Testimony of
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Chairman Inouye, Vice Chairman Stevens, and Members of the Committee, thank you for the opportunity to appear before you today to discuss the research we do related to the transportation sector on areas that are related to global climate change underway at the National Institute of Standards and Technology (NIST).

The well-being of U.S. citizens is affected every day by NIST's measurement and standards work. Virtually every segment of the economy, from transportation to computer networks, banking, food processing, health care and communication, depends on NIST research, products and services. More broadly, the quality of the water we drink, the air we breathe, the energy that we use, and the food we eat depends in part on that work.

The work NIST is doing on climate change is important. Some of the drivers of climate, such as the sun's output, have small variations that change slowly over time. As a result, climate predictions depend on developing absolute measurements of the sun's energy that can be compared accurately over decades from different sensors. Other important variables include the sizes, shapes, and chemical composition of particles or droplets (aerosols) in the atmosphere. Whether aerosols contribute to the warming or the cooling of the Earth depends upon their composition.

In the area of transportation, let me start with one example. NIST conducts research and provides measurement science and services that underpin many stages of auto manufacturing--from the production of materials like sheet metal for body panels to monitoring the final quality of the vehicle assembly. NIST's work extends beyond the car to the transportation infrastructure itself, including both fossil and alternative fuels; emissions; advanced materials like cement for bridges and highways to lightweight metals and composites for auto body parts; fuel cells; and more efficient and greener manufacturing processes:

In addition, NIST works in the following areas:

- Composition, volume, and weight standards for fuels and oil to allow confidence in trading in low to high sulfur content fuels in competitive markets. This covers everything from measures and standards for fossil fuels to biofuels, and from train cars of coal to gallons of gasoline at the pump.

- Gas reference standards for sulfur dioxide and nitrous oxides that enable automotive manufacturers to meet Environmental Protection Agency (EPA) standards and generally allow industry to tune and trade their emissions through the EPA sulfur dioxide cap and trade system.

- Composition of refrigerants in automotive air conditioning systems to eliminate chlorofluorocarbons and find replacements that minimize impacts on ozone depletion in the upper atmosphere, as well as climate forcing due to these gases.

- Production of roadway materials, and the composition, strength, and durability of road and bridge materials and construction techniques to minimize greenhouse gas (GHG) emissions.

- Lightweight metal forming and composites to enable manufacturers to have high performance, high durability and safe materials to increase efficiency in the automotive and aerospace industry.

- Developing Smart Grid standards for plug-in hybrid electrical vehicles scheduled to be in showrooms in 2010.

- More efficient, greener manufacturing through a partnership with EPA on the Green Supplier Network.

Now I would like to cover some specific work NIST is undertaking to improve efficiencies in the transportation industry that could reduce the impact of the industry on climate change. I also want to note that NIST has requested budget increases in FY09 that would enable us to expand and accelerate our work in this area. It also is important to note that nearly all of NIST's work is planned and done in partnership with others in industry, universities, and government at all levels.

Supporting Innovations in Fossil, Bio Fuels and Hydrogen Fuel Cells – Monitoring Emissions and Developing New Fuel Capabilities and Standards

Fossil Fuels Standard Reference Materials (SRMs) - Standards in Emissions. Beginning in June 2006 the U.S. Environmental Protection Agency mandated ultra-low sulfur diesel (ULSD) fuel to make possible more efficient exhaust emissions. The accurate determination of sulfur in ULSD at low levels is a major measurement challenge with enormous economic consequences, mostly in avoided costs, for petroleum refineries and for every link in the distribution system. To meet this challenge, industry must have highly accurate sulfur standards. These SRMs ensure the accurate make up of the fuel and enable compliance to EPAs regulations regarding sulfur fuels. NIST is the place to go for an SRM for a fossil fuel. NIST's first fossil fuel SRMs were issued in 1967 and continue to be issued today.

These standards represent some of NIST's most successful products. According to the study *Economic Impact of Standard Reference Materials for Sulfur in Fossil Fuels*, NIST work returned a calculated rate of return for the program of 1,056 percent. Studies also demonstrate that NIST standards for sulfur in fossil fuels have a net value to society of more than $409 million since 1984.

Biofuels. Biofuels have gained popularity worldwide both as a renewable energy source and as a way to reduce greenhouse gas emissions and move away from dependence on fossil fuels. NIST is participating in this arena. The United States, Brazil and the

European Union have convened a task force of experts to study existing biofuels standards and catalog similarities and differences between them. Out of this partnership, NIST and Brazil are collaborating on the development of joint measurement standards for bioethanol and biodiesel by the end of 2008.

Getting an Accurate Fill-Up. Working very closely with State weights and measures organizations, NIST has long maintained the standard for ensuring that consumers actually receive a gallon of gas every time they pay for one. Now NIST researchers are incorporating the properties of hydrogen in standards that will support the development of hydrogen as a fuel in vehicles. One of the challenges in the use of hydrogen as a vehicle fuel is the seemingly trivial matter of measuring fuel consumption. Consumers and industry are accustomed to high accuracy when purchasing gasoline. Refueling with hydrogen is a problem because there are currently no mechanisms to ensure accuracy at the pump. Hydrogen is dispensed at a very high pressure, at varying degrees of temperature and with mixtures of other gases. NIST's research and new technological innovations will enable accuracy in hydrogen fill-ups.

Fuel Research for Aviation, Aerospace and Vehicular Transportation. NIST has a major effort underway to characterize and model fuel fluids. All reformulations of these fuels changes the way they operate and NIST is working to identify how they are affected. These liquid fuels have long been the most convenient fuel source for all sectors of transportation- aircraft, rockets, cars, trucks, locomotives and military vehicles. The design and specification of these fuels has environmental considerations. Redesigning fuels with environmental considerations as a factor can only be done after NIST does its job of understanding how different additives and formulations affect the fuel.

Enabling the Use of Hydrogen Fuel. As mentioned above, NIST is working to enable the use of hydrogen as a fuel. Hydrogen offers the possibility of lowering the impact of motor vehicles on the environment, and reducing our nation's dependence on foreign oil. While the burning of fossil fuels produces carbon dioxide and other emissions harmful to the environment, hydrogen fuel can be made from many energy sources, including renewables, and produces zero emissions.

Technical challenges need to be overcome to make hydrogen-powered vehicles more practical and economical. Fuel cells need to operate as reliably as today's gasoline engine. We need systems that can store enough hydrogen fuel to give consumers a comfortable driving range. We need science-based standards that will guide local officials in establishing codes for building and fire safety as they relate to something like a hydrogen fueling station. And we need a technical infrastructure to ensure the equitable sale of hydrogen in the marketplace, as exists today for gasoline.

Expansion of research efforts at NIST is essential to achieving widespread use of hydrogen as a fuel. The distribution and sale of hydrogen will require entirely new systems for ensuring equity in the marketplace. In fiscal year 2009, NIST has requested $4 million to accelerate its research in this area. NIST has been a leading provider of data on the chemical and physical properties of hydrogen for more than 50 years. It has statutory responsibility under the Pipeline Safety Act of 2002 (PL 107-355) to develop research and standards for gas pipeline integrity, safety, and reliability. It is the lead U.S. agency for weights and measures of vehicle fuels, and it develops test protocols for stationary fuel-cell systems, covering issues of efficiency, performance, and compatibility with the power grid for interconnection purposes.

NIST's Center for Neutron Research (NCNR) is the premier facility for real-time, three-dimensional imaging of hydrogen in operating fuel cells. NIST's operations have won awards and wide praise for providing the diagnostics that industry needs to make fuel cells more reliable and less costly. The unique resources developed at this NIST facility will also help reduce technical barriers for efficient hydrogen production and storage. Indeed, NIST participates in two of the three Centers of Excellence established by DOE to develop better means of hydrogen storage.

Transporting and Distributing Hydrogen. Gasoline consumption in the U.S. exceeds 388 million gallons per day and at $4.00 a gallon that is a growing investment. Producing hydrogen fuel from domestic energy sources will increase domestic control and substantially reduce greenhouse gas emissions. One barrier to this switch is pipelines. There are currently 700 miles of hydrogen pipelines in operation – that is in comparison to 1 million miles of natural gas pipelines. To move to a more nationwide use of hydrogen, safe and effective pipelines have to be developed. This work will also be part of the NIST Fiscal Year 09 Hydrogen initiative request of $4 million dollars to accelerate research in this area. NIST is working on both sensor development to monitor the pipelines and steel and material testing to ensure the safest pipeline possible. NIST is working to establish the codes and standards necessary to ensure safe distribution of hydrogen fuels. The future "hydrogen economy" will depend on efficient transport of fuel across the U.S. In order to use the existing network of pipelines, tests have to be developed to test for the degradation that is likely to occur to the metals that can be caused by hydrogen weakening the pipeline. By establishing the unique test facilities and standard test procedures, we will provide pipeline operators with critical data on the durability of pipeline material in high-pressure hydrogen gas environments.

Hydrogen Storage. Hydrogen is promoted as a petroleum replacement that presents an attractive alternative for fueling automobiles and trucks while maintaining a cleaner global environment. A major roadblock associated with the use of hydrogen is the inability to store it efficiently. Because hydrogen's properties have been shown to embrittle metals and because current storage technologies limit the potential range of hydrogen powered vehicles, NIST is working on measurement tools to determine hydrogen's absorption/desorption characteristics that will accelerate discovery of new materials that can be used to store hydrogen for use across the U.S.

Fuel Cell Research. This is another area where innovations can have an impact on the environment. A huge array of emerging technologies, from new portable electronic devices to smart energy vehicles, depend on the successful development and deployment of efficient, lightweight, reliable and cost-effective fuel cells. The potential market for these new products represents billions of dollars to the U.S. economy. NIST's Center for Neutron Research (NCNR) works with General Motors and others in this area. NIST's expertise is essential for making fuel cells less costly and more reliable.

To develop fuel cells for practical use, NIST researchers are developing measurement methods to characterize the nanoscale structure and dynamics of polymer membranes inside the fuel cell to enable stronger fuel cells. Industry's use of the unique facilities and instruments at NIST will help reduce technical barriers for efficient hydrogen production, storage, and use.

Supporting Innovation in Advanced Materials - Lightweight Materials and Nano Composites

In addition to the work NIST is doing in the area of hydrogen fuel, other researchers at NIST are looking at materials that will make more efficient cars, airplanes and trains. These efficiencies also will strongly benefit the environment by introducing lighter, more fuel efficient transportation.

Automobiles and light trucks consume 79 percent of all U.S. distilled fuel and emit 19.8 percent of all U.S. CO_2 emissions. Lightweight materials are a big part of the solution to reduce our consumption. The Department of Energy, Office of Vehicle Technologies states that lightweight materials are needed to "offset the increased weight and cost per unit of power of alternative powertrains (hybrids, fuel cells) with respect to conventional powertrains."

Lightweight Materials for Automobiles. The transportation industry in general, particularly the automotive industry, is looking for lightweight materials such as new lightweight aluminum and high-strength steel alloys to improve fuel efficiency. Introduction of these alloys is limited by severe manufacturing difficulties tied to unpredictable micron-scale stresses during production. NIST and industry scientists developed a way to measure and map stresses on the micron scale using X-ray microbeams that are 100 times thinner than a human hair. These measurements have solved key scientific questions about how metals deform and this knowledge will accelerate the introduction of new lightweight alloys into fuel-efficient vehicles.

NIST is partnering with the automotive industry to accelerate the introduction of aluminum and high-strength steel into automobile production and is collaborating with the Argonne National Laboratory's Advanced Photon Source and the Oak Ridge National Laboratory to measure stresses in deformed metals at the nanoscale level.

NIST Center for Metal Forming. The NIST Center for Metal Forming is developing the measurements, standards and analysis necessary for the U.S. automotive industry and metal suppliers to transition to new ways of forming metals. This will enable the industry to transition to new advanced and lightweight materials more easily as more accurate data and material models will lead to more accurate die designs, reducing redesign and new model development costs. The reduction of sheet metal forming redesigns through improved material data and models is projected to save the U.S. auto industry a large portion of the $600 million lost per year on redesigns.

Determining the Life Cycle and Environmental, Health and Safety Performances of Polymer Nanocomposites. Polymer nanocomposites, defined as material systems in which one or more dimensions is less than 100 nm, have greatly improved performance properties relative to traditional polymeric materials and are forecast to make significant in roads in the near future in high volume markets including infrastructure, automotive, and aerospace industries. However, use of these materials in products is hindered by the lack of performance data for them, as well as significant societal concerns regarding the release of significant quantities of nanomaterials into the environment during or at the end of the product service life. Critical information and data is lacking for characterizing and predicting life cycle performance and in-service release rates of nanoparticles from polymer nanocomposites. Although current research focuses on nanoparticle exposure during the manufacturing process, in-service release of nanoparticles from nanocomposites is expected to be greater by several orders of magnitude. NIST will develop and apply measurement science over a wide range of length and time scales to enable a comprehensive understanding of life cycle performance and nanoparticle release rates of polymer nanocomposites.

Timely, accurate, and precise material life cycle performance estimates will enable a revolutionary transformation from initial cost to life cycle cost-based materials selections. Information regarding nanoparticle release rates over the life cycle of nanocomposite materials will ensure safety in commerce by directly addressing public, environmental, and regulatory concerns regarding the environmental, health, and safety aspects of these materials. This research will also foster innovation throughout the nanocomposites supply chain such as material and product manufacturers, and end users and improve the competitive position of U.S. industry in the global market.

While NIST’s work in the automotive and related industries is important to reducing our impact on the environment, there are many ways in which NIST’s research in the area of transportation infrastructure could reduce our impact on our climate.

Supporting Innovation in Transportation Infrastructure Via Concrete Research That Will Have an Impact on the Environment

Most of the U.S. and the world's infrastructure - transportation structures, tunnels, airports, buildings, dams, industrial plants - is made out of concrete. There has been significant work in the area of concrete technology over the last few decades to greatly improve processing and properties making concrete more sustainable.

Why is this important to climate change? The cement and concrete industry is a large generator of greenhouse gas, mainly carbon dioxide (CO_2), during the manufacturing production process. One U.S. ton of cement produces about one ton of CO_2 and the annual world production of cement – 2.5 billion tons -- is equal to a 3-9 percent estimated share of world man-made CO_2. In 2006, the U.S. produced 96 million tons of cement and 37 million tons were imported for use in the U.S. It is estimated that 1.5 percent of U.S. man-made CO_2 generation comes from concrete production. And while this is a large number, cement production is forecast to greatly increase over the next 20-40 years because of burgeoning demand for new and replacement infrastructure.

In the U.S., the energy efficiency of cement production is already high, and is probably only capable of fairly small improvements. One is limited to reducing the CO_2 that is given off from the raw materials by partially substituting another material for the cement in concrete, such as the substitution of non-CO_2 containing materials for a portion of the limestone in the raw materials. Around the world, the two most common minerals used to substitute for cement are fly ash and granulated ground blast furnace slag. The use of fly ash and slag in concrete can actually improve the properties of concrete, especially the durability.

NIST is planning to incorporate research on fly ash into our research program in this year and is currently collaborating with several research institutions in submitting joint proposals in response to a Federal Highway Administration Broad Area Announcement pertaining to fly ash. In addition, our researchers have published extensively on the incorporation of fly ash into concrete for other federal agencies.

Let me highlight some of NIST's work to address the needs of the concrete industry itself. All of our work will improve our understanding of how cement and concrete actually work, and ultimately should make possible improvements in the formulation and use of cement that could save hundreds of millions of dollars in annual maintenance and repair costs for concrete structures and the country's infrastructure. This work should also lead to improving the properties and performance of concrete while decreasing energy costs and reducing the CO_2 emissions from its production.

Using NIST State of the Art Tools to Study Concrete. Using the most modern tools of materials research, researchers from NIST and industry are exploring one of the oldest but most complex construction materials—cement.

Cement may be the world’s most widely used manufactured material—more than two billion metric tons are consumed each year—but it also is one of the more complex. And while it was known to the Romans, who used it to good effect in the Coliseum and Pantheon, questions still remain as to just *how* it works, in particular how it is structured at the nano- and microscale, and how this structure affects its performance. NIST’s investigations should lead to a better understanding of the contribution of the nanoscale structure of cement to concrete durability, and how to improve it.

Processing of High-Performance Concrete: Mixing and Flow Properties. NIST researchers are looking at ways to develop cement paste and mortar measurement techniques. Researchers are also looking at models of mortar and concrete flow, and guidelines for optimizing the proportioning and processing of high-performance concrete (HPC). At present, there are no generally accepted guidelines for formulating and mixing HPC and no standard tests for measuring the workability of HPC in terms of fundamental flow quantities such as yield stress and plastic viscosity. In the selection of mixture proportions, many methods exist for present-day concretes, but none has received general acceptance and only a few are based on performance rather than prescription; all require the making and testing of numerous batches, which is not the most efficient way to test. We need to link the mixture composition with performance, including flow properties. A method for predicting the flow properties of HPC from mixture proportions will result in a significant reduction of cost in designing HPC mixtures with optimum performance, both in the fresh and hardened states. NIST is developing models to simulate various scenarios to address this issue and to improve the performance of concrete.

Virtual Cement and Concrete Testing Laboratory (VCCTL) Cement Hydration Modeling. A new hydration model is part of a NIST/industry consortium to design, develop, document, and validate a novel, next-generation computer model of microstructure development of hydrating cement paste. The hydration of portland cement pastes is an extremely complicated phenomena involving many chemical reactions. The VCCTL consortium is committed to the development of a computer model, based on accepted reaction thermodynamics and kinetics that can make reliable predictions of the kinetics of 3-D microstructure development and its dependence on various chemical admixtures. Such a model could become a valuable research tool for cement and admixture companies and could help them reduce the amount of physical testing that they currently perform.

Micro- and Macrostructural Characterization of High-Performance Concrete. NIST is developing methods for characterizing of the micro- and macrostructures of cements and high-performance concrete. To understand how concrete will react under certain circumstances - in numerous environments - one has to understand concrete at the micro level. The methodology developed by NIST will form the basis for assessing and predicting concrete composition and texture influences on performance. This project will lead to an improved understanding of concrete degradation and therefore reduce the need for repeated replacement of concrete and thereby reducing the CO_2 emissions associated with the production of cement.

Simulation of the Performance and Service Life of High Performance Concrete. NIST is also looking at computer simulation algorithms for the service life of high-performance concrete. The service life of HPC depends on almost all performance properties, such as transport properties like resistance to chemical penetration and mechanical properties like elasticity. These properties need to be predicted at the design stage, so that HPC can be designed for durability and lifecycle cost requirements, not just strength requirements. The only accurate way that different kinds of HPC can be handled is to base such predictions on fundamental materials science that includes microstructure, cement chemistry, concrete mixture design, and expected curing. Since concrete is made up of particles at many length scales (e.g., cement, fly ash, silica fume, sand, gravel), quantitative characterization of particle shape is needed so that real particles can be used in these kinds of quantitative models.

Adaptive Concrete Technologies. NIST researchers are investigating adaptive concrete technologies including internal curing and the incorporation of phase change materials into concrete to increase its service life. Field concrete is exposed to a wide variety of environmental conditions and distress. These environmental factors often result in premature degradation and/or failure. Examples include early-age cracking due to shrinkage and degradation as a result of repeated cycles of freezing and thawing, and deterioration due to damaging reactions of chemicals (chloride, sulfate, and alkali ions, etc.). An adaptive concrete is one that dynamically and actively “responds” to these stimuli in such a manner as to reduce their impacts. The results of this research may encourage the industry to have another look at what composition is truly optimum for applications such as pavements and bridge decks, where durability is much more important than strength.

Doubling the Service Life of Concrete. NIST is working to have a dramatic effect on the concrete industry through doubling the service life of new concrete by altering the composition of concrete. One of the main goals of high performance concrete is to increase service life. Under most chemical erosion scenarios, the service life of concrete depends on its reaction to external chemicals entering it. There are a number of ways to significantly increase the service life of concrete including reducing the porosity and adding mixtures to provide increased resistance to the infiltration of chemicals. Unfortunately, one of the side effects of these modifications is a large increase in the propensity for early-age cracking, and the desired barrier performance of a dense concrete is easily compromised by the formation of just a few cracks. Time until the steel reinforcement in the concrete rusts is related to the depth of concrete cover, so that if you increase the thickness of concrete over the steel by 50 %, you get approximately double the expected service life. More concrete covering the rebar may not be feasible because of design constraints, and both additional concrete and changing the composition to resist chemicals can add considerable cost to construction. NIST researchers propose a different approach to modification of the physical properties of the concrete structure by using a combination of electrical conductivity, ion diffusivity, and viscosity measurements.

In addition to these programs, NIST cement Standard Reference Materials (SRMs) have underpinned product quality for the cement industry for nearly 50 years. The cement SRMs series has proven to be essential to laboratories that certify concrete products for performance and that evaluate mechanisms for concrete corrosion and failure.

Summary

For 107 years, NIST research has been critical to our nation's innovation and competitiveness by directly supporting technological advances in broad sectors of the economy that will quite literally *define* the 21st century -- as well as improve the safety and quality of life for all our citizens.

Today, more than at any other time in history, technological innovation and progress depend on NIST's unique skills and capabilities. Helping the U.S. to drive and take advantage of the increased pace of technological change is a top priority for NIST. The technologies that emerge as a result of NIST's development of these tools are enabling U.S. companies to innovate and remain competitive. That absolutely includes the need to develop both information and better tools to enable the United States and other nations to deal with the potential and real climate-related impacts of transportation systems and components.

To ensure that NIST programs deliver the highest impact, the Institute, working with our stakeholders in Congress, industry, academia, and other government agencies, will continue to identify the most critical measurement, standards, and technological challenges – including our efforts that relate to the transportation sector and climate change. We look forward to working with you, Mr. Chairman, and members of the Subcommittee, throughout this process.

Biography

Dr. James M. Turner, Deputy Director

Dr. James M. Turner 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.) Turner 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 2,800 scientists, engineers, technicians, support staff and administrative personnel at two main locations in Gaithersburg, MD and Boulder, CO. Along with the Department of Energy Office of Science, and the National Science Foundation, NIST is slated for substantial budget increases for its core research programs under the President's American Competitiveness Initiative.

Prior to joining NIST on April 16, 2007, Turner served as the Assistant Deputy Administrator for Nuclear Risk Reduction in the Department of Energy's National Nuclear Security Administration. In that position, he was responsible for major projects in Russia to permanently shutdown their last three weapons-grade plutonium-production reactors. He also worked with foreign governments and international agencies to reduce the consequences of nuclear accidents by strengthening their capability to respond to nuclear emergencies.

Prior to that assignment, Turner held several senior management posts at DOE concerned with laboratory oversight and with nuclear safety and the safeguarding of nuclear weapons both here and abroad.

He holds degrees in Physics from the Massachusetts Institute of Technology (Ph.D.) and Johns Hopkins University (B.A.), and taught for five years as an Associate Professor of Physics and Engineering at Morehouse College.

Among other honors, he has received the U.S. Government Presidential Rank Award for Meritorious Service, three times received the U.S. Department of Energy Exceptional Service Award, and earned the Secretary of Energy Gold Award and the National Nuclear Security Administration's Gold Medal. Dr. Turner is an active member of the American Physical Society, the American Chemical Society, the American Nuclear Society, the American Association for the Advancement of Science, ASTM, the Council on Foreign Relations, IEEE, Phi Beta Kappa, Sigma Xi, and the World Affairs Council.

Dr. Turner is a native of Washington, DC, is married, and has five children and one grandchild. He enjoys doing yoga and Tai Chi. He and his wife, Paulette, reside in Olney, Maryland.