncertainties is critical for assessing accuracy and quality. Accurate SI-traceable climate change measurements provide confidence in measured and predicted climate change trends and aid the development and assessment of mitigation strategies.

There are unique challenges in climate monitoring associated with measurements from space, air, and surface¹-sensors. Climate change monitoring has more stringent measurement requirements than those for weather forecasting. Strategies are required to improve the accuracy and stability of weather-forecast measurements to enhance their utility for climate monitoring and prediction. A 2006 workshop on Achieving Satellite

² <http://www1.bipm.org/en/CGPM/db/23/11/>

Instrument Calibration for Climate Change (ASIC³), sponsored by NIST, NOAA, NASA and others, highlighted the challenges of using weather satellites for climate monitoring. Many of the challenges have also been highlighted in the 2004 NRC report, “Climate Data Records from Environmental Satellites.” This report stresses sensor accuracy, characterization, uncertainty analysis, interagency collaboration, and continued reanalysis of climate data records. Furthermore, satellite programs within NASA and NOAA generally have requirements that the prelaunch calibration be tied to international standards based on the SI system of units. The WMO affirmed this goal by stating in one of the twenty Global Climate Observing System (GCOS) Climate Monitoring Principles⁴ that “Rigorous pre-launch instrument characterization and calibration, including radiance confirmation against an international radiance scale provided by a national metrology institute, should be ensured.” Airborne- and surface-based measurements likewise need such traceability to help validate and calibrate satellite measurements and provide comparability with satellite measurements when integrated into climate data records.

NIST’s role is in addressing the unique challenges associated with satellite remote sensing by developing the appropriate standards, calibration and characterization methods, and creating the tools to analyze measurement uncertainties. NIST’s role is important not only to government satellite programs but also to the commercial satellite industry and various civilian and government programs that depend on remote sensing measurements and data. The NIST laboratories possess unique measurement science capabilities needed to address the demanding accuracy of remote sensing for climate change monitoring. Specialized laser facilities, radiometers, and optical radiation sources developed at NIST tie measurements performed by satellite sensors to fundamental standards traceable to SI units. To ensure the quality of NIST standards and of climate change measurements tied to these standards, NIST participates in measurement comparisons with the climate change research community and with national standards laboratories around the world. Current NIST research is lowering the uncertainties on fundamental standards to meet the increasingly stringent measurement requirements for climate research. The requirements for such measurements are defined through our collaborations with NASA, NOAA, USGS in their satellite-based climate change research and monitoring programs.

NIST’s Role in Supporting Mitigation Efforts

Rigorous and traceable measurements will also be needed to support and implement any climate change mitigation strategy. Recently, various approaches for mitigating greenhouse gas emissions have been proposed. Many proposals are modeled on the successful 15-year-old cap-and-trade system for industrial sulfur emissions within the U.S.,⁵ which enabled the reduction of sulfur dioxide emissions by approximately 30%

³ *Achieving Satellite Instrument Calibration for Climate Change (ASIC³)*, edited by G. Ohring, available at <http://www.star.nesdis.noaa.gov/star/documents/ASIC3-071218-webversfinal.pdf>.

⁴ The complete set of Global Climate Monitoring Principles are found at <http://www.wmo.int/pages/prog/gcos/index.php?name=monitoringprinciples>.

⁵ Clean Air Act of 1990, Public Law 101-549, <http://thomas.loc.gov/cgi-bin/bdquery/z?d101:SN01630:%7CTOM:/bss/d101query.html%7C>

relative to 1980 levels. The sulfur dioxide program focused on the relatively small number of electricity generating plants in the central U.S. It is based upon:

- emission source monitoring, with support from NIST measurement standards,^{6,7}
- the use of SO₂ mitigation technologies, and
- energy efficiency improvements by users.

NIST's primary role in the sulfur dioxide emissions program was to provide measurement traceability to the SI for cylinder gas standards used to calibrate emission stack monitors. This was accomplished by supplying calibrated gases through our establishment of the NIST-Traceable Reference Materials (NTRM) program in conjunction with the private sector.

Confidence in greenhouse gas mitigation policies also depend on accurate measurements of greenhouse gases. Accurate measurements of all greenhouse gas emissions are critical for establishing emission baselines, monitoring compliance, and verifying performance of other policies and offset or project-based approaches. Measurement strategies are strongly influenced by the nature of the greenhouse gas emission, e.g., CO₂ emissions are generated by many economic sectors ranging from power generation and manufacturing to transportation vehicles and residential heating to land use and land use change, but methane, with a global warming potential 25 times that of CO₂, is emitted primarily from landfills, the transport and use of natural gas, livestock production, and coal mining⁸. The geographical characteristics of greenhouse gas emissions also vary from localized point sources, such as electricity generation and manufacturing plants, to those that span a broad spatial scale, such as landfills and agriculture. Advances in measurement science can provide new and additional scientifically credible metrics to support implementation of effective policies to reduce greenhouse gas emissions.

Measurement capabilities necessary to support a robust and effective greenhouse gas mitigation program will also rely on various technological approaches. Since CO₂ and other greenhouse gas emissions are generated from a wide number of economic sectors, the range of greenhouse gas measurement and estimation capabilities range from established technologies, such as commercially available continuous emission monitoring instruments that are often used for large point source emission quantification (and are a mainstay of the successful sulfur emissions cap-and-trade system), to approaches to estimate emissions as a function of levels of activity or production. Indeed some quantification systems, such as the continuous monitoring of extended geographical areas, are currently not available.

Although the measurement and estimation requirements to implement greenhouse gas reduction policies are still being defined, NIST, as the Nation's NMI, offers unique capabilities to support such policies through its measurement science mission and expertise. Such support includes measurement science research, sensor calibration, artifact and chemical standards, documentary standards, fundamental data, and laboratory

⁶ S.A. Martin, et al., *Economic Impact of Standard Reference Materials for Sulfur in Fossil Fuel*, <http://www.nist.gov/director/prog-ofc/report00-1.pdf>.

⁷ J.T. Schakenbach, Use of Calibration Gases in the U.S. Acid Rain Program, *Accreditation and Quality Assurance* 6(7), 297-301 (2001).

⁸ U.S. EPA, Methane Sources and Emissions, www.epa.gov/methane/sources.html.

accreditation programs that allow transparent and efficient emissions measurements by ensuring the accuracy and comparability of quantitative measurements of greenhouse gas emissions and reductions (e.g., offsets).

A host of recent workshops has highlighted the increasing interest in implementing a greenhouse gas mitigation program and active discussions are ongoing to determine the attributes of a possible U.S. program. NIST participates in measurement and monitoring discussions in many strategic working groups, committees and workshops along with other federal agencies, the academic climate change research community and the private sector. Such groups have produced reports and recommendations, including the U.S. Climate Change Science Program report on the State of the Carbon Cycle, the international Committee on Earth Observation Satellites, the workshop on Achieving Satellite Instrument Calibration for Climate Change (ASIC3), and most recently, the Air and Waste Management Association's First International Greenhouse Gas Measurement Symposium. NIST's active participation in such working groups helps to facilitate the measurements and standards development component of this effort. NIST also teams with the private sector and others to undertake a continuous assessment to identify new measurement needs.

Through NIST's identification of measurement needs, multiple issues stand out:

- **Assess Baseline Emissions** – There is a clear and critical need for more accurate methods to assess baseline amounts of CO₂ and other greenhouse gases emitted by multiple industries and technology sectors in a consistent and verifiable manner both nationally and internationally. The UN has issued guidelines for how countries should estimate CO₂ emissions, but even with best practice guidelines, the question of uncertainty in emissions from key sectors remains a major issue. Additional research to support better emission measurement, monitoring, and modeling techniques is necessary to reduce these uncertainties.
- **Need for Improved Monitoring Technologies** – Accurate and standardized monitoring technologies are needed to support greenhouse gas emission inventory efforts. The greenhouse gas inventory community needs to reconcile measurements of greenhouse gases made from top-down approaches, typically used by the climate science community for long-term climate records, and the bottom-up approaches that are essential to the implementation of policies to reduce greenhouse gas emissions. A variety of measurement approaches and techniques will be required to address the many specific sources of greenhouse gas emissions, spanning point or local sources to emissions from broad spatial scales. Methods based on ground- and satellite-based remote sensing are anticipated to require new scientific and technological developments.
- **Need for Accurate Data for Determining Limits for Greenhouse Gas Emissions** – Accurate inventories of emissions and the methods for verifying them are an important foundation for policy-makers and regulators charged with the development and implementation of policies, as well as for the facilities and sources that must comply. Such data, and an understanding of the measurement technologies required, are also critical to the establishment of realistic and effective limits.

- International Recognition – Ensuring transparency and trustworthiness in international carbon markets requires a centralized and agreed-upon set of standards and methods for accrediting various monitoring organizations and laboratories. Implementation of such a system will benefit from the existing infrastructure of the international SI system of units and the international metrology community.

Furthermore, successful implementation of U.S. greenhouse gas reduction policies is a multi-faceted issue and will involve several federal agencies. NIST has a long history of successful collaborations with EPA on emission measurements and standards, e.g., the highly successful sulfur emissions trading system, collaboration on development and maintenance of the NIST/EPA Gas-Phase Infrared Database and the NIST/EPA/NIH Mass Spectral Library, and the standards that underpin automobile emissions testing. NIST also has strong partnerships with NOAA and NASA in the area of sensor calibration for environmental measurements and has, for example, provided spectroscopic data for NASA's Orbiting Carbon Observatory (OCO) and the Active Sensing of CO₂ Emissions over Nights, Days, and Seasons (ASCENDS) mission concept.

Summary

Accurate SI-traceable climate change measurements provide confidence in measured and predicted climate change trends and aid the development and assessment of mitigation strategies. The NIST laboratory programs provide the measurement science, measurement traceability, production and dissemination of fundamental data, and standards development and dissemination (both artifact and documentary) to support other Federal agencies and their satellite, air, and surface-based measurement programs by ensuring the accuracy, comparability, and stability of their data. NIST is also uniquely poised to provide private-sector manufacturers and users of greenhouse gas emissions monitoring equipment with the tools to make accurate measurements and assess measurement accuracy.

Thank you for the opportunity to testify today on NIST's work on measuring, monitoring, and verifying greenhouse gas emissions. I would be happy to answer any questions the committee may have.



Dr. Patrick D. Gallagher, Deputy Director

Dr. Patrick Gallagher is the Deputy Director of the U.S. Department of Commerce's National Institute of Standards and Technology (NIST). He is also carrying out the responsibilities of the Director. (The NIST Director position is vacant.) Gallagher provides high-level oversight and direction for NIST. The agency promotes U.S. innovation and industrial competitiveness by advancing measurement science, standards, and technology. NIST's FY 2008 resources total \$931.5 million and the agency employs about 2,900 scientists, engineers, technicians, support staff and administrative personnel at two main

locations in Gaithersburg, MD, and Boulder, CO.

Prior to becoming Deputy Director, Gallagher served as Director of the NIST Center for Neutron Research (NCNR), a national user facility for neutron scattering on the NIST Gaithersburg campus, since 2004. The NCNR provides a broad range of neutron diffraction and spectroscopy capability with thermal and cold neutron beams and is presently the nation's most used facility of this type. Gallagher received his Ph.D. in Physics at the University of Pittsburgh in 1991. His research interests include neutron and X-ray instrumentation and studies of soft condensed matter systems such as liquids, polymers and gels. In 2000, Gallagher was a NIST agency representative at the National Science and Technology Council (NSTC). He has been active in the area of U.S. policy for scientific user facilities and was chair of the Interagency Working Group on neutron and light source facilities under the Office of Science and Technology Policy.