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MONITORING, MEASUREMENT, AND VERIFICATION OF GREENHOUSE GAS EMISSIONS, PARTS I AND II

HEARINGS

BEFORE THE

SUBCOMMITTEE ON ENERGY AND ENVIRONMENT

COMMITTEE ON SCIENCE AND TECHNOLOGY

ONE HUNDRED ELEVENTH CONGRESS

FIRST SESSION

February 24, 2009
and
April 22, 2009

Serial No. 111–3
and
Serial No. 111–18

Printed for the use of the Committee on Science and Technology

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HOW DO WE KNOW WHAT WE ARE EMITTING? MONITORING, REPORTING, AND VERIFYING GREENHOUSE GAS EMISSIONS

TUESDAY, FEBRUARY 24, 2009

HOUSE OF REPRESENTATIVES,
SUBCOMMITTEE ON ENERGY AND ENVIRONMENT,
COMMITTEE ON SCIENCE AND TECHNOLOGY,
Washington, DC.

The Subcommittee met, pursuant to call, at 10:00 a.m., in Room 2318 of the Rayburn House Office Building, Hon. Brian Baird [Chair of the Subcommittee] presiding.

BART GORDON, TENNESSEE
CHAIRMAN

RALPH M. HALL, TEXAS
RANKING MEMBER

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Hearing on

How Do We Know What We Are Emitting? Monitoring, Reporting and Verifying Greenhouse Gas Emissions

Tuesday, February 24, 2009
10:00a.m. – 12:00p.m.
2318 Rayburn House Office Building

Witness List

Mr. John Stephenson
Director
Natural Resources and Environment
Government Accountability Office

Ms. Jill Gravender
Vice President for Policy
The Climate Registry

Ms. Leslie Wong
Director
Greenhouse Gas Programs
Waste Management, Inc.

Mr. Rob Ellis
Greenhouse Gas Program Manager
Advanced Waste Management Systems, Inc.

HEARING CHARTER

SUBCOMMITTEE ON ENERGY AND ENVIRONMENT COMMITTEE ON SCIENCE AND TECHNOLOGY U.S. HOUSE OF REPRESENTATIVES

How Do We Know What We Are Emitting? Monitoring, Reporting, and Verifying Greenhouse Gas Emissions

TUESDAY, FEBRUARY 24, 2009
10:00 A.M.–12:00 P.M.
2318 RAYBURN HOUSE OFFICE BUILDING

Purpose

On February 24, 2009, the House Committee on Science and Technology, Subcommittee on Energy and Environment will hold a hearing entitled *"How Do We Know What We Are Emitting? Monitoring, Reporting, and Verifying Greenhouse Gas Emissions."* The purpose of the hearing is to determine the federal role in supporting research and development of monitoring technologies, emissions factors, models, and other tools necessary to support reliable accounting of baseline greenhouse gas emissions and changes in emissions relative to the baseline under a regulatory program for greenhouse gases.

The Subcommittee will receive testimony on the procedures and methods used to monitor, report, and verify greenhouse gas (GHG) emissions from businesses, government agencies, and localities and to identify the challenges associated with accounting for emissions associated with different activities. The Subcommittee will also receive testimony on whether opportunities exist to improve the technologies, models, or other methods used to track greenhouse gases.

Witnesses

- **Mr. John Stephenson,** *Director, Natural Resources and Environment, Government Accountability Office.* Mr. Stephenson will discuss the systems designed to track greenhouse gas emissions from businesses and government agencies and the strengths and limitations of the information provided by existing greenhouse gas emission registries and the use of this information in a GHG regulatory system.
- **Ms. Jill Gravender,** *Vice President for Policy, The Climate Registry.* The Climate Registry is a nonprofit organization that establishes standards for businesses and governments to calculate, verify, and publicly report greenhouse gas emissions into a single registry. Ms. Gravender will discuss the general approach The Climate Registry has taken to develop protocols that both bring consistency to emissions reporting and provide assurance that the values reported by members are robust.
- **Ms. Leslie Wong,** *Director of Greenhouse Gas Programs, Waste Management, Inc.* Ms. Wong will discuss Waste Management's efforts to develop a corporate-wide greenhouse gas emission inventory and the company's participation in the California Climate Action Registry, the Western Climate Initiative, and the Chicago Climate Exchange.
- **Mr. Rob Ellis,** *Greenhouse Gas Program Manager, Advanced Waste Management Systems, Inc.* Mr. Ellis will discuss Advanced Waste Management Systems' role in verifying the information reported to greenhouse gas registries, such as The Climate Registry.

Background

In order to develop a framework to address greenhouse gas (GHG) emissions, it is essential to have a credible system for monitoring, reporting, and verifying GHG emissions. Accurate accounting of emissions is used to project changes in the concentration of GHGs in the atmosphere (inventories) and to determine emission contributions from specific sources (registries). Inventories of GHGs provide information about the net emissions within political or geographic boundaries (states, nations or continents) or within economic sectors containing many individual entities (e.g., transportation, manufacturing, power generation). GHG registries provide information about the emissions from specific entities within sectors (e.g., individual companies, towns, or universities) or the emissions associated with specific projects (e.g., under the Clean Development Mechanism of the Kyoto Protocol). This hearing will concentrate on information reported to GHG registries.

Measurement, reporting and verification are the backbone of a cap-and-trade or any other GHG control scheme. In a cap and trade system, permits to emit GHG's are considered commodities and their price is established by trading these commodities on the GHG market. Incorrect emissions data can undermine a program's legitimacy and effectiveness. Also, determination of the baseline emissions is essential to defining the emissions cap and to allocating allowances under a cap and trade system. A successful market-based GHG control scheme will need a fair, robust, and accurate monitoring, reporting, and verifying system, thereby ensuring that emissions reductions have, in fact, occurred.

Measuring Greenhouse Gas Emissions

Greenhouse gas emissions can be quantified by measuring emissions of greenhouse gases[1] directly or by estimating emissions using other information such as fossil fuel combustion. Estimation is used more often than direct measurement and is the principle means used to support the European Union's Emissions Trading Scheme (ETS). Emissions are calculated by multiplying measurable activities such as fuel usage, with an emissions factor which is a numerical constant that links estimated emissions to a measurable activity that causes the emissions to occur.[2]

Emissions levels may also be quantified through mass balance calculations. For example, if two kilograms of the greenhouse gas HFC–134a was injected into an automobile air conditioner and years later the remaining kilogram is removed, then one can assume that the other kilogram was emitted into the atmosphere.[3]

Emissions can be directly measured. On type of measurement device is a continuous emissions monitor (CEM). CEMs are rare in the European Union, but in the United States they are used to monitor carbon dioxide (CO_2), sulfur and nitrogen oxide emissions for entities regulated under the acid rain program of Title IV of the *Clean Air Act.* CEMs continuously monitor the flue gas emitted from coal, oil, and natural gas power generating units (over 25 MW) and some large manufacturing facilities. While the *Clean Air Act* does not currently regulate CO_2, the reporting provision has given utilities and other combustion sources experience in monitoring CO_2 emissions and a baseline of information on CO_2 emissions.

Reporting Greenhouse Gas Emissions

The information provided by different registries varies with respect to the gases monitored, the time period for reporting, the specific reporting protocols, and the data verification required of participants in the registry. For each registry the goal is to ensure that all entities are able to produce consistent and robust emissions data that will enable comparisons to be made from one reporting period to the next.

In the United States, there are several GHG registries that support reporting requirements for State and regional programs. At the federal level, there are currently two voluntary reporting programs, The Environmental Protection Agency's (EPA's) Climate Leaders Program and the Department of Energy's Voluntary Reporting of Greenhouse Gases Program or the 1605(b) program. EPA is expected to issue a notice of proposed rule-making for a mandatory GHG reporting program very soon.

Over the past few years, states and regions have established policies to qualify and control GHGs. The California Climate Action Registry (CCAR) tracks emissions associated with specific entities and activities in California, and The Climate Registry compiles information on annual emissions from each member of the registry. Participation in The Climate Registry is voluntary, and The Registry has members throughout North America. The Chicago Climate Exchange (CCX) a GHG emissions

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[1] The six greenhouse gases are: Carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6).

[2] Office of Policy and International Affairs, United States Department of Energy. *Technical Guidelines: Voluntary Reporting of Greenhouse Gases (1605(b)) Program.* January 2007.

[3] Office of Policy and International Affairs, United States Department of Energy. *Technical Guidelines: Voluntary Reporting of Greenhouse Gases (1605(b)) Program.* January 2007.

trading market also provides a framework for reporting emissions from entities participating in the Exchange to its registry.

Verifying Greenhouse Gas Emissions

In order to ensure consistency and quality of reported emissions information, a GHG registry will often require third-party verification of the reported emissions. During a verification audit, the verifier will check that the proper procedures, emissions inputs, use of emissions factors, etc., adhere to the registry's guidelines.

Verifiers themselves are accredited by the American National Standards Institute (ANSI). ANSI evaluates verifiers by assessing whether they have the technical expertise to perform verifications, are knowledgeable about monitoring, reporting, and verification protocols, including the international standard (ISO 14065) and the protocols of the specific registries they will work with.

Chair BAIRD. Good morning and thank you all for joining us. I especially want to welcome the students who are here. This is the senior class from Herndon, Virginia, do I understand? Welcome to our Science and Technology Subcommittee hearing, and we are glad you are all here. Make yourself at home. We will fit these kids in so they can see a little bit of this hearing because it is on a topic I think is of great importance to their future. I am particularly pleased to be able to chair this subcommittee and excited to be able to work with Mr. Inglis who is a good friend and with whom I have had the privilege of traveling to look at some of the effects of climate change.

By the way, Bob, my take, and you will hear this a lot on this committee this year, is I am no longer going to refer to what we are talking about as climate change because it is actually in my judgment lethal overheating of the planet and acidification of our oceans. You will hear this a lot from me, but climate change sounds nice. Change you can believe in just helped elect the President, and global warming sounds like a good thing. We like to be warm. But I hate to be overheated, and acidification of the ocean is actually also happening. I raised that, and actually we have the sad news today, apparently a rocket malfunctioned carrying a carbon-observing satellite and caused that satellite to go into the ocean instead of space earlier this morning. It was a big setback for us scientifically. The other side, maybe the satellite knows something we don't, and it realizes that part of the carbon problem is in the ocean and we need to spend more attention there. That is looking on the bright side. Of course, it will be worthless to us there.

This is an important hearing, and it is going to give us an opportunity to examine the quality of the information being collected on the emission of greenhouse gases. A number of states have established programs to address climate change, lethal overheating, and to reduce their greenhouse gas emissions. Over 130 nations will meet in Copenhagen, Denmark this coming December. This is an incredibly important meeting to negotiate a new agreement to control greenhouse gas emissions. Members of the U.S. House of Representatives and the Senate have stated their intention to develop legislation to regulate greenhouse gases. And the Environmental Protection Agency is planning to release a federal register notice soon to establish a mandatory greenhouse gas reporting system.

However, in order to evaluate programs, either mandatory or voluntary, for controlling greenhouse gases, we must be able to track emissions accurately. We need an accurate measurement of baseline emissions. We need to know the emissions levels we are starting from, and we need a good baseline estimate as a benchmark to determine whether control programs are effective or not in reducing emissions.

We have experience and technologies to monitor emissions from utilities that we gained through the acid rain program under Title IV of the *Clean Air Act.* However, there are many more entities that need to be monitored under a greenhouse, ocean acidification gas control program and some of these organizations have to initiate new programs to track emissions accurately.

If we are going to develop a program to control greenhouse and ocean acidification gas emissions, we need to start developing tools that will enable regulated entities to track their emissions using methods that are accurate and that are not overly burdensome.

We have an excellent panel of witnesses today here to tell us about how this could work. All of our witnesses bring extraordinary expertise. I look forward to their testimony and to their recommendations on how we can ensure that information on greenhouse and ocean acidification gas emissions provides a reliable measure of emission sources and of the effectiveness of policies we may put in place to control the emissions.

[The prepared statement of Chair Baird follows:]

PREPARED STATEMENT OF CHAIR BRIAN BAIRD

Good morning and welcome to the first hearing of the Subcommittee on Energy and Environment in the 111th Congress. I am looking forward to working with all of you over the next two years.

This morning's hearing provides us with an opportunity to examine the quality of the information that is being collected on the emissions of greenhouse gases. A number of states have established programs to address climate change and to reduce their greenhouse gas emissions. Over 130 nations will meet in Copenhagen, Denmark this coming December to negotiate a new agreement to control greenhouse gas emissions. Members of the U.S. House of Representatives and the U.S. Senate have stated their intention to develop legislation to regulate greenhouse gases. And, the Environmental Protection Agency is planning to release a *Federal Register* notice soon to establish a mandatory greenhouse gas reporting system.

In order to evaluate programs—either mandatory or voluntary—for controlling greenhouse gases, we must be able to track emissions accurately. We need an accurate measurement of baseline emissions. We need to know the emissions levels we are starting from and we need a good baseline estimate as a benchmark to determine whether control programs are effective or not in reducing emissions.

We have experience and technologies to monitor emissions from utilities that we gained through the acid rain program under Title IV of the *Clean Air Act.* However, there are many more entities that need to be monitored under a greenhouse gas control program and some of these organizations have to initiate new programs to track their emissions accurately.

If we are going to develop a program to control greenhouse gas emissions, we need to start developing tools that will enable regulated entities to track their emissions using methods that are accurate and that are not overly burdensome.

We have an excellent panel of witnesses with us here this morning whose experience encompasses all three aspects of our hearing topic today. I look forward to their testimony and to their recommendations on how we can ensure that information on greenhouse gas emissions provides a reliable measure of emission sources and of the effectiveness of the policies we put in place to control these emissions.

Chair BAIRD. With that, I would recognize my friend and colleague, Mr. Inglis, for his opening statement.

Mr. INGLIS. Thank you, Mr. Chairman, and first of all, let me congratulate you on having the gavel in this committee. For those of you who don't know, Dr. Brian Baird is really quite an expert on the topics he was just speaking about and has taught me a great deal. And I think it really is a great thing to have you in the chair, and we look forward to working with you in a collaborative fashion. You know, my view is that compromise is not really what we want. That is a zero-sum game where somebody has won and somebody else has papered over a loss. Collaboration is where you draw the strengths from both parties, and you figure out how to use those strengths to produce something better than either party acting alone could produce. And so that is the spirit that I think that Chairman Baird brings to this committee and one that I also want to make evident here.

And so I am excited about this first hearing in this committee because I am hoping the panel, Mr. Chairman, is going to help with an idea that we are working on in my office that I have mentioned to you. It has to do with a revenue-neutral carbon tax as perhaps a better idea than a cap-and-trade system. Two problems with cap-and-trade, one is a massive tax increase. Second, it has the vicissitudes of the prices of the credits going up and down, up and down, traded by Wall Street traders. I don't think that sounds too good in today's environment. But a revenue-neutral carbon tax, transparent so that we can see what the tax is, and revenue-neutral, which starts with an equal, offsetting tax reduction—the payroll tax—means that technology then has a source of funding. Reduce the payroll tax and impose a price on carbon and now people have money in their pocket to afford the new technology and to drive into the energy market the kind of transformational change that we saw with the Internet and the PC. What Microsoft and Apple did for the Internet and the PC, I think the revenue-neutral carbon tax can do for energy. It can make it so that entrepreneurs and inventors get married at a certain point on that line of that transparent carbon tax because there will be clear price signals as to when they should marry and when they should take out the incumbent technology.

So the reason that this hearing is relevant to that is that we are also trying to figure out a way to make that so that it does not punish American manufacturing, and the key to that is perhaps a WTO compliant, and we are struggling to get it WTO compliant but I think we can get there, border adjustment so that when products come in from overseas, we are happy to have them. It is just that we want to apply the same tax that we have applied domestically to those imported goods. And one of the key challenges there is figuring out how do you make that fair adjustment. And if you can tell me some scientific way that we can judge the carbon output, or I should say carbon input, into those products that are being imported, and particularly if it is something mathematical, some easy way of doing that—of course that easy part may be a little bit difficult—but if there was some way to project what is the carbon footprint of imported goods and then apply it equally to domestically produced goods so that then you really are looking at the spirit of WTO compliance, and perhaps we can work it into technical compliance as well with WTO rules.

So I am excited about this hearing because I am hoping you have some insights into that and how this monitoring might—that the measuring devices that you are talking about may help us as we try to figure out a way to measure the carbon footprint of goods produced and imported here. It is a key part of this revenue-neutral carbon tax concept. It is also one of the more complicated parts of it because the last thing we want is to have American manufacturing subject to this and say the developing world exempt from it. That results simply in the export of American manufacturing capacity, and that is why Kyoto failed 96 to nothing in the U.S. Senate.

So we can improve on that if we collaborate, and I am happy to be next to my friend, Dr. Baird, here on the Committee and hope that we can collaborate and look forward to learning from this panel today, Mr. Chairman.

[The prepared statement of Mr. Inglis follows:]

PREPARED STATEMENT OF REPRESENTATIVE BOB INGLIS

Thank you for holding this, the first Energy and Environment Subcommittee hearing of the 111th Congress, Mr. Chairman. This committee has a long-standing reputation for bipartisanship and cooperation, and I look forward to carrying on that tradition with you in this subcommittee.

Last summer, the cap and trade bill withered in the Senate. By itself, cap and trade is a massive tax increase. That's not such a good idea in the midst of this economic downturn.

A better solution is to put a price on carbon, and give the consumer a way to pay for it. All it will take is a simple carbon tax coupled with an equal, offsetting reduction in payroll taxes. We need to impose a tax on the thing we want less of (carbon dioxide) and reduce taxes on the things we want more of (income and jobs).

Improving our ability to monitor emissions will help us push industry, utilities, and manufacturers, to finally internalize the external costs of carbon emissions. A carbon tax would attach the national security and environmental costs to carbon-based fuels like oil, and cause the market to recognize the price of these negative externalities. That, in turn, can lead us to improve our efficiency in energy and manufacturing production, create new jobs in a competitive clean energy market, and reduce our dependence on foreign oil.

I'm excited about this hearing, because it gives us a glimpse of the tremendous opportunity we have as a country to jump-start a new energy economy. I'm eager to hear from our witnesses today, and would invite their thoughts on how to monitor and verify emissions in international countries like China and India.

Thank you again for holding this hearing, Mr. Chairman.

Chair BAIRD. Thank you, Mr. Inglis, for your comments. If there are other Members of the Committee who want to submit additional opening statements, your statements will be added to the record at this point.

[The prepared statement of Mr. Costello follows:]

PREPARED STATEMENT OF REPRESENTATIVE JERRY F. COSTELLO

Thank you, Mr. Chairman, for calling this hearing today and thank you to our panelists for their testimony.

The issue of regulating Greenhouse Gasses (GHGs) is particularly timely as Congress begins to consider wide-sweeping climate change legislation during the 111th session. To ensure the success of a cap and trade system, permits for GHGs must be accurately reported and assigned a fair price in order to establish a functioning market. Incorrect emissions data can undermine a program's legitimacy and effectiveness.

As we all know, climate change is not just a phenomenon unique to the United States, it is a global problem. It is integral that our own system of calculating and reporting emissions be established and precise, not only to ensure its success, but also to effectively coordinate the framework and structure with other international standards.

Many energy industries in the U.S. and around the world are in flux-waiting, relying on Congress to address the incredibly important policy issue of global warming. It is imperative that the measurements and standards upon which we base our policies are thoughtfully considered and accurate. I believe this hearing is a step towards that end.

Thank you, Mr. Chairman for my time and I look forward to hearing from the panel.

[The prepared statement of Ms. Johnson follows:]

PREPARED STATEMENT OF REPRESENTATIVE EDDIE BERNICE JOHNSON

Good morning, Mr. Chairman and Ranking Member.

For any policy regarding cap and trade of greenhouse gas emissions, we must have good information on how to measure these emissions.

Measurement, reporting, and verification truly are the backbone of a cap and trade or any other greenhouse gas control scheme.

In addition, we need to be able to determine baseline emissions, so that we can then define appropriate emissions caps. Only then can we properly allocate allowances under a cap and trade system.

The Science Committee has an important role to play here. Hearings like today's will help inform us and give us a sense of the issues to be considered that will be the foundation of any greenhouse gas-reducing policy.

The witnesses who will join us are true subject experts. It is my hope that they can provide Subcommittee Members with good information that is based on science.

I want to commend Chairman Baird for holding this hearing.

While I anticipate that we may get into some pretty technical details on just how these emissions are quantified, this is just the kind of information we need.

Many of the Members of the Science Committee are themselves scientists.

Many Members of this subcommittee, like me, represent energy producing states. We care deeply about this issue and have a strong stake in the proceedings.

We recognize that the Federal Government has some voluntary reporting repositories for greenhouse gas emissions.

Also, some states are moving toward mandatory reporting requirements for such emissions.

I am interested to know the witnesses' opinions of the two federal voluntary reporting programs: the Environmental Protection Agency's (EPA's) Climate Leaders Program and the Department of Energy's Voluntary Reporting of Greenhouse Gases Program or the 1605(b) program.

EPA is expected to issue a notice of proposed rule-making for a mandatory greenhouse gas reporting program soon.

Mr. Chairman, as a nurse, I am concerned about the effect that global warming could have on our world food supply. I am concerned that the ice caps at the Earth's poles are melting. I am concerned that devastating storms like Hurricanes Katrina, Rita and Ike are damaging Texas and other gulf states with increasing frequency.

Greenhouse gas emissions are at the root of many of these problems. We cannot delay in implementing science-based policies to mitigate these harms.

The United States must demonstrate leadership on this issue. Only then will other nations move toward positive changes regarding greenhouse gas emissions.

Thank you, Mr. Chairman. I yield back the balance of my time.

Chair BAIRD. At this point I would like to introduce our witnesses. Mr. John Stephenson is the Director of Natural Resources and Environment at the Government Accountability Office. Ms. Jill Gravender is the Vice President for Policy at The Climate Registry. Ms. Leslie Wong is the Director of Greenhouse Gas Programs at Waste Management, Inc., and Mr. Rob Ellis is the Greenhouse Gas Program Manager at Advanced Waste Management Systems, Inc.

As our witnesses know, you will each have five minutes for your spoken testimony. Your written testimony will be included in the record for the hearing, and when you have all completed your spoken testimony, we will begin with questions. Each Member of the panel here will have five minutes to question, and we appreciate again your presence here and look forward to your input. We will start with Mr. Stephenson.

STATEMENT OF MR. JOHN B. STEPHENSON, DIRECTOR, NATURAL RESOURCES AND ENVIRONMENT, U.S. GOVERNMENT ACCOUNTABILITY OFFICE

Mr. STEPHENSON. Thank you, Mr. Chair, and other Members of the Subcommittee. I am here today to talk about the importance of developing reliable emissions data for carbon dioxide and other greenhouse gases. In other words, we must know how many tons of such gases are actually released into the atmosphere by power plants, industrial facilities, and thousands of other emitting sources, and be able to measure the changes in those emissions over time before we can successfully institute any market-based mitigation scheme such as cap-and-trade or the tax program we just heard about that would create a price for all six primary greenhouse gases—carbon dioxide, nitrous oxide, methane, and the three synthetic gases.

It is important to note that the data needs, whether emissions on a facility-specific basis or emissions on an economy-wide basis, depend on the point at which the program regulates emissions, that is, whether the program attempts to regulate a small number of up-stream emitters such as fossil fuel producers and importers or, instead, a much larger number of downstream emitters such as individual industrial facilities.

For example, an upstream program for carbon dioxide would likely regulate fewer than 3,000 sources and cover virtually all carbon dioxide emissions from fossil fuels, whereas a downstream program would regulate about 10,000 large emitters, like power plants, and cover only about half of the total carbon emissions. In general, the challenges in establishing baseline emissions data, as well as in monitoring, reporting, and verifying those emissions over time will increase as the number of regulated entities' activities and greenhouse gases increase. Upstream programs would generally have less complex data requirements than downstream programs. The U.S. has economy-wide fuel use data which could be used for an upstream program, but this would not be suitable for facility-level emissions data needed for a downstream program.

The U.S. also has facility-specific data for carbon dioxide emissions, as you mentioned, for coal-fired power plants, but such data is not available for other greenhouse gases or other industry sectors. Experiences with existing cap-and-trade programs demonstrate the criticality of quality emissions data. For example, the U.S. has, since 1995, operated a highly successful cap-and-trade program to limit the emissions of sulfur dioxide, not a greenhouse gas but a pollutant that causes acid rain. The Acid Rain Program has been successful largely because regulated entities are required to routinely monitor, report and verify emissions. On the other hand, as we reported in November 2008, the European trading scheme has been less successful largely because of the lack of quality emissions data, causing an inaccurate allocation of allowances in the beginning and the price of a ton of carbon to plummet to zero.

It is important to note that the EU program is attempting to regulate only one greenhouse gas, carbon dioxide, in only one industry sector, the power sector. Data on emissions for other greenhouse gases in sectors such as methane from landfills, nitrous oxide from agricultural operations, is far less refined than that for carbon dioxide. Determining emissions of these gases will be more challenging due to limited historical monitoring and a lack of reliable emissions factors. Nevertheless, comprehensive reliable emissions data for all greenhouse gases in all sectors will be essential for any market-based mitigation scheme, whether cap-and-trade or tax currently being debated in the Congress.

There are some existing emissions inventories and registries, and you will hear about some today, that provides a starting point for understanding the challenges in establishing baselines and tracking emissions over time. For example, the U.S. Environmental Protection Agency maintains an official U.S. emissions inventory to meet our commitments to the U.N. Framework Convention on Climate Change. This inventory uses models to estimate emissions at the national and the industry sector level and would not be suitable for a downstream cap-and-trade system. Several private and non-profit efforts also provide data collection services. For example, the World Resources Institute Greenhouse Gas Protocol is a widely used international accounting system for quantifying and managing greenhouse gas emissions, and it has developed accounting and reporting standards that are compatible with most inventory programs. In addition, The Climate Registry that you will hear about next includes standards for emissions monitoring and for reporting those emissions through its website. The Chicago Climate Exchange also has emissions reduction and trading scheme and requires its participants to use specific protocols to establish emissions baselines and track progress toward emissions reduction goals. But none of these inventories or the registry is at the scope or complexity contemplated for a nationwide program.

In conclusion, Mr. Chair, we believe this hearing highlights a critical element of the climate change debate, the need to develop high-quality emissions baselines for all greenhouse gases in all sectors and the ability to monitor, report, and verify future emissions against those baselines.

Thank you, Mr. Chair. That concludes my statement. I would be happy to answer questions at the appropriate time.

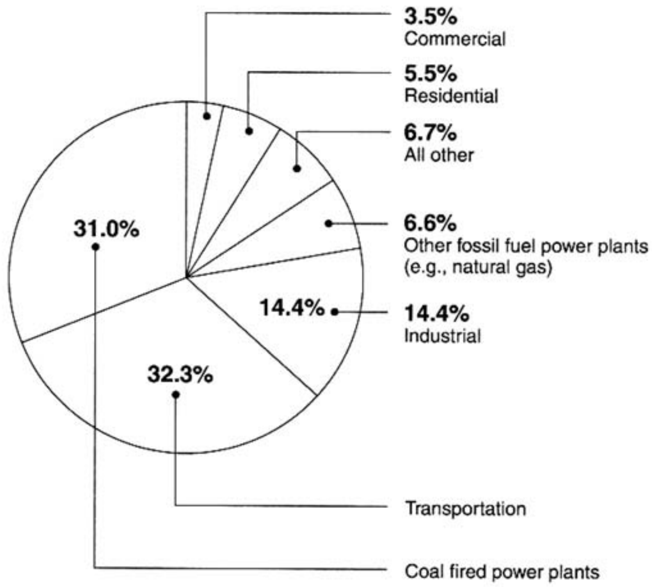
[The prepared statement of Mr. Stephenson follows:]

PREPARED STATEMENT OF JOHN B. STEPHENSON

Mr. Chairman and Members of the Subcommittee:

I am pleased to be here today to discuss the importance of high quality data on greenhouse gas emissions in the development and implementation of programs intended to address climate change. In recent years, key scientific assessments have underscored the importance of reducing or stabilizing emissions of carbon dioxide and other greenhouse gases—including methane, nitrous oxide, and several synthetic gases—to mitigate the adverse effects of climate change. According to the National Academy of Sciences, global temperatures have already risen 1.4 degrees Fahrenheit since the start of the 20th century—with much of this warming occurring in the last 30 years—and temperatures will likely rise at least another two degrees Fahrenheit, and potentially more than 11 degrees, over the next 100 years. Most scientists agree that the warming in recent decades has been caused primarily by human activities that have increased the amount of greenhouse gases in the atmosphere. This warming will cause significant changes in sea level, ecosystems, and ice cover, among other impacts. In the Arctic region, temperatures have increased almost twice as much as the global average, and the landscape is changing rapidly. Figure 1 below identifies the contribution of carbon dioxide emissions, the most prevalent greenhouse gas, from various sources in the United States.

Figure 1: Contribution of Various Sources to Total U.S. Carbon Dioxide Emissions



Source: GAO analysis of data Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2006* (April 2008).

The Congress is currently considering various proposals to address or mitigate the adverse effects of climate change, including actions to limit greenhouse gas emissions. In the United States, most debate over mitigation options generally focuses on market-based programs—such as carbon tax or cap-and-trade system—that would create a price on emissions of greenhouse gases. For either program, the point of regulation may occur (1) "upstream" and cover sources of carbon dioxide when they first enter the economy, such as fossil fuel producers; (2) "downstream" and cover direct and indirect emitters, such as power plants; or (3) at a combination of upstream and downstream sources.

In general, under a cap-and-trade program, the government would limit the overall amount of greenhouse gas emissions from regulated entities. These entities would need to hold allowances for their emissions, and each allowance would entitle them to emit a specific amount of a greenhouse gas. Under such a program, the government could sell the allowances, give them away, or some combination of the two. Firms that find ways to reduce their carbon dioxide emissions to below their allowed limit could sell their excess allowances to firms that emit more than their limits, effectively creating a market for allowance trading and establishing a price for a ton of emissions based on supply and demand.

Another possible mitigation policy is a tax on greenhouse gas emissions. A tax would establish a direct price on emissions by levying a charge on every ton of carbon dioxide emitted, creating an economic incentive for emitters of greenhouse gases to decrease their emissions by, for example, using fossil fuels more efficiently. Unlike a cap-and-trade program, a tax would provide more certainty as to the cost of emitting greenhouse gas emissions, but the precise effect of the tax in reducing emissions would depend on the extent to which producers and consumers respond to higher prices.

In discussing the emissions data required for a climate change mitigation program, it also is useful to distinguish between emissions inventories and emissions registries. Emissions inventories aggregate emissions data on a high level—for example, by state, industrial sector or country. Inventories generally account for greenhouse gases emitted and removed from the atmosphere over a specific timeframe. An emissions registry, on the other hand, is a tool for collecting, verifying, and tracking emissions data from individual facilities or projects. Because registries can serve a variety of purposes, their structures may vary substantially. For example, registries may vary in terms of the gases monitored, the timing of data collection, and the method of data verification.

In this context, my testimony today discusses (1) the need for high quality data on emissions in the context of a program intended to limit greenhouse gas emissions, and (2) key considerations in developing reliable data on greenhouse gas emissions. This testimony is based on our previously issued work and a review of relevant literature.[1]

High Quality Emissions Data Are Critical to the Integrity of Programs Intended to Limit Greenhouse Gas Emissions

The domestic and international experiences with market-based air pollution control and climate change programs demonstrate that comprehensive and accurate information on emissions is critical to a program's success. Since 1995, the United States has operated a cap-and-trade program to limit sulfur dioxide emissions, an air pollutant that contributes to acid rain, from electric utilities. Under Title IV of the *Clean Air Act Amendments of 1990,* this program has reduced sulfur dioxide emissions by capping total emissions, distributing allowances to emit sulfur dioxide through a combination of free allocation and auctions, and allowing electric utilities to buy and sell allowances as needed to cover their emissions.

Prior GAO reports and independent studies have shown that strong data collection, monitoring, reporting, and verification requirements have been central to this program's success. First, with respect to setting a baseline level of emissions from regulated entities, the program relied on data spanning several years rather than any one year in particular. Specifically, it used historical average emissions from 1985 to 1987 as the baseline against which to measure reductions required to begin in 1995 and 2000. The use of historical data reduced the covered entities' incentive to increase emissions prior to the program's establishment to obtain a greater allowance allocation—the baseline years occurred too far before the announcement of the program.[2] Averaging these data across several years also helped to ensure that the baseline reflected changes in emissions that can result in a given year due to economic and other conditions. As a result, the program achieved greater assurances that it reduced emissions from historical levels. In addition, electricity generating units regulated under Title IV of the *Clean Air Act Amendments of 1990* are required to monitor and report their sulfur dioxide, nitrogen oxide, and carbon dioxide emissions, among other data. The monitoring and reporting requirement has ensured a high degree of compliance and overall program integrity. It is important to note that regulating a single pollutant, such as sulfur dioxide, from a largely homogeneous population of electric utilities is less complicated than monitoring, reporting, and verifying emissions of up to six different greenhouse gases from diverse types of facilities.

The European Union also has experience implementing a cap-and-trade program that illustrates the importance of quality data in a market-based system. As discussed in our November 2008 report, the European Union's Emissions Trading Scheme (ETS) relies on a cap-and-trade model similar to that used in the U.S. acid rain program.[3] The ETS began with a learning period—phase I—to gain experience with emissions trading from 2005 to 2007. Phase I included approximately 11,000 electric power and industrial installations in 25 member states, which accounted for about half of the EU's carbon dioxide emissions.

While the first phase provided key lessons about emissions trading, its cumulative effect on emissions is uncertain because of a lack of baseline emissions data. In the first phase, each EU member state had to identify which entities to regulate under the ETS (such as power plants, oil refineries, and other manufacturing facilities), obtain baseline emissions data for the covered entities, establish an emissions cap, and determine how many allowances to distribute to each covered entity. At the

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[1] We conducted our work in accordance with all sections of GAO's Quality Assurance Framework that were subject to the objectives of each engagement. The framework requires that we plan and perform each engagement to obtain sufficient and appropriate evidence to meet our stated objectives and to discuss any limitations in our work. We believe that the information and data obtained, and the analyses conducted, provided a reasonable basis for the findings and conclusions in these reports.

[2] See GAO, *Air Pollution: Allowance Trading Offers an Opportunity to Reduce Emissions at Less Cost,* GAO/RCED–95–30 (Washington, D.C.: Dec. 16, 1994).

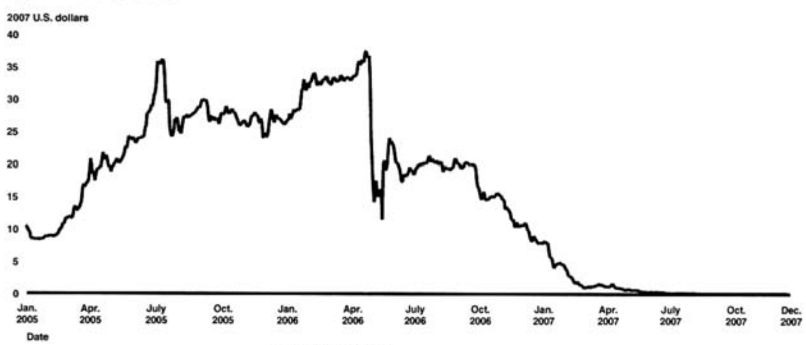
[3] See GAO, *International Climate Change Programs: Lessons Learned from the European Union's Emissions Trading Scheme and the Kyoto Protocol's Clean Development Mechanism,* GAO–09–151 (Washington, D.C.: Nov. 18, 2008).

time, most member states had high-level, aggregated estimates on carbon dioxide emissions that accounted for sources within and outside the scope of the ETS, but did not have baseline data on a facility-specific basis. This facility-specific data was necessary to determine both the total emissions released by all entities covered under the ETS—a downstream program—as well as how many allowances each particular entity would need to cover its annual emissions. In addition, some member states had limited authority to collect data because they did not yet have in place a national law or regulation mandating submission of emissions data. Accordingly, member states based their emissions caps and allocation decisions on business-as-usual emissions projections and baseline data voluntarily submitted by covered entities.

The inherent uncertainty about business-as-usual projections—i.e., how actual emissions compare to the emissions that would have occurred in the absence of the ETS—was compounded by the assumptions underlying the models used by member states to forecast emissions. The models incorporated assumptions about factors that influence business-as-usual emissions projections, such as economic growth and relative fuel prices. Some member states made relatively optimistic assumptions about economic growth, which resulted in higher projections of emissions. As such, while the first phase provided key lessons about emissions trading, the lack of facility-specific baseline data means its cumulative effect on emissions is uncertain.

The lack of facility-specific baseline data also affected the price of ETS allowances. Under the ETS, covered entities are required to report emissions data that have been verified by third parties to their member states. In 2006, the release of emissions data revealed that the supply of allowances—the cap—exceeded the demand, and the allowance price collapsed. This illustrated the problems that can arise when a program relies on poor baseline emissions data and highlighted the need for accurate baseline data in setting an effective emissions cap and achieving the intended environmental objectives. See Figure 2 for a graph displaying the allowance price trends in phase I.

Figure 2: EUA 2007 Prices



Source: Point Carbon (2007).

As we reported in our prior work on lessons learned from the international climate change programs, many experts participating on a panel we assembled in cooperation with the National Academy of Sciences would not expect the United States to encounter the data challenges experienced in the EU's first trading phase because some baseline emissions data are already available.[4] Several experts also stated that existing data on fossil fuel consumption are sufficient to establish an emissions trading program. These data can be used to estimate economy-wide carbon dioxide emissions as well as facility-specific data on carbon dioxide emissions from certain industrial sectors, such as power plants that have participated in the U.S. sulfur dioxide emissions trading program.

Collecting and reporting emissions data can also provide benefits beyond ensuring the integrity and results achieved through a greenhouse gas reduction program. Such data can be used by researchers to analyze environmental conditions and trends, create atmospheric and economic models, and provide early warning of potential environmental problems. It can also help inform and direct environmental

[4] See GAO–09–151.

management efforts. The availability of emissions data may aid strategic planning in the private sector, enabling individual firms to make better-informed decisions pertaining to capital investments and energy use. Because many states, municipalities, and private firms have established voluntary climate goals, emissions data will enable these organizations to assess progress and better account for performance. Finally, the availability of emissions data can provide a consistent and transparent basis for comparison between countries, industries, and individual firms and enhance public understanding of emissions sources.

Collecting Reliable Data on Greenhouse Gas Emissions Involves Key Considerations

Monitoring, reporting, and verification needs for reliable data on greenhouse gas emissions depend first on the purpose and intended use of the data; for example, the data required for a mandatory program to limit emissions may vary substantially from that required for a business or governmental entity that voluntarily tracks its emissions for public relations or other purposes.

First, as we have previously reported, the scope of a data collection effort—i.e., monitoring, reporting, and verification activities—is determined by the program's point of regulation. An upstream mitigation program would affect a relatively small population of regulated entities, such as fuel importers and producers, whose products could be less difficult to measure and report. The quantity of emissions associated with those products could be calculated using available emissions factors.[5] Under a cap-and-trade program, each importer or producer would have to hold an allowance for each ton of carbon dioxide emissions associated with its products. Alternatively, under an emissions tax, each regulated entity would have to pay the government a pre-determined amount of money for each ton of emissions associated with the combustion of its products. Under either system, accurate reporting and verification of emissions would help ensure the integrity of the program, and accurate and reliable baseline data would be necessary to track progress.

On the other hand, data collection, monitoring, and verification requirements become more substantial under a downstream program because it could affect a larger population of regulated entities, potentially including industrial facilities, agricultural operations, mobile and other fuel combustion sources, and users of refrigerants. Again, each regulated entity would need to have accurate and reliable data on historical and current emissions, and in some cases, gathering such information would be relatively straightforward. For example, electricity generating units regulated under Title IV of the *Clean Air Act Amendments of 1990* are required to monitor and report their carbon dioxide emissions. However, other regulated entities may face greater challenges in determining their emissions due to limited monitoring data or a lack of reliable emissions factors.

Furthermore, the data requirements for a mitigation program become more complex and challenging as the number and types of covered activities increases.[6] This challenge may be of particular concern in a downstream program that covers emissions from diffuse sources. Of the six primary greenhouse gases, emissions of some are better characterized than others.[7] For example, carbon dioxide emissions from energy-related activities and cement processing are relatively easy to estimate with a high degree of accuracy, whereas measuring the emissions of other greenhouse gases stemming from other types of activities is more challenging. Specifically, there may be insufficient scientific understanding to develop a data collection methodology, data may be incomplete or missing, or emissions factors may not be sufficiently developed. For instance, nitrous oxide emissions occur from the production of caprolactam—a chemical used to produce a polymer—but there are currently not enough data on the production of caprolactam to estimate these emissions in the United States.

In some cases, existing emissions inventories and registries that have been developed for a variety of purposes could help regulated entities in meeting potential requirements to establish baseline emissions levels and monitor, verify, and report

[5] An emissions factor is a representative value that attempts to relate the quantity of a pollutant released to the atmosphere with an activity associated with the release of that pollutant. These factors are usually expressed as the weight of pollutant divided by a unit weight, volume, distance, or duration of the activity emitting the pollutant (e.g., kilograms of particulate emitted per megagram of coal burned). Such factors facilitate estimation of emissions from various sources of air pollution. See, for example, EPA's AP–42 emissions factors, available at *http://www.epa.gov/ttn/chief/ap42/*

[6] See GAO–09–151.

[7] See U.S. EPA, Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2006 (April 2008), *http://www.epa.gov/climatechange/emissions/usinventoryreport.html*

their ongoing emissions. For example, the United States Environmental Protection Agency prepares an official U.S. greenhouse gas inventory each year to comply with its commitments under the United Nations Framework Convention on Climate Change (UNFCCC). This inventory provides national information on the activities that cause emissions and removals, as well as background on the methods used to make the calculations. In addition to the U.S. inventory, multi-state emissions reduction programs, such as the Regional Greenhouse Gas Initiative, a regulatory program targeting reductions in carbon dioxide from electricity generators, have developed emissions inventories to guide their programs. Many individual states also prepare greenhouse gas inventories using guidance provided by EPA. These existing inventories and registries could assist in the development of a mandatory emissions reduction program.

Other emissions inventories and registries developed by government and private entities also provide a useful starting point for understanding data requirements for establishing emissions baselines and monitoring, verifying, and reporting greenhouse gas emissions.[8] For example, the Department of Energy's Voluntary Reporting of Greenhouse Gases Program encourages corporations, government agencies, non-profit organizations, households, and other private and public entities to annually report their greenhouse gas emissions, emission reductions, and sequestration activities to a registry using consistent standards.[9] In addition, EPA's Climate Leaders Program, an EPA industry-government partnership that works with companies to develop comprehensive climate change strategies, has developed standards to measure and monitor emissions reductions from certain types of projects.

Several private and nonprofit efforts also provide data collection services. For example, the Greenhouse Gas Protocol, a widely-used international accounting system for quantifying and managing greenhouse gas emissions, has developed accounting and reporting standards that are compatible with most greenhouse gas inventory programs.[10] Another effort, the Climate Registry, is a nonprofit collaboration involving U.S. states and Canadian provinces that has developed standards to calculate, verify, and report greenhouse gas emissions. Both voluntary and mandatory programs can use the Climate Registry's standards and publicly report their emissions through its website. Other private initiatives, such as the Chicago Climate Exchange (CCX), a voluntary emission reduction and trading system, requires participants to establish emissions baselines and track their progress towards emissions reduction goals. Emissions reductions through CCX must be confirmed by an independent, third-party verifier. Finally, an entire industry of companies exists to help companies track and monitor their greenhouse gas emissions and many have developed protocols and best practices for measuring baseline emissions levels and tracking reductions. Many of these companies also provide external third-party verification services to help industrial and other facilities ensure the accuracy of their emissions accounting practices.

Mr. Chairman, this concludes my prepared statement. I would be happy to respond to any questions that you or other Members of the Subcommittee may have at this time.

BIOGRAPHY FOR JOHN B. STEPHENSON

Mr. Stephenson is currently the Director of Natural Resource and Environment issues for the U.S. Government Accountability Office—the independent investigative arm of the Congress. In that capacity, he has for the past nine years directed numerous studies and research projects, issued hundreds of reports, and testified on many occasions before several Senate and House Committees. His work has provided invaluable assistance to the Congress in its oversight and legislative role on diverse environmental protection issues such as clean air, clean water, safe drinking water, chemical controls, toxic substances, climate change, superfund, and hazardous materials spill prevention and cleanup, as well as critical infrastructure protection.

Prior to his current position, he led numerous GAO studies and investigation in the information technology and federal acquisition and federal grant areas. He has

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[8] Pub. L. No. 110–161, tit. II, 121 Stat. 1844, 2128 (2007) directs EPA to develop a rule requiring mandatory reporting of greenhouse gas emissions from all sectors of the economy.

[9] Sequestration activities refer to biological projects that pull carbon dioxide out of the air by, for example, planting trees or enhancing the management of agricultural soils, and geological projects that capture and store carbon dioxide in underground formations.

[10] The Greenhouse Gas Protocol was developed by the World Resources Institute, a U.S. nongovernmental organization, and the World Business Council for Sustainable Development, a Geneva-based coalition of 170 international companies.

extensive experience in dealing with Congressional Committees and Members, federal agencies, trade associations, special interest groups, and State and local governments. From April 1998–February 2000, he was Deputy Staff Director for the Senate Special Committee on the Year 2000 Technology Problem for the Chairman (Senator Robert Bennett, R–UT), and Vice Chairman (Senator Christopher Dodd, D–CT). In that capacity, he ran the day-to-day operations of the Committee including orchestrating over 35 hearings, preparing legislation, organizing briefings and floor activities for the full Senate, working with the White House's Year 2000 Director and staff, and organizing numerous press and public events. He returned to GAO in March 2000 where he was executive assistant to the U.S. Comptroller General (the head of GAO) until entering the Senior Executive Service in October 2000.

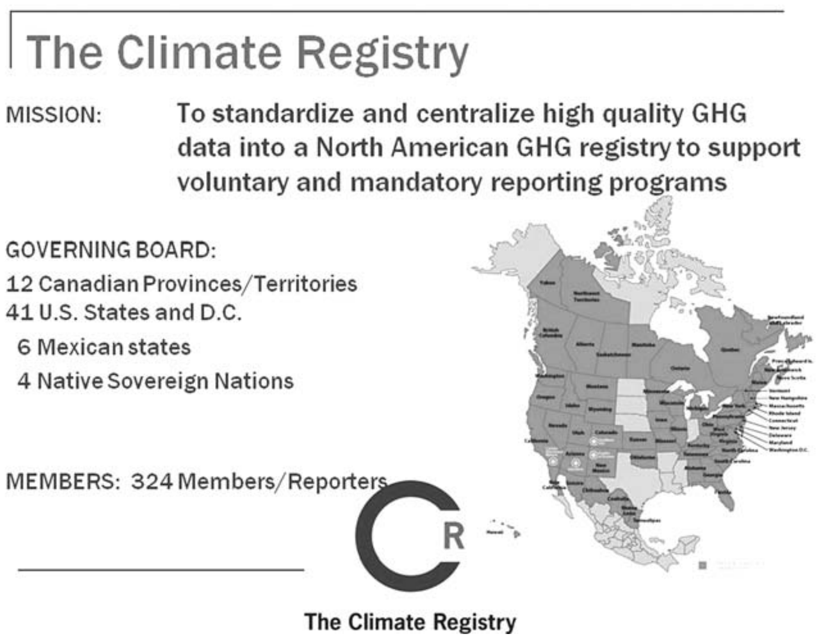
Mr. Stephenson holds a BS degree in Industrial Management from Purdue University, an MBA from Xavier University, and is a graduate of the Harvard Kennedy School of Government's Senior Executive Fellows program. He lives in Fairfax Station, Virginia with his wife, 11-year-old daughter, and 9-year-old son. He also has two grown sons who reside in Cincinnati, Ohio.

Chair BAIRD. Thank you. Ms. Gravender.

STATEMENT OF MS. JILL E. GRAVENDER, VICE PRESIDENT FOR POLICY, THE CLIMATE REGISTRY

Ms. GRAVENDER. Good morning Chair Baird and distinguished Members of the Subcommittee. Thank you for the opportunity to testify before you today. As an organization committed to the accurate and transparent reporting and verification of greenhouse gas emissions, The Climate Registry is pleased to brief the Subcommittee on these important topics.

First, I would like to provide a bit of background on The Climate Registry. The Registry is a non-profit organization created in a collaborative effort by North American states, provinces, territories and Native Sovereign Nations. The Registry is governed by a unique Board of Directors which today consists of representatives from 41 U.S. states and the District of Columbia, 12 Canadian provinces and territories, six Mexican states, and four Native Sovereign Nations.



In the map that is projected before you, the participating jurisdictions are highlighted in green.

The concept of The Registry took shape as states became increasingly interested in taking progressive action on climate change. They realized the opportunity to collaborate with one another to create a unified North American Greenhouse Gas Registry. As a result, The Registry's mission is to set consistent and transparent standards to calculate, verify and publicly report greenhouse gas emissions into a single North American registry. The Registry supports both voluntary and mandatory greenhouse gas programs and provides comprehensive data to promote the reduction of greenhouse gas emissions. To date, The Registry has more than 320 members representing large Fortune 500 companies, electric utilities, municipalities, colleges and universities, government agencies, and small businesses. The Registry's voluntary greenhouse gas reporting program is a rigorous initiative that requires its members to report their corporate-wide emissions of all six Kyoto gases from their operations throughout North America annually at the facility level. This program is based on two important international greenhouse gas accounting standards, namely, the World Resource Institute/World Council for Sustainable Development's Greenhouse Gas Protocol and the International Standard for Greenhouse Gas Accounting, ISO 14064–1. These standards are compatible and complementary and have become the foundation for greenhouse gas accounting globally.

The Registry's General Reporting Protocol, or GRP, builds upon these standards and provides specific direction on how to assemble greenhouse gas inventories and answers common questions such as, how do I report leased vehicles. Who reports if there are multiple owners of a facility? And how do I treat acquisitions? It is important to note that greenhouse gas reporting is substantially different from reporting criteria pollutants, which typically can be measured from smokestacks, since greenhouse gas emissions are ubiquitous and come from both large and small sources.

One of the most important aspects of The Registry's voluntary program is its requirement of annual third-party verification. Verification is a systematic, independent, and documented process for evaluating the emissions report against agreed-upon criteria. Verification is similar to an audit of financial statements. It is an external attestation to the quality and accuracy of reported information, and it creates confidence that the data is accurate. The Registry's verification and accreditation programs are also based on international standards and are explained in more detail in my written testimony.

Thus far, my testimony has focused on The Registry's voluntary program. The Registry supports both voluntary and mandatory greenhouse gas reporting programs. Many of the states and provinces comprising The Registry's Board of Directors have adopted or are in the process of adopting mandatory greenhouse gas initiatives either individually or as part of regional initiatives. The Registry is currently working with over 20 jurisdictions, including the states and provinces participating in the Western Climate Initiative and the Midwestern Greenhouse Gas Reduction Accord, to develop a common greenhouse gas data collection platform to serve mandatory programs across North America.

At the federal level, The Registry's Board of Directors recently adopted a policy statement to articulate the role it seeks for The Registry within a federal greenhouse gas reporting program. This statement is also included in my written testimony. In their statement, the Board of Directors expressed their desire for The Registry to be viewed as a model and a resource to support federal greenhouse gas registries.

The Subcommittee asked me to speak on the challenges and opportunities associated with tracking greenhouse gas emissions accurately. Before I do, I want to stress the fact that it is indeed possible for most organizations to accurately account for, report, and verify their emissions today. That said, there are challenges to reporting, and they tend to fall into two categories: organizational challenges and scientific uncertainty. Organizational challenges generally occur due to a lack of management systems specifically designed for greenhouse gas data collection. Since greenhouse gases have not been regulated before, many organizations do not have systems in place to monitor and track these emissions. Scientific uncertainty presents additional challenges to obtaining high-quality data. Quantification methods for certain sources of emissions either do not exist or contain high degrees of uncertainty. My written testimony describes specific areas of scientific uncertainty, the most notable of which is the quantification of fugitive emissions of methane. In terms of opportunities to improve the accuracy of greenhouse gas reporting, our recommendations include updating emission factors and quantification methods in a timely fashion, developing industry-specific protocols, and improving measurement technologies.

To conclude, The Registry was created to help organizations answer the very question posed by this hearing today, how do we know what we are emitting? Given the recent leadership of individual states and regions, the U.S. is well-positioned to think about emissions beyond the traditional smokestack approach and to work across State and federal jurisdictional lines to begin to tackle climate change in a new and collaborative way, and The Registry is uniquely positioned to help. We look forward to partnering with the Federal Government to serve a larger role in supporting national and North American greenhouse gas initiatives.

Thank you again for the opportunity to testify, and I would be happy to answer any questions you have.

[The prepared statement of Ms. Gravender follows:]

PREPARED STATEMENT OF JILL E. GRAVENDER

Good morning Chairman Baird and distinguished Members of the Subcommittee. Thank you for the opportunity to testify before you today.

As an organization that is committed to consistent, accurate and transparent reporting and verification of greenhouse gas (GHG) emissions, The Climate Registry (The Registry) is pleased to brief the Subcommittee on these important topics today.

In my testimony, I will:

- Provide an overview of The Registry and its voluntary GHG reporting program,
- Explain how The Registry is working to support mandatory GHG reporting programs at the State/provincial, regional, and federal levels,
- Discuss challenges to obtaining quality emissions data, and
- Provide recommendations for research that could make tracking and reporting of GHG emissions easier.

1. Overview

The Climate Registry is a non-profit organization, created in a collaborative effort by North American states, provinces, territories and Native Sovereign Nations. The Registry is governed by a Board of Directors which today consists of representatives from 41 U.S. states and the District of Columbia, 12 Canadian provinces and territories, six Mexican states, and four Native Sovereign Nations. (See Appendix A—Map of The Climate Registry's Board of Directors.)

The Registry's mission is to set consistent and transparent standards to calculate, verify, and publicly report GHG emissions into a single North American registry. The Registry supports both voluntary and mandatory reporting programs and provides comprehensive, accurate data to promote the reduction of GHG emissions.

To date, the Registry has more than 320 members—representing large Fortune 500 companies, electric utilities, municipalities, colleges and universities, government agencies and small businesses. The Registry provides its members with a series of tools to help them successfully prepare their GHG inventories This includes: trainings, informational webinars, reporting and verification tips, a support hotline, and access to our web-based user-friendly on-line reporting tool, the Climate Registry Information System (CRIS).

1.1. Evolution of The Registry:

The evolution of The Registry is an interesting, important, and unique one. Individual states began to take progressive action themselves to help mitigate the negative impacts of climate change several years ago. As states became increasingly interested in developing voluntary GHG reporting programs to track GHG emissions at the corporate level, they realized the opportunity to collaborate with one another to create a single unified GHG registry to serve all of North America. By working together they could create a centralized repository of high quality, accurate, transparent, and consistently verified GHG emissions inventories for the public.

2. The Registry's Voluntary GHG Reporting Program:

The Registry's voluntary GHG reporting program is a rigorous initiative that provides companies, governments, and organizations with the tools and technical guidance necessary to establish an accurate entity-wide inventory of their GHG emissions.

The Registry's voluntary GHG reporting program is based on two important and related international standards:

- World Resources Institute/World Business Council for Sustainable Development *Corporate Greenhouse Gas Protocol,*[1] which was the first to document key principles and concepts for corporate GHG accounting, and
- International Organization for Standardization (ISO) standard for GHG accounting (ISO 14064–1)[2]

These "standards" are compatible and complementary, and have become the foundation for GHG accounting globally. Both standards are written at a conceptual level and do not provide all of the necessary prescription for multiple organizations to compile comparable emissions inventories.

As a result, a number of organizations developed "GHG accounting protocols" based on these international standards to document specific reporting rules and requirements to ensure that the resulting GHG data would be consistent and comparable across organizations. The California Climate Action Registry (the California Registry) was one of the first organizations in the U.S. to translate the international standards into specific program protocols.

The California Registry's rigorous reporting and verification protocols became the basis for The Registry's protocols. Through a public stakeholder process, The Registry expanded and improved the California Registry's protocols to be applicable throughout North America.[3]

The California Registry is now transitioning to become the Climate Action Reserve, and will soon change its focus from entity level inventory reporting to emission reduction projects. The Climate Registry's voluntary GHG program will continue to serve as the premier voluntary registry in North America.

2.1 Key Components to the Voluntary Reporting Program

The goal of The Registry's voluntary reporting program is to provide high quality, consistent GHG emissions data to its members and the public. This "corporate-wide" or "entity-wide" approach to emissions reporting provides organizations with a comprehensive understanding of their GHG emissions sources and the total impact their operations have on the climate.

Corporations, organizations, and government agencies all voluntarily choose to join the Registry's program. By doing so, these organizations become Registry "Members" and commit to annually report and verify their emissions footprint for North America.

Members join The Registry for multiple reasons, but primarily because they are interested in:

- A cost effective means to track/manage GHG emissions;
- Access to software and technical support;
- Documenting their early actions;
- Preparing for mandatory State/federal reporting;
- Educating employees on GHG emissions;
- Gaining recognition as a global environmental leader;
- Having a voice in the development of GHG policies.

By joining The Registry members agree to report the following:

- "Entity-wide" or "corporate-wide" emissions across North America at the facility level;
- Emissions of all six internationally-recognized GHGs (carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons and sulfur hexafluoride)—the six "Kyoto Gases";
- All direct emissions—stationary combustion, mobile combustion, process and fugitive emissions (Scope 1);

[1] World Business Council for Sustainable Development (WBCSD)/World Resources Institute (WRI). Greenhouse Gas Protocol, Corporate Accounting and Reporting Standard, April 2004.

[2] 14064–1:2006, Greenhouse gases—Part 1: Specification with guidance at the organization level for quantification and reporting of greenhouse gas emissions and removals.

[3] The California Registry requires organizations to report their GHG emissions within the State of California.

- All indirect emissions from purchased electricity, steam, heating or cooling (Scope 2); and
- Emission on a calendar year basis.

Additionally, members are able to attach optional information (Scope 3 emissions, management plans, emission reduction goals) to their annual emission report in CRIS.

The Registry requires all emission reports to be third-party verified annually. Once The Registry reviews and accepts verified emission reports, The Registry makes the reports available to the public via CRIS.

2.2 The General Reporting Protocol

The basis of The Registry's voluntary reporting program is its General Reporting Protocol (GRP), which assembles international GHG accounting best practices into a user friendly document. Please refer to: *http://www.theclimateregistry.org/downloads/GRP.pdf* to view a copy of the protocol.

The Registry's GRP was developed through an open public process with input from businesses, environmental organizations, academics and GHG protocol experts and interested members of the public. The Registry intends to continue to refine the GRP over time in order to add clarity and specificity and incorporate new developments in GHG science and accounting methodologies.

The GRP contains policy guidance and GHG calculation methodologies for major emission sources for most operations (stationary combustion, mobile combustion, basic fugitive emissions, indirect emissions). Given the wide spectrum of process emissions that result from different industries, The Registry plans to develop industry specific protocols to provide further guidance to various industries.[4] Calculation methodologies for process emission from several key industries are included in Appendix E of the GRP.

The guidance in the GRP is rooted in the following GHG accounting principles:

- Relevance
- Completeness
- Consistency
- Transparency
- Accuracy

As a result, Registry members' annual emission reports contain meaningful information to help organizations better understand their GHG emissions. Since you cannot manage what you do not measure, this is a critical first step in reducing GHG emissions.

The following program design elements help The Registry ensure the accuracy and consistency of its GHG emission reports:

- Defined reporting scope (boundaries)
- Defined quantification methodologies
- Transparent data quality "Tiers"
- Automated calculation and reporting tools
- Rigorous third-party verification program

Defined Reporting Boundaries

In order to ensure consistent GHG data, the Registry requires members to define the following boundaries:

- *Geographic Boundaries:* Members must report their North American emissions, and are encouraged to report their worldwide emissions.
- *Organizational Boundaries:* Members must identify the legal entity that is responsible for reporting, and must also determine an emissions consolidation method (control and equity share or control only).

[4] The Registry released two new draft protocols for a 30-day public comment period on February 23, 2009: the Electric Sector Protocol and the Local Government Operations Protocol. Copies of the draft protocols and additional information can be found on: *www.theclimateregistry.org*. The Registry is also currently working with the Western Regional Air Partnership to develop a protocol for the oil and gas exploration and production sector. This protocol will likely be released for public comment later in 2009.

- *Operational Boundaries:* Members must report their Direct (Scope 1) and Indirect (Scope 2) emissions. Additional indirect emissions (Scope 3) are optional.

Defining these boundaries transparently helps to ensure that end-users understand the scope and content of the emission reports.

Defined Quantification Methodologies

Once sufficient boundaries are defined, members can quantify their GHG emissions. In many instances the Registry provides multiple quantification methodologies for a single source of emissions. In this case, members may choose which quantification methodology makes the most sense for their operations. The Registry approves the use of all of the listed quantification methodologies contained in the GRP for its voluntary program. The Registry allows for both calculation-based quantification and measurement-based quantification of emissions.

Transparent Data Quality Tiers

The Registry uses a tiered quantification system to rank emission quantification methodologies according to their level of accuracy. In this system, "Tier A" designates the preferred, or most accurate, approach for a given emissions source; "Tier B" represents an alternative second-best approach; and "Tier C" represents the least accurate, but still acceptable approach. In some instances, The Registry defines multiple approaches to the same tier (A1, A2, etc.). The Registry encourages members to use the highest tier possible for all emission sources.

Automatic Calculation and Reporting

To ensure members consistently and accurately quantify their emissions, The Registry developed sophisticated emission calculation tools in its CRIS application. Members enter their raw activity data (gallons of fuel use, kWh of electricity consumed, etc.), select the appropriate built in calculation methodology in the system, and the tool automatically calculates the relevant GHG emissions. This tool eliminates calculation errors in the reporting process, and facilitates reporting for members. In addition, CRIS contains built in quality assurance checks that flag potential or existing problems with a member's emission report.

2.3 The General Verification Protocol

The most important aspect of ensuring the consistency and accuracy of data in The Registry's voluntary reporting program is its rigorous verification program. Verification is the systematic, independent, and documented process for the evaluation of a member's emission report against agreed upon verification criteria. This process is similar to an audit of financial statements—it is an external attestation to the quality and accuracy of the reported emissions.

Third-party verification is necessary to provide confidence to users (State regulatory agencies, native sovereign nation authorities, investors, suppliers, customers, local governments, the public, etc.) that the emissions data submitted to the Registry represents a faithful, true and fair account of emissions—free of material misstatements and conforming to the Registry's accounting and reporting rules.

Third-party verification is becoming widely accepted for ensuring accurate emissions data, and has been relied upon by several GHG regulatory programs, including the European Union's Emissions Trading System (EU ETS) and the United Kingdom's GHG Emissions Trading System.

The Registry's General Verification Protocol (GVP) contains the verification criteria, policies and procedures that Verification Bodies must comply with when conducting verification activities for Registry members. (Please visit our website to view the GVP: *http://www.theclimateregistry.org/downloads/GVP.pdf*)

The Registry's verification program is based on the international standard for GHG verification (ISO 14064–3[5]), which outlines the following key principles of verification:

- Independence
- Ethical Conduct
- Fair Presentation
- Due Professional Care

[5] ISO 14064–3:2006, Greenhouse gases—Part 3: Specification with guidance for the validation and verification of greenhouse gas assertions.

Verification Bodies must demonstrate and embody the above criteria to successfully review and assess GHG emission reports. A Verification Body is a firm that consists of technically competent and independent personnel (Verifiers) who are knowledgeable about GHG emissions inventories, management systems, and data and information auditing.

Since the credibility of a member's emission report is attested to by a Verification Body, it is crucial that the Verification Body provide an objective review of the emissions report. To ensure that no organizational, personal, or case-specific conflicts exist between a Verification Body and a member, The Registry developed a rigorous Conflict of Interest (COI) process.

Verification Bodies must complete a case-specific COI assessment prior to conducting any verification activities for a member. In some instances, where potential or real conflicts do exist, Verification Bodies must take steps to mitigate high COIs before the Registry will allow verification activities to proceed. Any Verification Body that determines that its risk for COI is anything other than low may not provide verification services to that member. The Registry prohibits Verification Bodies from providing GHG verification services for any member for which the Verification Body has provided GHG consultancy services, regardless of the point in time that these services occurred.

Four additional concepts play a key role in shaping The Registry's verification program:

1. *Risk-Based Approach to Verification:* Given the impossibility of assessing and confirming the accuracy of every piece of GHG information in an emissions report, The Registry adopted ISO 14064–3's risk-based approach to verification. This approach directs Verification Bodies to focus their attention on those data systems, processes, emissions sources and calculations that pose the greatest risk of generating a material misstatement.
2. *Materiality:* Verification Bodies use the concept of materiality to determine if omitted or misstated GHG emissions will lead to significant misrepresentation of a member's emissions, thereby influencing conclusions or decisions made on the basis of those emissions. Therefore, a material misstatement is one where the error could affect the decisions of intended users of the emissions report.

   The Registry defines the materiality threshold for its voluntary program at five percent (for both understatements and overstatements) of a member's direct (Scope 1) and indirect (Scope 2) emissions. The Registry requires Verification Bodies to assess the accuracy of a member's direct and indirect emissions separately. Therefore, a member's direct and indirect emissions must both be deemed as accurate (within five percent) for a Verification Body to issue a positive Verification Statement.
3. *Level of Assurance:* The level of assurance a Verification Body attaches to its verification findings dictates the relative degree of confidence the Verification Body has in its assessment of the reported data. The Registry requires its Verification Bodies to provide a reasonable level of assurance that an emission report is materially correct. A reasonable level of assurance is considered to be the highest possible level of confidence; absolute assurance is not attainable because of factors such as the use of judgment and inherent limitations of control.
4. *Inherent Uncertainty:* For purposes of its voluntary reporting program, The Registry defines inherent uncertainty as the uncertainty associated with 1) the inexact nature of calculating GHG emissions (metering equipment, emission factors, etc.).[6]

The Registry does not include inherent uncertainty in a Verification Body's assessment of materiality. Therefore, for The Registry's voluntary program, when determining the accuracy of an emissions report, a Verification Body must focus their attention on the completeness of the emissions inventory, the use of appropriate calculation methods, the mathematical accuracy of the calculations, and a member's adherence to The Registry's programmatic requirements.

[6] Inherent uncertainty also applies to the inexact nature of the calculations associated with the Registry's permitted use of simplified estimation methods (for up to five percent of a member's emissions).

Core Verification Activities

In order to attest to the accuracy of an emissions report, a Verification Body must complete the following five core verification activities:

1. Assess conformance with The Registry's reporting and verification requirements;
2. Assess the completeness of the emission report;
3. Perform a risk assessment based on a review of information systems and controls;
4. Develop a sampling plan (identify records to be reviewed and facilities to be visited);
5. Evaluate the GHG emissions, information systems and controls against The Registry's criteria (five percent materiality threshold).

Verification Documentation

At the end of the verification process, a Verification Body must produce two documents: 1) a Verification Report that summarizes their verification activities and findings, and 2) a Verification Statement that attests to the member's compliance with the Registry's reporting and verification requirements.

2.4 Accreditation Program

To ensure the competence of the Verification Bodies in The Registry's program, The Registry adopted the international standard for accrediting GHG Verification Bodies (ISO 14065[7]) and further defined specific Registry requirements in addition to this standard. Through this process, Verification Bodies must demonstrate that they are independent, impartial, and competent to conduct GHG verifications.

The Registry's Guidance on Accreditation (GoA) describes the details of The Registry's accreditation requirements. It is located on The Registry's website: *http://www.theclimateregistry.org/downloads/GoA.pdf.*

Since ISO standards are implemented by national Accreditation Bodies, The Registry plans to partner with each of the three national Accreditation Bodies in North America[8] to carry out its accreditation program. The American National Standards Institute (ANSI), the national Accreditation Body in the U.S., is the first Accreditation Body to partner with The Registry.

Through this partnership, ANSI manages a rigorous review of all interested Verification Bodies in an effort to assess each firm's independence, impartiality and competence. This process includes a review of a Verification Body's internal management systems, an assessment of the competency of their staff, and an on-site assessment of a Verification Body's ability to successfully complete the verification activities required by the Registry.

ISO 14065 details a series of requirements that Verification Bodies must meet to become accredited to the standard. The standard includes requirements for demonstrating:

- Impartiality
- Competency
- Deployment and Management of Personnel
- Communications and Records Retention
- Verification processes
- Appeals and complaint processes, and
- Management system requirements.

In addition to the requirements above, Verification Bodies interested in conducting verifications for members of The Registry must also demonstrate their ability to meet twelve additional accreditation criteria set forth by The Registry. The Registry participates in ANSI's review process and additionally "recognizes" the ANSI-accredited Verification Bodies deemed competent to conduct verification activities for The Registry.

Only ANSI-accredited, Registry-recognized Verification Bodies are permitted to provide verification services to Registry members.

[7] ISO 14065–2007, Greenhouse gas—Requirements for greenhouse gas validation and verification bodies for use in accreditation or other forms of recognition.

[8] The North American Accreditation Bodies consist of the American National Standards Institute (ANSI) in the U.S., the Standards Council of Canada (SCC) in Canada, and Entidad Mexicana de Accreditación (EMA) in Mexico.

3. The Registry's Support of Mandatory GHG Reporting Programs

Thus far, my testimony has focused on The Registry's voluntary reporting program, however, The Registry's mission indicates that it supports *both* voluntary and mandatory GHG reporting programs. While The Registry does not have the authority to develop or implement mandatory reporting programs, it is uniquely positioned to leverage its GHG accounting expertise to assist states (and provinces) to best implement and manage their own mandatory GHG programs.

The Registry aims to accomplish the following through its support of mandatory GHG reporting programs:

- Streamline and centralize the reporting process for regulated parties;
- Assist jurisdictions to standardize approaches to calculate, report, and verify emissions;
- Provide jurisdictions with a turn-key, low cost solution for implementing data collection and management of GHG programs;
- Facilitate the transfer of data from mandatory programs to the Registry's voluntary program; and
- Leverage the investment that The Registry has made in the Climate Registry Information System (CRIS).

Many of the jurisdictions comprising The Registry's Board of Directors have adopted, or are in the process of adopting, mandatory GHG reporting requirements, either individually or as part of regional GHG initiatives.

The Registry assists these jurisdictions in implementing their mandatory GHG programs by:

- Providing assistance to promote consistency (where applicable) with The Registry's protocols;
- Developing tools for jurisdictions to understand the options available to develop accreditation & verification programs;
- Offering two technical support options via CRIS
  - The Common Framework for Mandatory GHG Reporting
  - Data Transfer

Utilizing The Registry's web-based reporting platform, CRIS, as a foundation, The Registry is developing a "Common Framework" for mandatory GHG reporting. The Common Framework consists of the CRIS application plus additional GHG reporting infrastructure components necessary to support most mandatory reporting programs. While the Common Framework ensures that multiple jurisdictions will share many of the same reporting requirements, it also allows jurisdictions to customize the application to meet their specific jurisdiction's needs.

The beauty of this concept is that multiple jurisdictions will have similar mandatory GHG data collection systems located on one server, but each jurisdiction will maintain confidential access to their own data (agency staff can only view the data submitted to their state). Therefore, regulated parties may enter emissions data for multiple mandatory GHG reporting programs through a common IT interface, thereby significantly reducing their reporting burden.

Through the Common Framework, The Registry offers jurisdictions with mandatory GHG reporting programs the benefits of a cost-sharing opportunity with other jurisdictions and economies of scale resulting from shared system approach, while also minimizing the reporting burden for organizations with operations in multiple jurisdictions and encouraging voluntary reporting.

The Registry's second technical support option, Data Transfer, will permit states to transfer mandatory GHG data from their own GHG database systems to the Registry's voluntary program and other regional GHG programs.

Currently, The Registry is working on a pilot project with the State of Nevada to support its mandatory reporting program and is working with over twenty jurisdictions to develop the Common Framework for potential use across North America.

3.1 Regional GHG Initiatives

Two significant regional GHG initiatives are currently in development in the U.S.: The Western Climate Initiative (WCI) and the Midwest Greenhouse Gas Reduction Accord (MGGRA), both of which include multiple U.S. states and Canadian provinces working together to achieve regional GHG reduction goals through mandatory GHG reporting and cap and trade programs. The Registry is working with both initiatives to ensure as much consistency of GHG emissions as possible. In addition, both initiatives have indicated that they intend to use The Registry's IT infrastructure to serve as their common data repository.

3.2 Relationship to Federal GHG Reporting Programs

The FY 2008 *Consolidated Appropriations Act* included language requiring the U.S. Environmental Protection Agency (U.S. EPA) to promulgate a rule to "require mandatory reporting of GHG emissions above appropriate thresholds in all sectors of the economy." The draft rule was due in September 2008 and the final rule is due by June 2009. We understand that U.S. EPA has developed a draft rule which has not yet been publicly released.

The Registry's Board of Directors recently adopted a federal policy position statement (Appendix B) to articulate the role it is seeking for The Registry in the context of a federal GHG reporting program. In their statement, the Board of Directors expressed their desire that future federal climate programs recognize the states, provinces and Native Sovereign Nations for taking early policy actions, including creating The Registry.

The Board stated that The Registry should be viewed as a model and a resource to support a federal GHG registry. It further asserted that federal mandatory GHG reporting rules should utilize the systems and infrastructure already put in place through the states and The Registry. By securing a role for The Registry in a federal GHG reporting regime, the Board seeks to ensure GHG data consistency across North America, reduce the reporting burden on the regulated community, reduce administrative costs, avoid duplication and recognize the efforts of companies who have chosen to rigorously report and reduce their emissions early.

The Board strongly endorsed that federal GHG reporting and regulatory programs should partner with The Registry as a cost-effective central repository or clearinghouse for reporting and/or tracking emissions and should preserve states' abilities to continue to be innovators and leaders on climate policy.

4. Challenges to Obtaining Emissions Data

The Subcommittee specifically asked me to speak to the challenges that members face when reporting their emissions to The Registry. Members primarily face two types of challenges: 1) organizational challenges, and 2) scientific uncertainty.

Organizational challenges generally result from a lack of data collection systems specifically designed for GHG data collection. Since GHGs have not been regulated before, many organizations do not have management systems in place to monitor and track these emissions. It can take time to develop such systems, which has delayed some members' ability to report.

Additionally, compiling a corporate emissions footprint requires an organization to collect GHG emissions information from all of its sources. Some of an organization's sources may constitute a small percentage of their emissions inventory, but they are still important to identify and include in an entity-wide inventory. This challenge may not be as great for mandatory reporting programs that use a traditional regulatory approach to collect data from sources with emissions above a certain threshold, as the reporting of smaller sources is not required.

Scientific uncertainty presents additional challenges to obtaining high quality data. Measurement and/or calculation methodologies for certain sources of emissions either do not exist, or contain a high degree of uncertainty. Several major areas of scientific uncertainty are:

- Fugitive emissions of methane (from landfills wastewater treatment plants, flaring, and other sources);
- Fugitive emissions of refrigerants;
- Out-of-date emission factors;
- Unknown carbon content of materials.

Appendix C contains a list of calculation methodologies with high uncertainty that could be improved with additional scientific research and technological developments.

It is important to note that this scientific and inherent uncertainty is a critical consideration for mandatory GHG programs that seek to implement a cap and trade component to their program. Under such a program, since GHG emission reductions equate to a financial commodity, it is critical to the integrity of the carbon market that the emissions are quantified with acceptable accuracy. While this may vary from program to program, both the WCI and the EU–ETS have generally found that uncertainty of plus or minus five percent is acceptable for their cap-and-trade programs.

As a result, cap-and-trade programs will likely be constrained to only include emission sources with calculation methods that contain an acceptable level of uncertainty. The more research and development that can be directed to eliminate or reduce the uncertainty of large emission sources, the more robust a cap-and-trade program will be.

5. Recommendations to promote more accurate GHG reporting

The Subcommittee specifically asked me to provide recommendations that will promote more accurate GHG accounting verification and reporting, but before I do, I want to stress the fact that it is possible for organizations to accurately account for, report, and verify GHG emissions today.

While scientific certainty does need to be improved in specialized sectors, most organizations are capable of accounting for their major GHG emission sources (stationary combustion, mobile combustion, indirect emissions, etc.). Significant progress has been made to develop best practices for reporting, and organizations no longer feel daunted by the process—as is evidenced by the over 300 members who have joined The Registry's voluntary program in less than a year.

Given that reduced scientific uncertainty would help increase organizations' ability to accurately report GHG emissions, opportunities exist to improve accuracy in GHG reporting by:

- Updating emission factors in a timely fashion (EPA, EIA, DOE, etc.);
- Conducting comprehensive surveys GHG emission information to produce better emission factors and quantification methods;
- Developing more industry-specific protocols;
- Funding the development of improving measurement technology
    - Remote sensing
    - Laser methane gas detector monitoring of emissions from landfills
- Incentivizing the use of existing measurement technology.

6. Conclusion

To conclude, The Climate Registry was created to help organizations answer the very question posed by this hearing, "How do we know what we're emitting?" The Registry took great care in designing its reporting, accreditation, and verification programs to ensure that GHG emission reports are comprehensive, accurate, consistent, and transparent, such that they are meaningful not only to the organizations themselves, but to the public and policy-makers as well.

The Registry was created by states, provinces and Native Sovereign Nations to be a model for a federal registry and to establish a single unified registry across North America. To date, The Registry has developed robust reporting and verification protocols, established clear and specific calculation methodologies, and has created a comprehensive GHG database application that is capable of supporting both voluntary and mandatory GHG reporting initiatives.

Time is of the essence when it comes to mitigating the negative impacts of climate change. Currently, given the leadership of individual jurisdictions, the U.S. is well positioned to work across State and federal jurisdictional lines to begin to tackle climate change in a new and collaborative way, and The Registry is uniquely positioned to help. We look forward to partnering with the Federal Government to serve a larger role in supporting national and international programs.

Thank you again for the opportunity to present this testimony. I would be happy to answer any questions that you may have.

Appendix A: Map of The Climate Registry Board of Directors

Appendix B: The Climate Registry's Federal GHG Policy Statement

The Climate Registry

Action Item #4

Resolution 01.14.09 – 4

THE CLIMATE REGISTRY BOARD OF DIRECTORS ADOPTS THE FOLLOWING POSITION REGARDING FEDERAL GHG PROGRAMS AND THE ROLE OF THE CLIMATE REGISTRY

BACKGROUND

The Climate Registry is a not-for-profit organization governed by 40 U.S. states, 12 Canadian provinces and territories, 6 Mexican states and 4 Native Sovereign Nations. The goal of the states, provinces and nations in creating The Climate Registry is to set consistent and transparent standards for the accounting, verification and public reporting of greenhouse gas emissions throughout North America in a single unified registry. Today, The Climate Registry supports both voluntary and mandatory GHG reporting programs, provides high quality meaningful information to reduce greenhouse gas emissions, ensures consistency with international standards and embodies the highest levels of environmental integrity.

Through many actions, from the creation of The Climate Registry to RPS standards to California auto emissions policies to regional GHG cap-and-trade programs, states and provinces have been the leaders in addressing climate change.

THE ROLE OF THE CLIMATE REGISTRY IN FEDERAL CLIMATE PROGRAMS

While The Climate Registry has taken no official position on the need for federal reporting programs, both the U.S. and Canada have embarked on federal rulemaking to require GHG reporting. Given that reality, The Registry believes all federal climate programs should recognize states, provinces and Native Sovereign Nations for early policy action, and should seek to create an international system. The Climate Registry should be viewed as a model and a resource to support national greenhouse gas registries. Federal mandatory GHG reporting rules should utilize the systems and infrastructure already in place and continue to provide a role for the states and The Registry in the collection and management of GHG data. This will ensure consistency across North America, reduce the reporting burden on the regulated community, reduce administrative costs, and recognize the efforts of companies that have chosen to rigorously report and reduce their emissions early. A North American approach should recognize the importance of reporter convenience and aim to avoid duplication.

Specifically, The Climate Registry Board of Directors strongly endorses that any federal GHG reporting and regulatory program in North America should partner with The Climate Registry as a cost effective central repository or clearinghouse for reporting and/or tracking GHG data.

At a minimum, every federal GHG reporting program must:

1) utilize GHG calculation and accounting methodologies that are consistent with The Climate Registry's standards

2) allow states, provinces and Native Sovereign Nations to collect data for federal program requirements

3) maintain state, provincial, and sovereign nations' ability to require reporting to their respective jurisdictions or directly to The Registry, for emissions reporting that is above or beyond, but not inconsistent with, federal requirements

The Climate Registry encourages EPA, Environment Canada, and Semarnat to work in partnership with each other, states, provinces and Native Sovereign Nations on GHG reporting as well as on broader climate policies and programs.

These measures would support strong federal actions while preserving the ability of states and provinces to maintain their role as innovators and leaders on climate change policy and directly monitor progress in achieving GHG reductions.

Appendix C: List of GHG Calculation Methodologies with High Uncertainty

Areas of Uncertainty in GHG Emission Accounting	
Cement	
	Plant-specific weight fractions in clinker from each kiln of: CaO, MgO, uncalcined CaO, uncalcined MgO
	Weight fraction of carbonate CO2 in the CKD
	Weight fraction of carbonate CO2 in the raw material
	Total organic carbon contents of raw materials.
	Quantity of clinker produced
	Quantity of CKD discarded
	Quantity of raw materials consumed (i.e. limestone, sand, shale, iron oxide, and alumina)
Lime Manufacturing	
	Weight fractions:
	Plant-specific weight fractions in quick lime from each kiln of: CaO, MgO, uncalcined CaO, uncalcined MgO
	Plant-specific weight fractions in lime kiln dust (LKD) from each kiln of: CaO, MgO, uncalcined CaO, uncalcined MgO
	Quantity of quick lime produced
	Quantity of LKD discarded
	Quantity of raw materials consumed (i.e., limestone, dolomite, aragonite, chalk, coral, marble, and shell)
Iron and Steel Manufacturing	
	Carbon Content of By-products: blast furnace gas, coke oven gas, coal tar, light oil, coke breeze, sinter off gas
	Carbon Content of Carbon electrodes
	Direct reduced iron inputs: natural gas, coke breeze, metallurgical coke
	Energy used in direct reduced iron production (i.e., from natural gas, coke breeze, metallurgical coke)
	Quantity of coke production inputs (i.e., coking coal, blast furnace gas, other process materials)
	Quantity of coke produced
	Quantity of other coke production outputs (i.e., coke oven gas, other by-products)
	Quantity of iron and steel production inputs (i.e., coke, coke oven by-products, directly injected coal, limestone, dolomite, carbon electrodes, other carbonaceous and process material, coke oven gas)
	Quantity of steel produced
	Quantity of iron produced (not converted to steel)
	Quantity of blast furnace gas produced
	Quantity of sinter production inputs (i.e., coke breeze, coke oven gas, blast furnace gas, other process materials) and outputs (i.e., sinter off gas)
Electronics (Semiconductor) Manufacturing	
	Fraction of gas remaining in shipping contained (i.e., heel)
	Mass of individual gas species fed into individual processes
	Use rate (i.e., fraction destroyed or transformed) of each gas species/process
	Fraction of each gas species/process fed into process with emission control technology

	Fraction of gas destroyed by emission control technology
	By-product emission factor for amount of $CF_4/C_2F_6/CHF_3/$ C_3F_8 created for each gas species/process
Lead Production	
	Carbon contents of reducing agents: blast furnace gas, charcoal, coal, coal tar, coke, coke oven gas, coking coal, electric arc furnace (EAF) carbon electrodes, EAF charge carbon, fuel oil, gas coke, natural gas petroleum coke
	Quantity of reducing agents (i.e., blast furnace gas, charcoal, coal, coal tar, coke, coke oven gas, coking coal, electric arc furnace [EAF] carbon electrodes, EAF charge carbon, fuel oil, gas coke, natural gas petroleum coke)
Soda Ash Manufacturing	
	Carbon content of Ore, Sodium Carbonate-rich Brine and Soda Ash
	Waste material (i.e., collected kiln dust)
	Quantity of soda ash produced
	Quantity of waste material
	Quantity of raw materials consumed (i.e., trona ore, nacholite ore, sodium carbonate-rich brine)
Adipic Acid Manufacturing	
	Destruction factor
	Chemical composition of feedstock (i.e., cyclohexanone, cyclohexanol)
Aluminum Manufacturing	
	Quantity of materials consumed (i.e., paste, carbon, anodes, coke, recovered tar, coke dust)
	Quantity of aluminum produced
	Binder content in paste
	Pitch content in anodes
	Volatile content in coke
	Smelter-specific operating parameters (i.e., current efficiency, anode effect frequency, anode effect duration, anode effect over-voltage)
Ferroalloy Production	
	Carbon content of Ore, Finished Product and Non-product outgoing stream
	Volatiles in individual reducing agents
	Quantity of inputs (i.e., ore, individual reducing agents, individual slag-forming materials)
	Mass fractions in Fixed Carbon, Volatiles and Ash
HCFC-22 Production	
	Concentration of HFC-23 in vented gas stream
	Gas stream mass flow rate
	Current process operating rate used as proxy
	Duration of atmospheric venting (not to a destruction system)
	Quantity of HFC-23 recovered for use as a chemical feedstock
	Concentration of HFC-23 in product reactor
	Mass of HCFC-22 produced at specific concentrations of HFC-23
Coal Mines	
	Mine-specific methane measurements from ventilation air and/or degasification systems
	CH4 from coal mining and coal storage
Natural Gas Production, Transmission and Distribution (Direct Venting and Fugitive Emissions)	
	Transmission Dehydrator Venting Emissions Factors for Methane
	Transmission Gas-assisted Glycol (Kimray) Pumps Vented Emission Factors for Methane
	Storage Station Venting Emission Factors for Methane

	Storage Gas-assisted Glycol (Kimray) Pumps Vented Emission Factors for Methane
	Maintenance/Upsets Vented Gas Emission Factors for Methane
	Gas-driven M&R Station Control Loop Emission Factors for Methane
	M&R Station Blowdowns Emission Factors for Methane
	Storage Station Venting Emission Factors for Methane
	Storage Gas-assisted Glycol (Kimray) Pumps Vented Emission Factors
	Pipeline Blowdowns Emission Factors for Methane
	Gas-driven Pneumatic Devices Emission Factors for Methane
	Chemical Injection Pumps Emission Factors for Methane
	Compression Station Control Loop Emission Factors for Methane
	Maintenance & Upset Emission Factors for Methane
	Pipeline Dig-ins Emissions Factors for Methane
	M&R Station Blowdown Emission Factors for Methane
	M&R Station Odorizer & Gas Sampling Vents Emission Factors for Methane
	M&R Station Pneumatic Devices Emission Factors for Methane
Stationary Combustion	
	CH4 and N20 from units with CEMS
Solid Waste Management (Landfills)	
	Fugitive CH4 emissions
	Quantity of landfill gas produced
	Composting
Wastewater Treatment	
	CH4 and N2O emissions
Transportation	
	Emissions from Aviation
	Emissions from Marine Vessels

BIOGRAPHY FOR JILL E. GRAVENDER

As Vice President of Policy for The Climate Registry, Ms. Gravender oversees the development of The Registry's voluntary greenhouse gas (GHG) reporting program, designs tools to assist jurisdictions with the implementation of mandatory GHG reporting programs, and provides overall policy direction to the organization.

Ms. Gravender has over ten years of experience in environmental policy and management. She has specifically focused much of her work on climate change policy and greenhouse gas emissions management. In her current role with The Climate Registry, Ms. Gravender is responsible for promoting consistent reporting, accreditation, verification, and data collection standards for GHG emissions between The Registry's voluntary reporting program and emerging mandatory GHG reporting programs. In this capacity, she regularly interfaces with state/provincial; regional, and federal policy-makers.

Prior to joining The Climate Registry, Ms. Gravender served in multiple key roles at the California Climate Action Registry including, National & Operations Officer, Vice President of Programs, and Technical Director. In addition to her expertise in GHG accounting and verification issues, she previously served as the Director of Water Programs for the Environment Now Foundation, the Director of Operations for the New America Foundation, and as an independent consultant working on a variety of environmental and climate change issues.

Ms. Gravender has a Bachelor's degree in Economics from Arizona State University and a Master's degree in Environmental Science and Management from the University of California, Santa Barbara.

Chair BAIRD. Thank you. Ms. Wong.

STATEMENT OF MS. LESLIE C. WONG, DIRECTOR, GREENHOUSE GAS PROGRAMS, WASTE MANAGEMENT, INC.

Ms. WONG. Chair Baird, Ranking Member Inglis, and Members of the Subcommittee, thank you for the opportunity to speak with you today about Waste Management's greenhouse gas programs and our efforts to measure and understand our company-wide greenhouse gas emissions.

Waste Management (WM) is the leading provider of waste management, recycling and environmental services in North America. We also produce renewable, waste-based energy, enough now to power over one million homes a year. Waste Management has chosen to voluntarily participate in greenhouse gas inventory and reduction efforts since 2004, both to achieve our own sustainability goals and to help our customers achieve their goals.

It is important to note, however, that the waste sector is a very small contributor to U.S. greenhouse gas emissions; it is less than three percent. And through advancing technology, environmental regulation and recycling, we have decreased greenhouse gas emissions by more than 75 percent in the past decade, despite a twofold increase in waste generation during that time period. In addition, EPA's 2008 greenhouse gas inventory found that landfill methane emissions have decreased by more than 16 percent since 1990.

We are a big organization to inventory. We have about 2,500 sites in 48 U.S. states and Canada. We have recycling facilities, transfer stations, clean energy power plants, hauling companies with over 22,000 vehicles, and about 300 active and closed landfills. Our primary greenhouse gas emissions include direct carbon dioxide from using fossil fuel in vehicles and facilities, direct carbon dioxide emissions from the non-biogenic portion of the waste combusted in our waste-to-energy plants, indirect greenhouse gas emissions from the use of electricity, direct emissions of HFC's, PFC's and sulfur hexafluoride in de minimus amounts, and finally direct methane and carbon dioxide emissions from landfills—this includes fugitive and combustion emissions from landfill gas which is itself approximately half carbon dioxide and half methane. We are already working to reduce our greenhouse gas emissions by tripling our recycling volume by 2020, by investing in innovative technology for landfill fleet management and doubling our renewable power production by 2020.

To complement our greenhouse gas reduction efforts, we have participated in two voluntary greenhouse gas management programs, and we are now undertaking a voluntary greenhouse gas footprint of our own development.

Waste Management is a founding member of the Chicago Climate Exchange and was the first solid waste company to join. Since 2004, we are on track to meet our membership commitment of a six percent reduction from our CCX baseline by 2010. As a CCX member, we prepare a third-party verified annual inventory of carbon dioxide from fuel combustion and from waste combustion at our wholly owned waste-to-energy facilities.

Then in 2006, Waste Management was the first solid waste company to join the California Climate Action Registry, known as CCAR. We report direct carbon dioxide emissions from fuel consumption, indirect carbon dioxide emissions from electricity use, and these are also third-party verified reports. We also opted to report greenhouse gas emissions from landfills to pilot a landfill greenhouse gas inventory tool called the Solid Waste Industry for Climate Solutions, or SWICS, protocol. The protocol greatly enhances currently available gas generation models that rely on default values by replacing that with measured data. This protocol also recognizes carbon sequestration where the anaerobic conditions of a modern landfill allow significant amounts of biogenic material to not degrade.

Once CCX and CCAR got us started, we launched a two-year project to inventory our company-wide emissions using 2009 data to report in 2010. The Waste Management carbon footprint team has so far identified all of our sources, identified or developed emission calculation protocols and developed a software tool for collecting verifiable data from the field. The next step is data collection and then comes actual reporting.

Our data will be auditable to support third-party verification, but we have recommended to EPA that third-party verification is unnecessary in a mandatory federal reporting program. There is no precedent for third-party verification in any federal environmental statute under which we operate.

The protocols we are using at other landfills were developed by The Climate Registry in conjunction with CCAR, but to calculate landfill emissions we will use our SWICS protocol because it reflects the most sophisticated means of landfill assessment currently available through peer-reviewed science. However, estimation of fugitive landfill emissions is still a work in progress. A broadly accepted protocol does not exist. However, Waste Management, with other industry and academic leaders and EPA, is now conducting tests to measure landfill gas emissions under a variety of conditions, and this is detailed in our written testimony. We have urged the agency to consider waiting until the result of this research can be used to further refine greenhouse gas emission estimation before requiring landfills to report site-specific greenhouse gas emissions.

In our greenhouse gas inventory efforts, Waste Management has learned that developing a proper program takes significant time. We believe a phased approach that allows reporting for a limited range of greenhouse gases or limited set of sources for the first two to three years is essential. We recommend that a federal reporting program provide a transition period and exclude sources for which there is not an approved emission calculation protocol until such time that one is adopted.

Thank you for the opportunity to present this information, and I will be ready to answer questions when you are. Thanks.

[The prepared statement of Ms. Wong follows:]

PREPARED STATEMENT OF LESLIE C. WONG

Chairman Baird, Ranking Member Inglis, and Members of the Subcommittee, thank you for the opportunity to speak with you today about Waste Management's greenhouse gas programs and our efforts to measure and understand our company-wide greenhouse gas emissions.

Waste Management (WM) is the leading provider of comprehensive waste management, recycling and environmental services in North America. We are also a leading producer of renewable, waste-based energy—enough to power over one million homes each year. Waste Management is committed as an industry leader and environmental steward to identify our company carbon footprint, voluntarily reduce our greenhouse gas (GHG) emissions, and help our customers do the same.

Waste Management's greenhouse gas emissions include:

- CO_2 emissions from combustion of fossil fuel in our vehicles and in stationary sources at our facilities;

- CO_2 emissions from non-biogenic[1] waste combusted at our waste-to-energy plants (about 34 percent of an average waste-to-energy plant's total CO_2 emissions). These emissions are more than offset by production of renewable electricity;
- Indirect GHG emissions from our use of electricity; and
- Methane emissions from MSW landfills. These emissions are controlled by operation of gas collection and control systems, some of which generate renewable energy, combined with landfill cover management.

WM employs a number of innovative technologies to reduce greenhouse gas emissions, including:

- Saving virgin resources and energy through the Nation's largest recycling program. We announced in October 2007 that we plan to triple the amount of recyclable materials we manage by 2020;
- Advancing technology for alternative transportation fuels (e.g., landfill gas to liquefied natural gas) and engine design to lower GHG emissions from our vehicles. We are developing a landfill gas to liquefied natural gas plant in Altamont, California, and we plan to direct capital spending of up to $500 million per year over a ten-year period to increase fuel efficiency of our fleet by 15 percent and reduce our emissions by 15 percent by 2020;
- The operation of landfill-gas-to-energy, waste-to-energy and biomass plants that produce electricity and fuels to replace fossil fuel use. We plan to double our 2008 output of renewable energy by 2020;
- The recovery and destruction of methane gas from landfills in accordance with and beyond that required by regulation; and
- Development of "Next Generation" landfill technology that offers enhanced collection and beneficial use of landfill gas.

The Solid Waste Sector has Substantially Reduced GHG Emissions

Overall, the waste sector is a very small contributor to total U.S. GHG emissions—less than three percent. Through technological advancements, environmental regulations and emphasis on resource conservation and recovery, the solid waste management sector decreased GHG emissions from municipal solid waste (MSW) management by more than 75 percent from 1974 to 1997—despite an almost twofold increase in waste generation during that time period.[2] The EPA's 2008 U.S. GHG Inventory notes that just since 1990, landfill methane emissions have decreased by more than 16 percent.

WM is a Founding Member of the Chicago Climate Exchange

Waste Management was the first company in the solid waste industry to join with others to methodically reduce GHG emissions. As a founding member of the Chicago Climate Exchange (CCX), we meet CCX's membership commitment to decrease greenhouse gas emissions for both Phase I and Phase II of the program, which is a six percent reduction in emissions from our 1998–2001 baseline, in year 2010.

To demonstrate compliance, WM prepares an annual inventory of fuel consumption-related CO_2 emissions per the CCX Rules. Since 2004 WM has annually reported to the CCX our U.S. CO_2 emissions from fuel consumption, as well as waste combustion at our wholly-owned waste-to-energy facilities. This includes CO_2 from combustion of fuel in our U.S. operated collection vehicles and stationary facilities, small quantities of supplemental fossil fuel consumed by our waste-to-energy plants, and combustion of non-biogenic materials (primarily plastics) contained in the waste burned in our waste-to-energy plants. CCX members' annual inventories are third-party audited by the Financial Industry Regulatory Authority (FINRA) at the direction of CCX, and then certified.

Initial inventorying in California. WM joined the California Climate Action Registry (CCAR) in 2006 to pilot greenhouse gas inventorying by voluntarily measuring and reporting emissions from all of our California operations. Waste Management was the first solid waste company to join CCAR and was recently designated a "Climate Action Leader" by CCAR. As a member of CCAR, we reported our 2006 direct

[1] Non-biogenic describes waste that is not produced from a biological process, and includes materials such as plastics and synthetic textiles.

[2] K. Weitz et al., The Impact of Municipal Solid Waste Management on Greenhouse Gas Emissions in the United States, *Journal of Air & Waste Management Association,* Volume 52, September 2002.

CO_2 emissions from mobile and stationary source fuel consumption, and indirect CO_2 emissions from electricity use that occurred in the State of California in accordance with CCAR quantification and reporting practices. The 2006 emissions report was third-party verified and accepted by CCAR in May 2008. Our 2007 emissions inventory is undergoing verification.

WM is voluntarily reporting to CCAR GHG emissions from our California landfills, using the Solid Waste Industry for Climate Solutions (SWICS) protocol developed by SCS Engineers,[3] which we have shared with State regulators, the U.S. EPA, The Climate Registry, CCAR and the Subcommittee. The protocol presents an in depth literature review and makes recommendations on refining current landfill emissions models. It replaces default values for landfill gas collection efficiency and methane oxidation in existing EPA models with ranges, and thus better accounts for effects of climate, landfill design and landfill cover types. The protocol represents a first step in refining existing EPA models and protocols to improve landfill GHG emission estimation. The protocol has been accepted by TCR for inclusion in guidance to be provided, when finalized, to local governments to use in reporting emissions from landfills.

WM also voluntarily reported to CCAR:

- Estimated avoided emissions associated with renewable power production at our California landfill gas to energy projects and our biomass plant;
- GHG reductions associated with the recycling of municipal solid waste materials processed by WM operations in California; and
- Estimated annual carbon sequestration in our California landfills.

These results are publicly available at *http://www.climateregistry.org/CARROT/public/reports.aspx* under "Waste Management."

Company-Wide WM Greenhouse Gas Inventory

Our participation in CCX and CCAR has been a useful prelude to developing a company-wide greenhouse gas inventory, or as we are calling it, our company carbon footprint. In anticipation of State and federal regulation and in order to understand and disclose our carbon footprint, in December 2007 WM launched a two-year project using a multi-disciplinary team to inventory our 2009 emissions to be ready for voluntary or mandatory reporting in 2010. Once WM has completed its carbon footprint, we will be able to use the information to further develop GHG management and reduction strategies.

Inventorying GHG emissions is a big task for a large and complex company like Waste Management, which has a total of approximately 2,500 facilities and about 22,000 collection and transfer vehicles. The project team is applying the experience gained through membership in the CCX and voluntary GHG reporting in California. The team is identifying WM sources of GHG, calculating GHG emissions, and—where no methods exist—developing new protocols reflecting the state-of-the-art thinking on the most accurate, available GHG estimation methods.

The WM team is well on the way to meeting our goal of collecting and calculating our 2009 GHG emissions throughout this year and reporting them in 2010. The team organized itself around four major tasks, which have been largely accomplished:

1. Identifying all WM sources of GHG, and identifying existing or developing new protocols for measuring their emissions;
2. Developing the organizational structure for reporting emissions from individual facilities, up to the company as a whole, and identifying internal means to collect emissions data;
3. Benchmarking, selecting and configuring a software tool for managing and reporting WM emissions data, which we have named Climate Care; and
4. Communicating to internal and external stakeholders about what we are doing, and developing training for WM staff who will be involved in data collection.

This year the team's focus will be to provide training and to work with WM field personnel to collect, document and quality assure our 2009 emissions information, upload the data into our Climate Care software and calculate our carbon footprint in early 2010.

[3] SCS Engineers, Current MSW Industry Position and State-of-the-Practice on LFG Collection Efficiency, methane Oxidation and Carbon Sequestration in Landfills, Prepared for Solid Waste Industry for Climate Solutions (SWICS), Version 2.2, Revised January 2009.

For each source category in our inventory we have identified auditable data resources, for example fuel and utility invoices that have been subject to accounting audits. While we are preparing an inventory that can support third-party verification, we believe that third-party verification is unnecessary in a mandatory federal reporting program. There is no precedent for third-party verification in any federal environmental statute under which we operate. We do, however, support third-party verification of greenhouse gas offsets, which are tradable commodities with direct financial value.

The protocols and emission calculation methodologies we will employ for most of our GHG sources are those developed by The Climate Registry in conjunction with CCAR. For indirect emissions from electricity use, we will use monthly invoices to identify usage in kilowatts and calculate emissions using emission factors from U.S. EPA's eGrid table that provides information on the fuel mix used by electric utilities on a state-by-state basis.

To calculate CO_2 emissions from burning fossil fuels in our vehicles and in stationary sources at our facilities, we will use centralized company-wide fuel purchase data and monthly invoices to calculate the amount used of each fuel type, along with the TCR protocol and U.S. and Canadian tables for calculating the carbon content of each type of fuel used.

On an annual basis we will use stack-testing information along with waste characterization data to calculate CO_2 emissions from our waste-to energy facilities. Further, testing of stack gas from waste-to-energy plants using ASTM Standards D–6866 can determine precisely the percentage of carbon dioxide emissions attributable to biogenic and non-biogenic sources, so that we can differentiate the two for inventory accounting purposes under the TCR protocol.

WM emissions from use of refrigerants and high voltage equipment will be estimated at the end of 2009 and a more detailed inventory process developed for use in 2010.

On an annual basis, WM will be calculating the biogenic CO_2 emissions from landfill flares and landfill gas fired engines and turbines, as well as calculating fugitive emissions of biogenic CO_2 and methane using the SWICS protocol. TCR has recognized the SWICS protocol as additional guidance that may be used by TCR members to report landfill emissions in a protocol due to be published for public comment in the near future. In addition, WM will calculate the carbon sequestration attributable to the portion of annual receipts of biogenic waste that will not decompose in the landfill to produce methane. Inclusion of landfill carbon sequestration as an anthropogenic sink is consistent with both the UN Intergovernmental Panel on Climate Change (IPCC) and U.S. EPA national inventory practices, which account for carbon sequestration of undecomposed wood products, food scraps and yard trimmings disposed of in landfills. Both entities consider carbon sequestration to be an integral component of the landfill carbon mass balance calculations. We have recommended that EPA incorporate carbon sequestration into the landfill GHG emissions calculation methodology it eventually adopts for site-specific federal GHG reporting.

Lessons Learned:

Estimating fugitive landfill emissions is still a work in progress

While modeling aggregated landfill emissions across the U.S. using national default assumptions is possible, estimating individual landfill emissions is still a "work in progress" and not yet ready for site-specific or entity-based mandatory inventorying. A broadly accepted protocol for estimating the carbon mass balance of landfills does not yet exist. However, Waste Management and other landfill operators, along with the State of California and the EPA Office of Research and Development are investing significant resources to refine and improve existing models based on site-specific data.

WM along with other public and private owner/operators of landfills funded development of the SWICS protocol by SCS Engineers. The protocol represents a first step in refining existing EPA models and protocols to improve landfill GHG emission estimation.

As a second step, WM is conducting field emissions testing using tunable diode lasers and flux boxes, to measure landfill gas (LFG) emissions under a variety of conditions including: slopes and flat surfaces; daily cover and active working face; intermediate cover; final cover (with and without a geomembrane); and to measure seasonal variations in methane oxidation and capture efficiency. Ultimately, WM hopes to develop a database that describes methane emissions over the range of conditions one finds at both operating and closed landfills using field-validated numbers instead of uncertain models. The multi-year testing program will evaluate a minimum of ten cover types over a minimum of two seasons. Concurrently, WM and other waste sector members have also volunteered sites and are cooperating with research being conducted by Dr. Jean Bogner for the California Energy Commission. Additionally, WM and Veolia conducted field research for a comparative analysis of several landfill methane estimation techniques (flux box, tracer gas, micrometeorological, plume mapping, DIAL measurements). Results from this research initiative will be reported in 2009. The EPA's Office of Research and Development participated in the research with us and we are discussing further work with them under a cooperative agreement.

Finally, researchers at Florida State University working with WM are developing a model to evaluate methane oxidation in landfill cover. The FSU model will represent the physical and chemical processes in cover that control emissions and oxidation. This will provide a tool that will allow the design and operation of landfill cover systems, in concert with gas collection systems, to minimize emissions. It may also prove acceptable for use as an emissions inventory tool in a year or two once field validation is accomplished.

A great deal of research is underway or planned for the next two years that will be enormously valuable to EPA and the waste sector in better understanding the estimation and control of landfill methane and CO_2 emissions. We have urged the Agency to consider waiting until after the results of this research can be used to develop more refined emissions estimation methods before requiring landfills to inventory site-specific GHG emissions as part of a federal mandatory reporting program.

A Phased Approach to Inventory Development is More Workable

In our GHG inventory efforts from 2006 to date, WM has learned that developing a complete and accurate GHG inventory requires building an efficient, accurate and verifiable data collection system and identifying or devising reliable, scientifically accurate emission calculation protocols. Both efforts take time, particularly for organizations with a large number of diverse GHG emission sources. We believe a phased approach to inventorying that allows an organization to focus on reporting one GHG, or emissions from a selected set of sources in the first two to three years will allow an organization to develop the tools necessary to transition to full GHG reporting thereafter. Both TCR and CCAR recognize the need for a transitional period and make it available to their members to allow reporters to gain the knowledge and develop the tools necessary to comply with the full complement of the registries' requirements. We recommend that a federal mandatory reporting program, when implemented, incorporate a similar transition period.

Thank you for this opportunity to share with you this summary of our programs and efforts relating to GHG emissions. I will be pleased to try to answer any questions that you may have.

BIOGRAPHY FOR LESLIE C. WONG

Ms. Wong serves as Waste Management's Director of Greenhouse Gas Programs and, in that role, is overseeing the development of a company-wide greenhouse gas footprint and a corresponding greenhouse gas inventory and reporting program. Ms. Wong also assists Waste Management in the areas of air permitting, compliance, training and regulatory analysis. Prior to joining Waste Management in 2008, Ms. Wong was an environmental consultant and a landfill gas-to-energy project developer. Her professional experience includes greenhouse gas inventory development and review; renewable energy project development and environmental management; air permitting, compliance and offset management in ozone non-attainment areas, environmental regulatory analysis and interpretation and environmental agency negotiations support. She is a member of the State Bar of Texas, earned her Juris Doctor from the University of Arkansas at Little Rock School of Law, and earned her B.A. from Hendrix College in Conway, Arkansas.

Chair BAIRD. Thank you. Mr. Ellis.

STATEMENT OF MR. ROB ELLIS, GREENHOUSE GAS PROGRAM MANAGER, ADVANCED WASTE MANAGEMENT SYSTEMS, INC. (AWMS)

Mr. ELLIS. Thank you, Chair Baird and Members of the Subcommittee. I appreciate the opportunity to speak on this topic.

With greenhouse gas offset programs trading in markets such as the Chicago Climate Exchange and with companies publicly reporting their greenhouse gas emissions inventories in programs such as The Climate Registry, the consequences of error and opportunity for fraud are high. The protection against this is the requirement that disinterested third parties, such as Advanced Waste Management Systems, or AWMS, provide a verification that the reported values are accurate and complete. The ISO 14064–3 and ISO 14065 International Organization for Standardization Standards are the acceptable rules for conducting greenhouse gas verifications in the U.S. and the world. These are the standards utilized for obtaining accreditation to perform verifications for entities such as The Climate Registry and the Chicago Climate Exchange. Both of these organizations have tasked the American National Standards Institute, ANSI, with accreditation of these verifiers. Using these ISO standards and the protocols of the specific program, ANSI conducts a thorough audit of the verifier to ensure appropriate technical knowledge, auditing skills, knowledge of the appropriate protocols, and implementation of a management system capable of providing a consistent work product. This accreditation process entails both witnessing of actual verification work and of the verifier's management structure.

AWMS successfully completed the accreditation process and is now one of six companies accredited to perform verification for The Climate Registry. We are also accredited to perform verifications for the Chicago Climate Exchange. The process for performing greenhouse gas verification varies slightly depending on the program, but the need for certainty for the reported data is so great that any greenhouse gas verification is conducted in a very consistent and rigorous fashion. The verification process essentially is a complete deconstruction of a company's inventory data. The initial data analysis is performed remotely using supplied information such as internal tracking, spreadsheets, monitoring reports, fuel usage, receipts, et cetera. The verifier uses this hard data to ensure appropriate application of emissions factors and usage of correct equations when generating the inventory or offset amount.

Along with this more technical analysis comes simple analysis such as looking for transcription errors, data entry errors, things like that. The completed data analysis serves as the basis for risk assessment approach for on-site activities. Those areas of the company's inventory judged to be at greatest risk of error, material impact of the inventory, they are scheduled for detailed analysis by an on-site verification team. On-site activities focus on where the data originated. Examples include verification of monitoring equipment, maintenance and calibration, verification that all emission points are included in the inventory, and interviews with those responsible for collecting that data.

The final step in the verification process is a technical review by another verifier from within the verification body. This is an additional, complete verification with the exception being that the observations of the on-site verification team are used rather than adding additional on-site burden.

To conclude, I would like to emphasize the importance of the conflict of interest component to any verification program. The inherent risk of performing verification of consulting work that one's own company has conducted presents a conflict of interest that jeopardizes any greenhouse gas inventory or offset program. Such programs must protect against verification bodies hiding consulting work behind false or weak corporate separations. Additionally, relationships in which one verifies another's consulting work, if the favor is returned, must be watched for. Advanced Waste Management Systems, for example, performs no consulting activity of any kind.

Thank you very much, and I look forward to answering any questions.

[The prepared statement of Mr. Ellis follows:]

PREPARED STATEMENT OF ROB ELLIS

Over the past decade the world has developed sophisticated approaches to control and monitor greenhouse gas emissions, including creating an economic model by which greenhouse gas caps are mandated allowing industry to emit a set level of carbon dioxide equivalent tons (there are six greenhouse gases, each a multiple of CO_2 which is the base greenhouse gas).

An industry exceeding the cap is permitted to continue operation if it exceeds these limits, but it must buy offsets from industries that are emitting less greenhouse gas than the limit. This is the "Cap & Trade" mechanism well tested in many international markets.

The commerce in these carbon markets now involves tens of billions of dollars of trade in carbon credits. Carbon credits are essentially traded as a commodity in much the same way as corn or wheat. Successful markets include the European Union Emission Trading Scheme and here in the U.S., the Chicago Climate Exchange.

In addition, both voluntary and mandatory emissions reporting programs have been established. Examples include The Climate Registry, the Regional Greenhouse Gas Initiative (RGGI), and the *California Global Warming Solutions Act of 2006* (AB 32). These programs are fundamentally based upon companies accurately reporting their greenhouse gas inventories.

Given the value of greenhouse gas reductions claims, or credits, and the need for accurate emissions inventories, the opportunity for fraud is huge. Plus, a greenhouse gas credit is not obvious as is a bushel of corn. To ensure the validity of greenhouse gas claims a third-party, disinterested verifier is required. These verifiers must pass rigorous examination, field observation, and in-house auditing to become accredited to the international greenhouse gas verification standards, ISO 14064–3 and ISO 14065. The American National Standards Institute (ANSI) oversees this accreditation process. Advanced Waste Management Systems, Inc. (AWMS) was one of six North American firms to successfully pass these requirements for verifying greenhouse gas inventories for The Climate Registry. In addition, AWMS holds accreditation from The Chicago Climate Exchange to perform greenhouse gas offset project verification. We arrived at this point by operating an office in Europe since 2002 to pursue greenhouse gas verification under international UNFCCC protocols. Additionally, AWMS retained the top British trainer in greenhouse gas verification to come to our headquarters office in Tennessee to train all 10 of our degreed professional staff.

The Chicago Climate Exchange accreditation process entailed submitting detailed financial, operational, and personnel information in one complete package. This package was judged by the Chicago Climate Exchange to warrant accreditation of AWMS as a verifier within the project types of Landfill Methane and Renewable Energy. The Chicago Climate Exchange has determined, however, that ANSI accreditation will now be required of all verifiers.

The ANSI accreditation process began with an application phase that required AWMS to submit its complete management system. This management system was based upon AWMS international experience as well as the requirements of The Climate Registry. ANSI, based upon an initial review, judged the AWMS management system to be robust enough to warrant entry into the pilot accreditation program. This program was divided into two phases: a witness assessment and a program/ office assessment.

For the witness assessment, AWMS was required to make available a member of The Climate Registry pursuing verification to ANSI staff for the purpose of witnessing AWMS staff perform the verification. The ANSI auditor shadowed the AWMS verification team to judge whether the AWMS verifiers possessed the technical capabilities and knowledge of the protocols required. AWMS passed this phase of the accreditation process with no non-conformities or findings.

The program/office assessment entailed ANSI auditors auditing the AWMS management system at AWMS headquarters. The audit team reviewed our complete system and confirmed whether our program met the requirements of ISO 14065 and The Climate Registry. This audit included checks such as conflict-of-interest and impartiality assurances, methods for ensuring qualified personnel are assigned to each verification, on-going training tools, records keeping, AWMS' ability to adjust to revisions to relevant protocols, and AWMS' internal corrective and preventive action system. Again, AWMS successfully completed this phase of the verification.

Upon completion of the ANSI audits AWMS was granted accreditation as one of only six companies to pass the pilot application process.

Advanced Waste Management Systems, Inc. utilizes ISO 14065 as the foundation for its greenhouse gas verification procedures. This Standard dictates four phases to the verification process: Pre-Engagement, Approach, Verification, and Verification Statement. This ISO Standard is a general set of rules designed to allow their adaptation to more specific protocols such as those of The Climate Registry and the Chicago Climate Exchange. AWMS has created a specific set of procedures for our verification activities. Program specific protocols also provide specific guidance on performing verifications.

As an example, AWMS has created a procedure defining the process for verification of an inventory of a member of The Climate Registry. The Pre-Engagement phase of this procedure centers on formally establishing the relationship between the member and AWMS, the verifier. This process is initiated by an application filed by the member. This application includes information such as the number of sites comprising the member, the number of employees at each site, and the primary greenhouse gases emission sources at each of those sites. This information allows AWMS to determine the appropriate amount of resources required to perform the verification. The application also provides the required information to initiate a conflict-of-interest assessment. The Climate Registry, as with all greenhouse gas accounting programs in which AWMS has participated, has a very strict conflict-of-interest policy. For example, AWMS must demonstrate that no employee who will be involved in a verification owns greater than $5,000 interest in that member. This information is submitted to The Climate Registry for formal approval of the relationship. Upon approval of the conflict-of-interest AWMS submits to the member a Verification Agreement that formalizes AWMS' roles as that member's verifier. This document also outlines the member's rights and duties. AWMS assigns a Lead Verifier at this point, as well.

The Approach phase of this procedure centers on communication between the member and AWMS. Central to this communication is the Verification Plan. The Verification Plan includes sections defining topics such as the level of assurance, verification objectives, verification criteria, verification scope, and the materiality. This Verification Plan also defines the schedule of activities. A kick-off meeting is held during this phase that covers the topics of the Verification Plan in order to achieve consensus with the member. Once the Verification Plan is finalized a notification of activities is formally presented to The Climate Registry for approval. During this phase, AWMS also presents to the member a list of information that will need to be provided in order to perform the verification. Examples may include the spreadsheet or database used to track emissions, meter readings, electric and/or gas bills, emissions monitoring reports, maintenance and calibration records, etc.

The Verification phase of this procedure entails the detailed verification activities. The verification process is initiated with a desk audit. A desk audit is performed remotely using the electronic or hard copy data that has been submitted to AWMS by the member. The primary focus of the desk audit is to determine whether appropriate emissions factors and equations have been utilized to calculate the metric tons of CO_2 equivalent and to assess conformance to appropriate reporting protocols. In the case of The Climate Registry the desk audit also includes an assessment of the on-line based CRIS reporting tool. This tool allows the member to enter source data (e.g., electricity usage, fuel usage) into a web-based database that will then calculate the member's inventory using the appropriate emissions factors and equations. By utilizing CRIS the member can be assured that the appropriate calculations are being made, and AWMS as the verifier does not need to check each individual calculation. The option is available to the member, however, to perform their own internal calculations of their greenhouse gas inventory and to then input these final numbers into CRIS. In this case the desk audit is the stage where AWMS performs a detailed evaluation of these internal tools to confirm the calculations are correct. Typically this involves large spreadsheets with many internal links and source data. The desk audit specifically involves deconstructing these spreadsheets to understand how the data was utilized. AWMS utilizes the member provided information such as electric and gas bills to perform a check on data entry as well. Errors often include transcription errors, missing entries, and copy and paste errors. Any such errors are tracked on an issues log maintained by each member of the verification team.

The results of the desk audit are the basis of a risk assessment performed by the AWMS verification team to determine the schedule on-site activities. In the case of The Climate Registry an on-site assessment is always required for a member reporting an inventory of greater than 1,000 metric tons of CO_2 equivalent. The risk assessment is conducted to determine those areas of the member's reported inventory that have either the highest impact on the total inventory or those areas that have the highest likelihood of error. Examples might include a member with 90 percent of their inventory resulting from a single electric meter or a member with refrigerant usage that is tracked by a single maintenance technician. Upon completion of the risk assessment AWMS generates a formal Sampling Plan that is distributed to the member for planning.

The on-site portion of the verification is focused on the actual data utilized to generate the member's inventory. The fundamental principle of the on-site verification is that an inventory calculation is only as good as the data that it is based upon. The verification team is focused on determining whether this raw data is being appropriately tracked and gathered. This includes detailed checks on metrology such as flow meters, electricity meters, and continuous emissions monitors. These checks include verification that routine maintenance has been performed, and whether routine calibrations are performed as required. The on-site portion of the verification also entails detailed personnel interviews. These interviews are conducted to determine whether the data collection methodologies are appropriate and complete. Information such as whether the data is collected via electronic data logger versus hand written readings supports the accuracy of the raw data. For example, if the data is logged via handwritten forms, the verification team determines whether the individuals recording the data are trained on that instrumentation and whether there are trained backups available on-site should that technician be unavailable. In many cases the data is not collected as simply as one meter or instrument, but rather as an extrapolation. This is most common to vehicle emissions where fuel consumption may vary from on-site tanks that are routinely monitored to fleet vehicles which fuel at public gas stations. In these cases it is necessary for the verification team to confirm the validity of the techniques used to arrive at the final value. The Climate Registry protocols allow for varying levels of data quality, however the verifier must ensure that members accurately state their data quality. As with the desk audit phase, each member of the verification team maintains an issues log used to track any noted errors.

Upon completion of the on-site verification the AWMS verification team performs a debrief at which time the errors noted on each verification team member's issues log are reconciled. Noted errors are communicated to the member giving them an opportunity to perform possible corrective actions. AWMS at all times maintains third-party status and is obligated as a verifier to simply communicate error; at no time does AWMS engage in consulting as to how to fix the errors. The sum of the errors (in percentage of the direct emissions value and indirect emissions value) drives the necessity for corrective action. In the case of The Climate Registry any error of greater than five percent (regardless of whether it is under reporting or over reporting) results in a negative verification. In these cases the member must make corrective action in order to remain conformant with The Climate Registry. Corrective action must substitute good data for bad or missing data or result in a sound enough estimation technique to bridge the bad or missing data. Substitute data can be found, for example, by using electric bills in place of direct meter readings, or fuel purchase records in place of flow meter readings. Estimation techniques may include using sound data points from either side of the gap to create a trend. Members have the option to use simplified estimation techniques for up to five percent of their total inventory.

The Verification Statement phase of the procedure begins upon completion of the on-site verification activities that conclude with the verification team issuing the verification report. This report is handed off to an AWMS technical reviewer who may be any qualified verifier that has not participated in the verification in any way up until this point. It is the responsibility of this technical reviewer to conduct an additional complete review of the member's inventory. The technical reviewer utilizes the observations of the verification team in place of a repeat on-site assessment. The technical reviewer is responsible for issuing the final verification statement. This statement may reflect either a positive verification or a statement that the inventory was not verifiable.

The Climate Registry members must complete the verification process annually. Initial baseline verifications require a higher level of effort, but the process flow remains the same every time. AWMS maintains routine communication with those members that have verification statements issued by AWMS in order to determine if protocol driven triggers require a new baseline inventory. In cases where these triggers are not met, the verification process may take less time given the level of familiarity with the member's internal monitoring methodologies.

As programs continue to be developed and honed, AWMS sees one key issue that bears close attention: conflict-of-interest management. The situation of a company performing a verification of a body of work which that same company's consulting wing has generated must be protected against. As the various greenhouse gas inventory and offset programs continue to expand their membership the opportunity for this conflict expands as well. To maintain validity such programs must have thorough mechanisms to prevent verifiers from hiding consulting work behind false corporate separations. Similarly greenhouse gas programs must be aware that opportunity exists for several verifiers to pass work between themselves with a tacit agreement that Company A will verify Company B's consulting work if Company B returns the favor. The independence of the verification body is critical to the viability of any greenhouse gas trading scheme or inventory program.

BIOGRAPHY FOR ROB ELLIS

EDUCATION

University of Tennessee at Chattanooga, Chattanooga, TN—*M.S., Environmental Science*

University of Rochester Rochester, NY—*B.S., Geology*

Lead EMS Auditor course and exam

Lead OHSAS 18001 Auditor course

Lead GHG Verifier course and exam

WORK EXPERIENCE

August 2003–Present, *GHG Program Manager,* AWMS, Chattanooga, TN

- Management of greenhouse gas verification business activities.
- Development and maintenance of AWMS' internal greenhouse gas verification procedures and policies and management of successful ANSI accreditation.
- Perform greenhouse gas verifications to The Climate Registry protocols and Chicago Climate Exchange protocols.
- Perform environmental management system audits to the ISO 14001 Standard and health and safety management system audits to the OHSAS 18001 Standard.
- Provide support in the development and maintenance of AWMS' ISO 14001 and OHSAS 18001 registrar services.

August 2002–August 2003, *Env., Health and Safety,* ALSTOM Power, Chattanooga, TN

- Responsible for the design, implementation, and maintenance of OHSAS 18001 conforming health and safety management system.
- Maintenance of the ISO 14001 environmental management system.
- Maintenance of compliance with environmental, health and safety regulations and permits.
- Monitor environmental, health and safety statistics.

September 1999–August 2002, *Geologist,* Harding ESE, Knoxville, TN

- Field lead for installation of injection, extraction, and monitoring wells and associated conveyance and remediation systems.
- NDPES and DMR report filing for active remediation sites.
- Quarterly and Annual reporting to clients and regulatory agencies.
- Database management including analytical results, maintenance and construction logs, and field activities.
- Groundwater and soil sampling.

CERTIFICATIONS

- Professional Geologist
- AWMS GHG Lead Verifier
- RABQSA EMS Lead Auditor
- AWMS OHSMS Lead Auditor

DISCUSSION

UPSTREAM VS DOWNSTREAM ANALYSIS AND MONITORING

Chair BAIRD. I thank all the witnesses for very informative testimony. One of the things that strikes me about this process is it is extraordinarily complex, and my own perspective is I think similar to what Mr. Inglis has alluded to earlier. It seems to be on the carbon front in terms of the mass production. It might just be easier to go upstream and say, well, let us just tax a ton of coal or a barrel of oil and figure, well, somewhere downstream we are taking care of the CO_2 output from that. But at the same time, I think the testimony we have heard from Waste Management, from Ms. Gravender, suggest there is a need, particularly if you look at methane sources from agriculture and other things that are not so easily captured up front.

I wonder if you could share with us the sort of pros and cons of the upstream versus downstream analysis and monitoring and also carbon versus other non-CO_2 greenhouse gas emissions.

Mr. STEPHENSON. Are you directing that at me?

Chair BAIRD. Yeah, well, the whole panel.

Mr. STEPHENSON. I would say you are right. Much more is known about carbon emissions right now than probably any of the other greenhouse gases, and because of the Acid Rain Program, you do have in-stack monitoring for about 50 percent of the emitting sources of carbon dioxide.

That is not true for methane and other gases. For example, for methane from landfills there is probably not as much known. But there is a lot of progress as we have heard on working on factors to estimate those emissions. Nitrous oxide is even more difficult to estimate because it comes from farming and tilling soil, and how are you going to assign an emissions baseline to farms and how are you going to monitor that? So in general, I think upstream is easier just because there would be a fewer number of entities. The further upstream you go, the easier it is because of fewer entities, and the easier it would be to regulate. And it is a math problem, as Congressman Baird said, to estimate how much a ton of anthracite coal upstream, for example, would result in a ton of emissions of carbon downstream from the regulated entity. So a lot of the emissions baselines can be estimated at that high level.

Chair BAIRD. Let us hear from some of our other witnesses about this issue.

Ms. GRAVENDER. I think it is a very interesting observation. While the goal for greenhouse gas emissions is for reductions, there are different perspectives if you are talking about a downstream corporate-wide inventory versus an upstream inventory, and I think from The Climate Registry, we have really understood the benefit of having that corporate-wide footprint. It gives companies an opportunity to manage their emissions because as we like to say, you can't manage what you don't measure. So if you don't have a clear understanding of your own corporate footprint, it is difficult to make those reductions. While it may be easier to regulate upstream, there is still value in having a corporate inventory, and many of our companies have benefited from that, not only for reducing their own emissions but also for understanding policies that the Federal Government might take on in the future.

Chair BAIRD. Ms. Wong.

Ms. WONG. You could say that my business is the ultimate end of the stream for many products. But what I would like to add to this statement is that life cycle assessment is extremely important. What we need to do is determine the life cycle carbon emissions of a whole host of products and services and then start thinking about who needs to do the inventory, who needs to do the reductions. You have to have a place to start, and that is the life cycle inventory.

Chair BAIRD. Good point. Mr. Ellis, any comment on this?

Mr. ELLIS. Sure. I would just like to add that I think the downstream program encourages forward thinking. For example, the founding reporters to The Climate Registry are very forward thinking. They are taking ownership of their inventory, and oftentimes by the time they have called upon us as a verifier and we get there, they have already acted to reduce their footprint and reduce that inventory. And I think that that is something that is important to keep in mind when you talk about downstream reporting at the entity level.

INTERNATIONAL AGREEMENT ON MONITORING

Chair BAIRD. As we look toward Copenhagen, one of my problems with this approach is I see the urgency as much greater than the bureaucracy's pace, and my fear is as I listen to all the good work that has been done, that is encouraging, my own believe is we ought to set a 350 part per million standard at Copenhagen. And we are already above that, and that means dramatic reductions worldwide, particularly in our own country. And my fear, to be honest, is that we will spend a lot of time because of the complexities of this issue not agreeing on monitoring and thereby not reducing carbon. If you had to estimate, what do you think the likelihood is that something coming out of Copenhagen could say, well, okay, we re going to agree on this mechanism and this is how we will monitor it. What do you think the likelihood is we get to that agreement? Maybe that is not going to be the goal of Copenhagen, but at some point, if you are going to reduce, you are going to have to have some kind of monitoring.

Mr. STEPHENSON. What are you asking, whether we will reach an agreement on that or whether it is——

Chair BAIRD. No, let me say it this way. If you were to get some of the top experts, yourselves and some other folks in the room and say, look, we have to come up with a monitoring system, whether or not we establish cap-and-trade, but just set aside the cap-and-trade side, set aside a carbon tax, just an agreed-upon monitoring system and set aside Copenhagen, just you all get together with some other experts from around the world, what do you think it would take us to get to an agreed-upon system?

Mr. STEPHENSON. For carbon or for all——

Chair BAIRD. For all.

Mr. STEPHENSON.—greenhouse gas?

Chair BAIRD. Or parse it out if you want.

Mr. STEPHENSON. It is probably possible—the estimating techniques for carbon are better than the other greenhouse gases, so it is probably possible to get an emissions baseline that is pretty reliable, but the framework for estimating and therefore monitoring or establishing baselines get more complex for the other gases. And yeah, 85 percent of the greenhouse gases are carbon but in terms of potential warming potential, you know, methane and nitrous oxide are much more potent than carbon. So you can't exclude those other gases. So I think there is a lot of work to be done on just the estimating techniques, the metrics you use and everything else to be able to reliably estimate a baseline nationwide. It is going to be very difficult and time consuming.

Ms. GRAVENDER. My sense is that we will come out of Copenhagen with at least a rigorous agreement, and I think if we take the opportunity to look at something like The Climate Registry wherein companies are actually reporting their greenhouse gas emissions, and the majority of those emissions, say from stationary combustion or mobile combustion, are in fact easily quantifiable and verifiable. There are certainly some accuracy issues associated with some of the other Kyoto gases, but I think the first step is saying, "let us do this" and try to do it and perhaps give some flexibility on some of those gases where there isn't as much accuracy out there, but at least learn from that process and evaluate that over time to see where really the scientific accuracy is needed and how we can focus in on those areas to have a greater confidence in those additional gases. But I do think that we should and we need to take that step forward, and many of the emissions are able to be quantified and measured at this point.

Chair BAIRD. That is encouraging. My time is expired.

CARBON TAXES

Mr. INGLIS. Thank you, Mr. Chairman. I would like to ask an open-ended question, but I think my question is coming far enough out of left field that I need to describe it a little bit again. What I am looking for is your expertise on monitoring systems and figuring out what body of knowledge out there that might be applied to answering this question, and it is really just sort of a Ways and Means question, but if you want to be in compliance with WTO, you got to figure out a way to not discriminate against imported goods. But at the same time, we don't want them to get a freebie in the air. So what we want to potentially do, if you do this carbon tax, revenue-neutral carbon tax, you can apply it within the domestic market and that can be removed as a value-added tax can be removed when it hits international commerce. So you apply it domestically, and then you can remove it at the border when you are shipping out. Of course, when it gets to another country, they can apply it there. And so what we would like to do is say goods coming in be subjected to the exact same regime that we have got. But figuring out how to somehow take a shot at the measurement of—if we go with an upstream application of the revenue-neutral carbon tax, it seems the most reasonable administratively in this country. The question is how could you compare that to what China's carbon footprint might be in the materials that are being imported? One possibility is to say that here is the average carbon content in American steel, and that would be determined by figuring out all the inputs into that steel and then apply the same tax to imported steel. Now, in France, they want an adjustment because they would say, listen, we got a lot of nuclear. We would like to appeal for a lower assessment. In China, it is basically giving them a freebie because they are using dirtier technology and dirtier coal, right?

But do you have any ideas about how to help me out with measuring so that you can have an efficient, streamlined process of applying a domestic standard to internationally produced goods? Anybody want to take a shot at that? Thank you, Ms. Wong.

Ms. WONG. If I may, I don't know that what you really need is a way to calculate emissions from activities in other countries, but to have a base data collection effort in what different types of manufacturing activities emit, have them agreed upon at the international level, and be able to apply them to products. For example, if you use a nuclear-based energy to produce a product, it is going to have a lower carbon footprint than a high-sulfur coal with no scrubbers. Now, it would be huge undertaking and it would have to be agreed upon at an international basis in order to be applied internationally. But if the different countries could come together and agree to certain footprints for certain activities, they could be applied to a manufacturing process to come up with a life cycle.

Mr. INGLIS. Anyone else want to take a shot at that?

Mr. STEPHENSON. I would just say that let us take imports from China. Determining their carbon footprint and what kinds of inventory estimating techniques they use and having to verify and monitor that is going to be very problematic. I don't know whether you could estimate——

Mr. INGLIS. Yes, in fact——

Mr. STEPHENSON.—estimate the carbon footprint for a like-U.S. product maybe and apply that to the import.

Mr. INGLIS. That is exactly what we are thinking about doing.

Mr. STEPHENSON. And it would be much easier at the commodity level like the example you gave on steel than it would at the end product level, I would think.

Mr. INGLIS. Right. What we are looking for really is some mathematical system——

Mr. STEPHENSON. Yes.

Mr. INGLIS.—you can sort of take a——

Mr. STEPHENSON. For all kinds of products.

Mr. INGLIS. It wouldn't be exact, but it would be somewhere in the ballpark. And it is important that it not be discriminatory. It can't hurt imports more than it is applied to domestic-produced goods.

Mr. STEPHENSON. GAO does have some ongoing work right now for Senate Finance looking at revenue generation from climate change, and we are getting into this issue a little bit.

More on Monitoring Standards

Mr. INGLIS. That is another question I have. I have got a little bit of time left. Who is best to develop monitoring standards? What is the agency that is best to do that if we go into either cap-and-trade or revenue-neutral carbon tax? Is it NIST or is it EPA or is it somebody else?

Mr. STEPHENSON. Well, right now EPA is the one that estimates emissions inventories for Kyoto, for the framework convention, I should say. So they have probably a jump start on other agencies, but the Department of Energy also has a lot of information on estimating techniques.

Mr. INGLIS. And what I have been asking about here, do you think that is still within the EPA? That is where it is logical or is that somewhere else?

Mr. STEPHENSON. I don't know, I would have to think about that. It doesn't seem like EPA is a fit for that.

Mr. INGLIS. Right. Thank you, Mr. Chair.

Chair BAIRD. Mr. Luján.

Mr. LUJÁN. Mr. Chair, thank you very much. And first and foremost, thank you for holding this hearing. This is a very important issue. As we look not just at what is happening around the country, but around the world, especially as we move forward to continue to create the jobs we need, to be able to get the country moving in the right direction, to be able to be smarter about the way we are developing technologies and moving industry forward, but also in the way that we are going to be generating electricity, power, looking to power our vehicles in this country, and the amount of waste. Mr. Chair, you know we recently had a hearing on the importance of recycling waste when it comes to technologies with computers, cell phones and what we need to be looking at and how we are going to evaluate, how we can move forward into the future. Not only are we going to be able to monitor the amount of greenhouse gases, Mr. Chair, that are moving forward but we are also going to possibly create some job opportunities as a result of moving forward and monitoring.

Coordinating Agencies and States

And so Mr. Chair, my questions stem mainly from the coordination of carrying on the line of question we just had but from a coordination perspective. How will The Climate Registry be able to coordinate with the EPA and the states, those states that have moved forward? I am proud to say, Mr. Chair, that New Mexico was one of the first states to adopt a mandatory greenhouse gas reporting program. And so how do you envision that coordination? Anyone that may want to take that. Ms. Gravender.

Ms. GRAVENDER. Thank you very much for the question. It is an important one. The Climate Registry has been interacting with U.S. EPA, has been in conversations with them. They are certainly aware of our protocols, the work that we have done. While we haven't seen the mandatory rule yet that they are about to release on greenhouse gas emissions, we hope that it will be derived from much of the information that we have worked on so far. In our written testimony we do have a statement from our Board of Directors that stipulates that at a minimum, every federal greenhouse gas reporting program should utilize the greenhouse gas calculation and accounting methods that are consistent with The Climate Registry, allow states and provinces to collect data for federal programs, and maintain the states' abilities to collect additional information if they would like. So we feel that there is a lot of opportunity for collaboration, both on the policy side and also from a data collection standpoint. The Registry has a number of sophisticated programs that we feel would be useful to implementing some type of a federal greenhouse gas registry.

Mr. LUJÁN. Mr. Chair, anyone else?

Mr. ELLIS. I would just chime in on the verification side of things and point to the work that ANSI has done to coordinate that side of the house and ensure that there is consistency in verification activities, and an easy example to point to is the ISO 14065 and 14064–3. They are internationally recognized standards for performing verification. So as a verifier, having gone through the ANSI accreditation process, we are confident that we can operate on an international scale, and programs such as The Climate Registry and the Chicago Climate Exchange both point to that ANSI accreditation process as being a requirement. So on the verification side, I can say there is definitely a very good level of harmonization and consistency, which is critical to any program I think.

Mr. LUJÁN. Thank you. And Mr. Chair, a follow-up, Mr. Ellis. You state The Climate Registry permits the use of estimation techniques of up to five percent of their total inventory. Is it possible that some entity could calculate big greenhouse gas reductions under the five percent rule without actually achieving the greenhouse gas reductions?

Mr. ELLIS. They are simplified techniques. I suppose it is possible that they could wedge something into that five percent, but I think it is unlikely. These tend to fall out to things like, you know, the Chair's vehicle that he didn't keep good fuel receipts on or something like that that they can't really wrap their hands around but they need to acknowledge it is there. And I think you are unlikely to see some large-scale program revolving around the sales department's company vehicle or something along those lines. So it is very unlikely.

Mr. LUJÁN. And Mr. Chair, lastly, what I would like to encourage is that we do reach out to public utility commissioners around the country. I can tell you as a former public utility commissioner, the work that is being done, especially my familiarity with this with the western states is somewhere where I know that we could probably lean on getting some additional expertise or help in coordinating those efforts at that level, Mr. Chair. And again, thank you for holding this hearing. I yield back my time.

Chair BAIRD. Thank you, Mr. Luján, and you bring great expertise in that area, and thank you for that. Mr. Bartlett? Dr. Bartlett.

METHANE AND WATER VAPOR

Mr. BARTLETT. Thank you very much. Isn't it true that water vapor is far and away the largest greenhouse gas? I think that is true. And if that is true, then if the emission of other greenhouse gases increases the temperature of the Earth, should we not have more water vapor which would then start a self-reinforcing cycle, more water vapor, warmer Earth, more water vapor, warmer Earth? If this is true, then shouldn't we be in a position to measure global water vapor so that we could see if this vicious cycle is starting? Is there any focus on that at all? It would seem a priority that water vapor is the largest greenhouse gas, and I think it is, so if the other greenhouse gases increase global temperature, that would mean there would be more water vapor which would mean more global warming so this should start a—obviously we are in balance now and have been for a long time. But if we tip that balance, might not some pretty evil things happen?

Methane is what, 20 times more effective than CO_2 as a greenhouse gas? Do we know the total contribution of those two presently as greenhouse gases? Less methane but 20 times more effective.

Mr. STEPHENSON. Well——

Mr. BARTLETT. Which is the largest contributor now?

Mr. STEPHENSON. Well, right now methane is about six percent of the total greenhouse gas, but if you apply the factor that you are talking about, we haven't done the math but you could do that. In other words, you know, one ton of methane is probably worth 21 tons of carbon, and it gets even higher for nitrous oxide which is 300 times more potent than carbon dioxide.

Mr. BARTLETT. Yes, but a whole lot less of it. Now, we are focusing on landfills for methane, but my understanding is that the cattle on the Earth may produce more methane, may produce more effective global warming, than all the cars in all the world. Now, if that is true, why shouldn't we have a focus on having less animals? We would be healthier, by the way. The meat people bribed the nutritionists to lie about food groups, and we now have a meat food group and a dairy food group and they are not different. As a matter of fact, the best proteins in all the world come from the dairy group. Milk protein is the best protein in the world. Eggs are the second best. If you assign a value of 100 to milk, eggs are about 96, and meat starts at the low 90's and goes on down. If we are really worried about global warming, why shouldn't we have a focus on having less animals? That would mean more vegetarians and longer life for all of us?

Mr. STEPHENSON. I guess it has to be implementable. The public hasn't shown its desire to give up meat.

Mr. BARTLETT. I think that education is a big part of this. The American people need to know that the proteins they get from dairy products are far superior to the proteins they get from meat, and they need to know that the proteins produced by dairy products require what, about one-tenth to one-twentieth of the amount of feed that it requires to produce meat? Pork and chicken people brag that they get three pounds of pig for one pound of food. That is three pounds of wet pig, 70 percent water, you can't eat the bones, to one pound of grain which is about 90 percent dry matter. So on a dry-matter basis, it is at least ten to one for the pig and the chicken and maybe twenty to one for the steer. If you have a milk cow who will produce 20,000 pounds of milk in a year, a ton of dry matter in a year with little more feed than the steer would eat by the way, and at the end of the year you still got the cow to eat if you want.

So if we are really concerned about global warming, why shouldn't we be focusing on methane? You know, if most of our people became vegetarians, it would a far greater contribution to reducing greenhouse gases and every one of us driving a Prius. Isn't that true?

Mr. STEPHENSON. I suppose we should strive to reduce all forms of greenhouse gas.

Mr. BARTLETT. Now, this one is particularly important because not only are you reducing greenhouse gases, you are improving your health. So why shouldn't there be a focus on that?

Mr. STEPHENSON. I can't answer that. You are the policy-making body.

Mr. BARTLETT. Why couldn't we have an education program which you all could contribute to and inform the American people. You don't have to eat meat to get good protein. When you eat meat, you are really contributing to greenhouse warming because methane is 20 times more potent than CO_2. And again, back to one of the original statements I made, my understanding is that cows in the world produce more potential global warming than all the cars in all the world.

Chair BAIRD. Dr. Bartlett——

Mr. BARTLETT. If that is true, don't you think it would be advantageous if more of our people knew that?

Chair BAIRD. Dr. Bartlett, could we ask perhaps Ms. Gravender? I am very intrigued by the line of questioning. I wonder if Ms. Gravender in her work with greenhouse gas registry has evaluated methane output from feed lots for example or from animals. Maybe you can give us some data on that, maybe not?

Ms. GRAVENDER. At this point we have not looked at methane emissions from animals. That said, I do know that the California Climate Action Registry does have a methane—they are working on methane digesters which in part is capturing some of the emission from animals as an emission reduction project. So there has been some work that has been done on this. Otherwise I would say that I do think over all the public opinion is beginning to become interested in eating locally, if you will, to reduce the transportation associated and emissions associated with transporting food and emissions that result from that. So I do think that there is an increase in awareness of greenhouse gas emissions over all and our own personal impact on those emissions.

Mr. BARTLETT. Local variance I think you call them, don't they? People that eat——

Ms. GRAVENDER. That is correct.

Mr. BARTLETT.—no more than 300 miles from home.

Ms. GRAVENDER. That is correct.

Mr. BARTLETT. Thank you very much, Mr. Chairman.

Chair BAIRD. Thank you, Dr. Bartlett, for always an interesting approach and I think an important line of questioning. Dr. Lipinski.

CARBON MONITORING AND TRADE REGISTRY

Mr. LIPINSKI. Thank you, Mr. Chair. Certainly Dr. Bartlett has my mind thinking along different lines now, but the question that I really wanted to put forward, and I am here, and I thank the Chair and also the Ranking Member for having this hearing, just trying to understand and get a better handle on, we hear so much talk about cap-and-trade or a carbon tax. I am an engineer and I always want to know how do I measure that.

So I just wanted to ask, starting with Ms. Wong and anyone else who wants to also chime in here, what are the differences between the Chicago Climate Exchange and The Climate Registry protocols? I am just trying to get a handle on that for myself, the differences in those protocols.

Ms. WONG. That is a good question. To begin with, the Chicago Climate Exchange is an actual trading system. It is a cap-and-trade system that enforces reductions on its members. Of course, membership is voluntary. And the credits that are generated within the system can be traded among members. But the other one you asked about was not The Climate Registry but the California Climate——

Mr. LIPINSKI. No, The Climate Registry.

Ms. WONG. The Climate Registry is a set of protocols. It is not—they do not have their own carbon credits or trading process. It is a means of developing an inventory. It is a collection of protocols, calculations, scientific information, guidelines. They publish some guidelines for data collection also. They are very different. One is an organization in and of itself. The other is an aid to developing an inventory.

Mr. LIPINSKI. How does the CSX[1]—how is that measured? When you are trading, you have to have some sort of measurement of what you are trading.

Ms. WONG. Yes, sir. They do have their own protocols as well, and sometimes they borrow from other established protocols.

Mr. STEPHENSON. I think the Chicago Climate Exchange uses the World Resource Institute protocol to baseline, but we have The Climate Registry expert right next to me.

Ms. GRAVENDER. One of the main differences is that the Chicago Climate Exchange is focused on emission reduction products, so you are taking a baseline and then you are measuring the activity in addition to that baseline in order to quantify an emission reduction. The Climate Registry conversely is talking about putting together corporate-wide inventory. So that is the primary difference between the two activities. One is emission reductions that are then traded on the market, and the other is a corporate-wide inventory.

Mr. ELLIS. I would point out to you from the verification side the Chicago Climate Exchange is a bit more prescriptive in the things that we need to look for, for example, quarterly monitoring as opposed to just routine monitoring, that sort of thing, for methane content in the landfill sector for example. So there is a bit of a difference in the verification side of things which is natural since you are talking about dollars on the Chicago Climate Exchange, the

[1] The Climate Spot Exchange

need for absolute verification is a little bit more important when you insert money.

Mr. LIPINSKI. If you compare the measurements, and I know you were starting with a different—you have the baseline there and then you are talking about reduction with the CSX is what the interest is, but if you compared The Climate Registry and the measurements there and the measurements of the CSX, are they close? Is there a real comparison there? Has there been a comparison of that?

Ms. GRAVENDER. Well, again, they are measuring different things, so it is difficult to do a parallel comparison in some regard. Also, the Chicago Climate Exchange is a private operation whereas The Climate Registry is a public endeavor. So all of our protocols are vetted publicly with public comment periods. The Chicago Climate Exchange developed the protocols without that public feedback. So there is still a private and public difference between the two as well.

Mr. LIPINSKI. Do we not know what exactly what the Chicago Climate Exchange, what their other measurements are?

Ms. GRAVENDER. I will say that the Chicago Climate Exchange, the protocols are only available to those who participate. So they are not available for public consumption for us to do that assessment.

Mr. STEPHENSON. But right now, the baseline estimating techniques are not the same, and that is the point that you are making. I think that they need to be standardized for a nationwide system before it can work. There are lots of slightly different estimating techniques or protocols that you can use for various greenhouse gases.

Mr. LIPINSKI. I thank all of you for your testimony. Ms. Wong.

Ms. WONG. Just one small correction. Chicago Climate Exchange has posted their protocols on their website now. They were not available some time ago, but they have added them to their website. And if I may say, if you are looking to the underlying science, how do you calculate emissions from a typical process, they are going to be very, very similar. They just use the data in different ways.

Mr. LIPINSKI. Okay. Thank you.

LIEF CYCLE PRICING

Chair BAIRD. We will do another round of questions. This is a fascinating discussion. I am intrigued. Someone, maybe Ms. Wong or others acknowledge the importance of life cycle estimation. We had some folks from the forestry groups in yesterday, and they explained that they had some frustration, and I am not sure this is correct, but they felt that LEED certification on environmentally friendly businesses was so focused on sort of the R value if you will, of the insulating value, that it didn't look at lifestyles so that wood-framed buildings could be rated lower according to them than steel or concrete which strikes me in terms of my understanding of life cycle reanalyzing the acidification gas profile, a wood building is a carbon sink, whereas it burns a lot of fuel to make steel or concrete. The reason I ask that is are we at a point, and what would it take to get to a point, where I as a consumer who cares about the environment, whether it is through my dietary habits or decisions about cars or drinking water out of a bottle, to where I can make an informed decision, you know, I can look on this, you know, it is just water. But you can look at a bottle and say, okay, you have got X amount of vitamin B, X amount of high fructose corn syrup, whatever. But I can't do anything like that easily to inform myself about the life cycle carbon footprint. Are we at where we could do that, where you could have a label that tells you the life cycle carbon footprint, and not just on a product you buy but on a behavior you engage in?

Ms. WONG. If I could speak to that briefly, a lot of our activities that we have engaged in for sustainability purposes and greenhouse gas management purposes have been driven by our customers. Our customers have asked for it, and we have done the necessary research to supply them with the information they needed, either to conduct an activity or to measure the services we were providing for them. So yes, if there were a system available where life cycle analyses were available, it would be very helpful and it is occurring now. There is more information out there than you might think. Unfortunately, it is hidden in each individual company's website. It has not been compiled.

Ms. GRAVENDER. I believe The Carbon Trust in the U.K. has begun a program where they actually have an icon of a black footprint that is small or large as an indication of the emissions associated with producing that product. So I believe that we are starting to get to the point where consumer knowledge and consumer awareness is growing and is interested. In terms of the lifestyle, I am not sure how that is going to transpire. The Climate Registry is considering taking on some of these issue of life cycle assessment within our voluntary registry and will take all of your remarks into consideration.

Chair BAIRD. One of the things that strikes me, and I am sure you all know this better than I, but if you were to make a presumption that a sort of a morality or philosophical basis, there is no reason that one person on planet Earth should be able to produce more greenhouse gas and ocean acidification gases than another, and get I believe we are 20-some folds greater than where we need to be in order to get lethal overheating of our planet and acidification where it needs to be. We need to dramatically reduce, and you know, back to Dr. Bartlett's observation, I think there is a general sense that people feel, well, we are entitled to a certain lifestyle, and I think the gentleman, Mr. Stephenson, said people don't want to give up eating meat. You know, part of acting as a responsible person in a shared environment is you don't say what do I want to do, you say what is the right thing to do, what are the consequences of my action. And the reason I ask these questions is how do we get to that.

PREVENTING CARBON MARKET MANIPULATION

I want to ask Mr. Ellis, you made an interesting observation. We have seen a financial melt-down because, you know, credit default swap, nobody was paying attention and because there were conflicts of interest with people reporting one thing, even though they knew something else to be true because it was in their incentive to do so. As we look at a grand scheme of things, and as Mr. Inglis pointed out, we look at these fluctuations in the markets already in Europe, how do you get around that? If you come up with a complex cap-and-trade kind of system, how do we prevent it from market manipulation, dishonest numbers, et cetera?

Mr. ELLIS. Well, I think the simple answer is third-party verification. And along with that obviously needs to come a very strong management of that. And I think we can look to The Climate Registry as setting a good example in that regard. The amount of information that I as a verifier provide to them in order to be vetted, in order to even embark on a verification with one of their members, it is very detailed, and just simply asking the question I think helps start that. For instance, no member of our staff that has more than $5,000 personal interest in a company can perform any sort of verification work for that company. The greatest risk I see, however, is like I mentioned in my written testimony and here today, is thinly veiled consulting and verification sides of the same company. I think it is fairly easy to engineer something like that on paper to say, oh, that is our consulting branch. They don't do any verification work. It is pretty easy to make it look that way on paper. But I think when you really get out there in the field, you can pierce a hole through that veil pretty easily.

So that would be our biggest word of warning, and it is also why we, as a business, have made the absolute decision that we will not consult. It just introduces risk. I mean, even if I don't personally know the person that did the consulting work and I am the verifier, if I see my company logo on that report that I am verifying, I am going to feel some amount of pressure to reflect positively on that work product. So I think the simple answer is a strong verification will smooth those market fluctuations because there is faith that the product actually exists, especially when you are talking greenhouse gas that you can't see and hold.

Chair BAIRD. Ms. Wong.

Ms. WONG. If I could add to that, I think the key to the question was beginning with an extremely complex system. An extremely complex system with added complexity because third-party validation is added is not going to get us very far. What is going to get us to real reductions is a simple system that is predictable, that can be implemented quickly. You may not get all of the reductions you want immediately, but you will get some demonstrable reductions. And then you can take additional time to develop your program.

Chair BAIRD. What about a hybrid where you encourage the voluntary self-monitored thing, and then there are adverse or positive consequences if the third-party validates what you have done? In other words, if you get it right, you say, we have lowered it by 30 percent, these guys come along, low and behold you have lowered it by 30 percent, you get a fabulous prize. If you don't, you get a fabulous penalty.

Mr. ELLIS. There is a bit of that built into The Climate Registry right now, and the baseline verification is much stronger. You are building a relationship between the verifier and the reporter and saying, okay, you have the internal management structure to understand your inventory and manage this program well, and then every annual subsequent verification can be ratcheted down a bit because you have faith in the system and you are just verifying the system still in place, not necessarily every single work product of the system. So that has been acknowledged I think well by The Climate Registry.

Mr. INGLIS. Mr. Chairman, following up on that, could you lead me through an example, Mr. Ellis, of how verification might work in a particular business? Let us say Waste Management has a site. How would you go about verifying their compliance with a voluntary cap-and-trade? How does that work?

Mr. ELLIS. For instance, in The Climate Registry where it is a voluntary inventory program, it is a pretty simple flow chart if you want to call it that, where initially we gather remotely all their data, as much as they can send us, and we take a representative sample, for example, electricity usage, say. We would look at their spreadsheet by which they tracked that electricity usage, and then we would ask them to send us January's bills. And we look and learn how that interface happens. How did it get from the bill or the meter, whatever, to the spreadsheet? And we deconstruct every bit of that data and then rebuild it and see if we come up with the same numbers. And then that serves as a risk analysis to say there is the most inherent risk? Where did they most likely miss a meter or, you know, misdocument some information, something along those lines. And that is when we go on site and specifically target those high-risk areas and those areas that could most materially impact the verification. And that process holds true, just as an example, of the range that we deal with at AWMS. Our first verification was a small-scale ski resort, and we embark next week on verification of one of the largest electricity generation transmission and distribution utilities in the United States. So that mechanism holds true across almost literally as wide of a range of spectrum as you could possibly imagine.

Mr. INGLIS. In order to do the ski slope, do you have to have already the electric utility?

Mr. ELLIS. No. No, the protocols apply the same to each.

Mr. INGLIS. I guess what I am asking is the electric—how certain are you that the ski slope, the bill reflects the actual generation of the power? In other words, they know how much was nuclear, how much was—I mean, is that easily discerned?

Mr. ELLIS. It is, absolutely. You know, first we assess off-site, whether the bills are accurately transcribed. I mean, you can have simple data transcription errors that lead to a material impact. But then the on-site, in their case, electricity was a huge component. It was the overwhelming component of their inventory. So we literally said, okay, we are in this building, show me the meter, you know, and make sure that that meter marries up to what we physically see on site. So it can be physically verified. Absolutely.

Mr. INGLIS. And Ms. Wong, you made a very important point earlier about this being simple to do because we don't want to add a burden. If we can avoid the burden, we want to not add a burden. So you found it fairly easy to ferret out that information?

Ms. WONG. It depends on the source. In the case of electrical utility usage, there are eGRID standards published putting a value on the typical carbon impact of electrical generation in a particular state. It averages in all the different sources. And you can use that as a default value. Or if you are buying exclusively from a utility that uses green energy, you can do your own formula from that utility, but using the eGRID numbers provides a pretty robust result.

Mr. INGLIS. Electricity being really somewhat fungible, how certain are you that you can really track that? I mean, you feel comfortable with that, that if you are buying green energy you really are buying green energy?

Ms. WONG. Well, we produce green energy, and the green energy we produce we certainly validate as green energy. I don't think I can really speak to the subject of how to determine whether energy is green or not, but when you ask if I am comfortable with the end result, yes, because an invoice is ultimately audited as part of your financial data. Chances are if a company is paying an invoice, it is accurate. They are going to do something about it if they are overpaying, and the seller is going to do something about it if they are underpaying. So when you use an invoice as your core data source, it is inherently verifiable.

Mr. INGLIS. Did you want to add something to that, anything else?

Mr. STEPHENSON. Let me just add, you mentioned electricity grid is homogeneous. I mean, you can't tell whether your watt of electricity came from a nuclear plant or a wind farm or whatever. If 20 percent of our energy comes from nuclear, you can allocate the carbon emissions based on a watt of electricity. So you couldn't say this guy was nuclear and he has a smaller carbon footprint than this guy who got it all from those high-sulfur content coal or something.

Mr. INGLIS. Thank you, Mr. Chairman.

Chair BAIRD. Ms. Edwards.

VOLUNTARY AND MANDATORY STANDARDS AND REPORTING

Ms. EDWARDS. Thank you, Mr. Chair, and I apologize I wasn't here earlier for your testimony, but I looked at it and I just have one question or a set of questions for Ms. Gravender. Is that how you pronounce your name? Thank you. And it has to do with voluntary versus mandatory, you know, reporting and standards because I have had experience in dealing with companies reporting labor practices internationally. And there are many mixed messages about how and whether these kind of voluntary reporting systems can work when it is essentially sort of self-policing. And so I wonder if you could explore with me just for a bit about what kinds of incentives or not really enforcement mechanisms because it is a voluntary program, but what kind of incentives can be in place that encourage companies to straightforwardly and accurately report? And then what is in it for them? I mean, I looked in your testimony, and you indicated some of the reasons why folks would want to participate in a reporting program, but what is in it for them in the end? And then lastly, if you could talk to us about how one might make a transition from a voluntary system to a mandatory system and then what are the sets of things that need to be in place in order to encourage compliance even in a mandatory system?

Ms. GRAVENDER. Thank you for your questions. I think the first thing to understand is that while The Registry's voluntary program is voluntary and you elect to participate, it is not in fact self-policing. We have third-party verifiers such as Advanced Waste Management who must review and attest to the quality of the data that is reported. So you can't voluntarily choose which emissions you are going to report, rather you voluntarily choose to participate in the program and then the data that you report is reviewed by a third-party verification body annually. So that is a bit different.

What is in it for companies, as we said earlier, companies cannot manage what they don't measure. So it is very valuable for organizations to understand their corporate-wide footprint so that they can identify where there are opportunities for reductions. That may lead to emission reduction projects that create financial value to them, it may also just be an inefficiency approach for them where they an identify pollution, if you will, that they can reduce and act more effectively.

In terms of a transition from voluntary to mandatory, I think we are thinking of this from the mindset of most organizations will likely report mandatory emissions first. So I think it is sort of flipping the question in how can mandatory data be then used in a voluntary world. Assuming a company is required to report to a mandatory program, that is likely going to be facilities that trigger a certain threshold of emissions to their largest sources of emissions. And then to supplement that for the full corporate footprint if you will, can that mandatory data be transferred into a more robust voluntary database if you will where the organization could round out the rest of their emissions footprint. That is how we are seeing the intersection between mandatory reporting which will likely be at a certain threshold to voluntary reporting that will get more comprehensive in scope.

Ms. EDWARDS. And then are there incentives in terms of a company's relationship to a consumer or client that would encourage greater participation?

Ms. GRAVENDER. I think some companies are more aware, more concerned about the public perception and want to be seen as an environmentally progressive organization or particularly concerned about their emissions footprint. So I think there is just a different risk assessment and interest in that from a corporate perspective.

Ms. EDWARDS. I mean, if you look now for example at like LEED's standards and LEED's certification, you know, I mean there are developers out there who say they want that LEED's certification. And we haven't really had to do very much to necessarily require it, but it has become kind of an industry mantra. And I wonder if there is a similar application in the area of emissions.

Ms. GRAVENDER. Well, I think there is certainly the possibility. We have seen from the California Climate Action Registry which is a voluntary registry, when the State of California implemented mandatory reporting, we thought this will get an interesting observation. Will those companies that signed up for a voluntary program drop off and just participate in the mandatory program or will they maintain both? And what we have seen thus far, even though it is very early in the process, is that companies are staying in the voluntary registry because they derive value associated with that. So we expect to see, and hope to see, a similar experience. It will be very interesting to see how mandatory greenhouse gas emissions are required to be reported at the federal level to see how organizations react to that.

Ms. EDWARDS. Thank you very much. Thank you, Mr. Chair.

Chair BAIRD. Dr. Bartlett.

INFORMING THE PUBLIC

Mr. BARTLETT. Thank you very much. I enjoy the Waste Management ads on television. They have such beautiful nature scenes, but every time I see that ad, I am reminded that although burning that stuff is kind of green, that waste stream represents profligate use of fossil fuels, doesn't it? And so in an increasingly energy-deficient world, there is going to be less and less of that waste stream. And wouldn't it be greener to not have used that stuff initially so that it doesn't end up in the landfill? That is just an observation. How close are we to being able to have truth in advertising? I am not a big fan of government and government regulation, but I am a huge fan of truth in advertising and labeling. How close are we so that we can tell the consumer, and probably have to use something like CO_2 equivalence because that is what people are understanding about contribution to climate change and global warming. How close are we to telling the guy what this action will entail in terms of CO_2 equivalent footprint? Like when you sit down to eat that big beefsteak, if in big red letters on the menu it told him that that had a bigger carbon footprint than driving his Explorer there to eat it, don't you think we might have some change in behavior? Because I think most people are really concerned about this but they are ignorant, they don't know what they are doing. How close are we that we can put down the global warming contribution of all of our actions and things we buy and so forth?

Ms. WONG. Well, sir, we have the technology now to obtain the carbon footprint of just about any activity you would like to footprint.

Mr. BARTLETT. So why aren't we putting that down on the menu and on the gas pump and on your thermostat in your house if you turn it up two degrees, what is the CO_2 footprint? Why aren't we doing that? I think people would like to know the contributions they are making so they can use less destructive pursuits and products and so forth? Is that something we need to do or is that something the industry can voluntarily—I am not a big fan of Big Brother, by the way. I like industry to lead. Why doesn't industry lead in doing this?

Ms. WONG. Well, as an example, we have been engaged in greenhouse gas inventorying and reduction efforts since 2004, and it is still voluntary. We are still doing it, still advancing it, and we plan to disclose our company carbon footprint for 2009 in 2010.

Mr. BARTLETT. But that is on a website somewhere. It is not on your electric bill, it is not on your menu, it is not listed on the products you buy in the grocery store. Everything we buy, everything we do, you just can't live and use energy without having a CO_2 equivalent footprint, can you? Why aren't we being told what that is so that we can make wise choices? We have the capability to do it, don't we? Can we at least make a reasonable guesstimate as to the CO_2 equivalent contribution of everything we buy and everything we do? Why wouldn't that be desirable to have that there so that people can see?

Mr. STEPHENSON. It would, but the quickest way to do it is to mandate it, unless there is public pressure to have such information. That is usually the way it happens the quickest, if there is a great demand from the public to have better information on the carbon footprint of everything they do. There are many websites that individuals can go on and estimate their own carbon footprint, for example, but how many people do you think actually do it? They just don't for whatever reason.

Mr. BARTLETT. It is so easy to see it if it is on the gas pump, if it is on your menu, if it is on the box of Cheerios you buy. It is so easy to see it there. I would just like to see it there. I encourage industry to do this before government tells them to do it. You know, that just encourages government to get bigger, when industry doesn't do something and they are forced to do it because we ask them to do it. I would hope that you would encourage the industry you are all associated with to start putting the CO_2 equivalent of carbon footprint on everything that you sell, on all of our activities so that Americans know the contribution that they are making to potential global warming. I think most of us want to be responsible, but you know, there is enormous ignorance out there about the consequences of our activities. Well, thank you very much. Thank you, Mr. Chairman, for a good hearing.

INTERNATIONAL CARBON CONTROL

Chair BAIRD. Thank you, Mr. Bartlett. I want to talk a little bit briefly about how can we scale this up internationally if we go to Copenhagen, if we go to international cap-and-trade or something like that? How capable are other countries of learning our way of exporting this? We don't have it yet in our own country, so it is presumptuous I suppose. We export it, but Ms. Wong asserts and others seem to verify we can get a pretty good estimate of carbon footprint. We seem to think that either with the combination of upstream or downstream albeit with some imperfections we might be able to get a pretty good sense. How do we scale this up globally?

Ms. WONG. Well, I think you have kind of answered your question in asking. We do need to do a little more here before we can scale it up, and a good start is to provide a uniform base to do a small amount of reporting, a limited reporting scope, and then allow the states to enhance that to perhaps require more data or more intense data and compile that to come up with our own carbon footprint, and then we can lead through example.

Mr. STEPHENSON. I would just say I think you need to start where the information is the best right now in carbon and then work on the other greenhouse gases in increasing complexity as better information becomes available on the other gases.

Mr. ELLIS. These are programs that have been operating at an international level a lot longer than we have been in the conversation, so as opposed to looking at it maybe as an export situation, we can pay attention to the import situation. There is a lot of good science and a lot of good, real-life market experience out there. They have gone through a number of course corrections in the European emissions trading scheme, and there are a number of other international trading schemes out there. So I think the question should also include what can we import? It is a critical element.

Chair BAIRD. Excellent point, and there are certain other manufacturers that are working on making the electronics, automobiles, et cetera, far more recyclable than ours are. So it is a very, very good point.

CLOSING

Mr. Inglis, did you have any additional questions? With that, I want to thank our witnesses for an outstanding and informative hearing today. The record will remain open for two weeks for additional statements for the Members and for answers to any follow-up questions the Committee may ask of witnesses. With that the witnesses are excused and the hearing is now adjourned. I thank the witnesses and all those in attendance today. I thank our panelists.

[Whereupon, at 1:38 p.m., the Subcommittee was adjourned.]

Appendix:

Answers to Post-Hearing Questions

ANSWERS TO POST-HEARING QUESTIONS

Responses by John B. Stephenson, Director, Natural Resources and Environment, U.S. Government Accountability Office

We provide specific answers to your questions in the enclosure and also provide some general observations below that address a number of the items in your questions. It is worth noting that, in some cases, we do not have a basis to respond to some of the questions because we do not have ongoing or completed work in those areas. To the extent that the Subcommittee has a continuing interest in areas where we axe not able to provide complete responses, we are available to meet with you or your staff to discuss your interests and assist in developing a request for GAO to do additional work that would enable us to respond to these and other questions about greenhouse gas emissions data.

General Observations

- The data requirements to develop reliable emissions baselines depend largely on (1) the types of entities and gases covered in a regulatory program and (2) the point of regulation.

  First, the data requirements depend on the breadth of entities covered across economic sectors and the number of greenhouse gases covered. With respect to breadth, if a program were to only include electricity generating units, we already have adequate emissions data to establish an emissions baseline. If a program were to address emitting entities across all economic sectors—as many policy experts recommend—data gaps may exist. We have not evaluated the quality of baseline emissions data for sectors beyond electricity generating units. Any facility that has historical data on its combustion of different fossil fuels would be able to develop a reasonable estimate of its carbon dioxide emissions. However, including other greenhouse gases beyond carbon dioxide in a program could present challenges in establishing an emissions baseline. While carbon dioxide emissions from fossil fuel combustion can be calculated with a reasonable degree of certainty based on the use of different fuels, emissions of other greenhouse gas emissions can be more difficult to quantify. This is particularly true for nitrous oxide and methane, which are generally emitted by diffuse sources such as agricultural operations, fossil fuel extraction, and landfills. We have not evaluated the quality of methods for calculating emissions of the other three primary greenhouse gases (hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride), although these substances are produced by a relatively limited number of manufacturers and these manufacturers may be able to provide information on historical production and emissions that could help in establishing a baseline.

  Second, the point of regulation would play a major role in the need for additional data on baseline emissions levels. Specifically, an "upstream" program that focuses on a relatively limited number of fossil fuel and synthetic gas manufacturers, importers, and producers would greatly reduce the data requirements for establishing baseline emissions levels. For example, an "upstream" program might involve thousands of entities whereas a "downstream" program focused on individual industrial facilities and consumers could involve tens of thousands of regulated entities. Thus, developing a reliable emissions baseline for an "upstream" program would be much easier than doing so for a "downstream" program.

- Direct monitoring of emissions is not necessary to establish baseline emissions levels for carbon dioxide. Carbon dioxide emissions can be calculated with a reasonable degree of certainty using information on the type and quantity of fossil fuel combusted. The key data need here is reliable historical data on fossil fuel use rather than direct monitoring data. Direct monitoring may be useful or necessary for establishing baselines for other greenhouse gases, but we have not evaluated data needs for these gases. We are available to work with you to obtain more information on this issue if this is an area of further interest.

Questions submitted by Representative Bob Inglis

Q1. Mr. Stephenson, in your testimony you describe the method in which EPA determined a baseline of emissions for implementation of the Acid Rain program.

Q1a. How long will it take EPA to create a similar baseline for GHG?

A1a. EPA has baseline data on carbon dioxide emissions from power plants that are sufficient for that sector of the economy. We have not evaluated the extent to which EPA has reliable data for other economic sectors or greenhouse gases. Officials within EPA's Office of Air and Radiation may be better positioned to respond to this question.

Q1b. Could a GHG emissions baseline be generated in a similar manner to the acid rain program such that it is based on an average of a three-year time period that occurs well before implementation of the regulatory program to prevent gaming of the numbers?

A1b. This approach would help prevent gaming and could be used for regulating carbon dioxide emissions from the electric power sector but we have not evaluated the availability or quality of data for other gases or economic sectors. As we reported in our prior work on lessons learned from the international climate change programs, several experts stated that existing data on fossil fuel consumption axe sufficient to establish an emissions trading program, although we reported this information as expert opinion rather than independently verified fact.

Q2. What happened to those facilities in the EU during the first phase that did not have an accurate baseline to start with?

A2. Our review did not focus on the baselines of specific facilities. In the first trading phase, the EU generally lacked the facility-specific emissions data essential to the effective implementation of a downstream program that distributes allowances for free. Instead, most EU member states based the cap and allowance allocations largely on business-as-usual projections, which are inherently uncertain. During the first trading phase, verified emissions data reported by regulated entities revealed over-allocation—the cap, or supply of allowances, was greater than actual emissions. The number of allowances that each facility received, however, did not exceed its actual emissions. Some facilities, such as those in the power industry, were not given enough allowances to cover emissions and they purchased or reduced emissions. Other facilities, such as those in the energy-intensive manufacturing sectors, were given a surplus of allowances that they could trade on the market or hold. It is worth noting that EU member states have since taken verified emissions data from the first phase into account to set emissions caps in the second phase.

Q3. As you state in your testimony, EPA generates an emission inventory as part of the U.S. commitment to UNFCCC. You also claim that emission factors for some industries such as electricity and cement are very advanced, while others have yet to be generated.

a. How does EPA account for emissions for the industries where the agency lacks robust emission factors?

b. How much uncertainty is built into the EPA GHG inventory?

A3a,b. As stated in its most recent inventory, EPA adheres to UNFCCC reporting guidelines and IPCC protocols when compiling its annual greenhouse gas inventory. In 2006, the IPCC revised these guidelines in order to increase the comprehensiveness and detail of emissions estimates.

The specific methodologies used by EPA to calculate and account for uncertainty vary by the gas and the source, i.e., activity generating the emissions. Each annual inventory report contains descriptions of the uncertainty analyses performed for some of the sources, including the models and methods used to calculate the emission estimates and the potential sources of uncertainty surrounding them.

Carbon dioxide emissions from fossil fuel combustion can be estimated with a high degree of accuracy using emissions factors. According to EPA, combustion-related emissions represented approximately 94 percent of carbon dioxide emissions and 81 percent of total emissions in 2007.[1] Emission estimates for other gases, such as methane and nitrous oxide, are considered less certain.

Q3c. Is the EPA inventory an accurate enough accounting to base a regulatory program on? Wouldn't some industries be better positioned than others due to the greater amount of confidence on the accuracy of the emission factor for that industry?

[1] Measured in terms of carbon dioxide equivalent. Carbon dioxide equivalents provide a common standard for measuring the warming efficiency of different greenhouse gases and are calculated by multiplying the emissions of the non-carbon-dioxide gas by its global warming potential, a factor that measures its heat trapping ability relative to that of carbon dioxide.

A3c. We have not specifically answered these questions in our prior or ongoing work. In general, the data needs for a U.S. regulatory program would depend on its design—specifically, the point of regulation and the method of allowance allocation. For example, a "downstream" program, which regulates emissions at the facility level, would involve a large number of regulated entities and would require extensive data. Reliable data are especially important for a program that gives away allowances in order to determine how many each facility should receive. The ETS demonstrated that giving away allowances can create and transfer substantial assets of considerable value. Specifically, some power producers in the EU's deregulated energy markets passed on the market value of allowances, which they received for free, to consumers by adding the value of allowances to energy rates, resulting in windfall profits.

Conversely, an "upstream" program would regulate emissions at the producer/importer level, which would significantly reduce the number of reporting entities and the administrative burden of collecting the data.

Q3d. Should NIST play a role in setting these emission factors?

A3d. We have not assessed the appropriate role of NIST with respect to setting emission factors.

Q4. How would the data required for a mandatory program to limit emissions differ from a voluntary program? Many of the voluntary programs have similar reporting requirements. Why would a mandatory program be so different?

A4. High quality data are important for ensuring the integrity of voluntary and regulatory programs. Data quality takes on increasing importance in the context of regulatory programs such as a tax or a cap-and-trade system that place a price on greenhouse gas emissions.

Q5. How well would a mandatory program actually function if it was based on registries that are generated from emission factors and estimates versus direct monitoring? Would the level of emission reductions be compromised if the registries were based on estimates versus direct monitoring?

A5. We have not specifically addressed this question in our issued or ongoing work. In general, carbon dioxide emissions can be calculated with reasonable accuracy using emissions factors and data on fuel quantities and types. Thus, direct monitoring of carbon dioxide emissions may not be necessary to establish reasonable registries and baselines for carbon dioxide emissions, especially in an upstream system. Our work has not focused on the availability or quality of emissions factors or direct monitoring methods for other greenhouse gases.

Q6. At the federal level, the mechanism to create high quality emissions data will enable us to track progress and economic impacts; at the individual facility level, managers will be able to make better investment decisions with robust emissions data.

a. Do voluntary emission registry firms supply the protocols and standards to properly capture all emissive activities with the same amount of reliability?

b. Is ANSI doing a sufficient job in pushing these standards to a consensus?

A6a,b. We have neither assessed the standards or protocols of voluntary emission registry firms, nor have we focused on ANSI's role in pushing the standards to a consensus.

Q7. Are there any significant obstacles to the monitoring or verifying of emissions that Congress should consider?

A7. Our work has not identified the presence or absence of significant obstacles to monitoring or verifying emissions.

Q8. Other than those industries that are currently required to report their carbon dioxide emissions to the EPA, what other industries have developed technologies to directly monitor GHG emissions?

a. What industries do not have appropriate monitoring technology, but will likely need it under any mandatory program to limit emissions?

b. Are you aware of any government programs that are currently dedicated to developing direct monitoring technologies for GHG emissions?

A8a,b. GAO has not assessed the extent to which specific industries have developed direct monitoring technologies for greenhouse gas emissions, or whether any government programs contribute to these efforts. The need for such technologies would also depend on a regulatory program's scope and design.

ANSWERS TO POST-HEARING QUESTIONS

Responses by Jill E. Gravender, Vice President for Policy, The Climate Registry

Questions submitted by Chair Brian Baird

Q1. The Climate Registry requires its participating members to report emissions from all sources in North America. However, members may choose to report a global inventory. Are there different requirements for the emissions reporting for facilities outside of North America? How does the Climate Registry define a reputable verifier for the purposes of verifying emissions data for facilities outside North America?

A1. The reporting requirements for worldwide emissions (or non-North American emissions) are the same as The Registry requires for North American emissions. However, while The Registry has made a concerted effort to define emission factors for the U.S., Canada, and Mexico, The Registry has not currently done so for the rest of the world. While The Registry plans to include some basic emission factors from other countries in the near future, a member is responsible for determining proper emission factors and calculations, if necessary, to accurately calculate their emissions from sources outside of North America.

It is important to note that The Registry requires third-party verification of worldwide emissions, if a member chooses to report them. As a result, all reported worldwide emissions must obtain a verification finding of "reasonable assurance" that the reported emissions are within The Registry's five percent materiality threshold.

Members may choose to report their worldwide emissions two ways: 1) Members could use an ANSI-accredited, Registry-recognized Verification Body to verify their entire worldwide emissions, and 2) Members could use an ANSI-accredited, Registry-recognized Verification Body to verify their North American emissions inventory, and then use an ISO 14065-accredited Verification Body to verify their non-North American emission inventory.

The Registry depends on the national accreditation bodies in various countries to assess the general competency of Verification Bodies interested in verifying GHG emission inventories outside of North America. As The Registry's program grows, we will continue to monitor and evaluate the appropriateness of this policy to ensure that Verification Bodies are qualified to verify emission inventories worldwide.

Q2. As was noted during the hearing, power plants and large industrial facilities have continuous emission monitoring (CEM) equipment that record emissions of several gases. What other facilities emitting greenhouse gas emissions might it be possible to apply similar CEM technologies to?

A2. EPA's Acid Rain Program requires regulated facilities to use CEMs to report NO_X and SO_2 data to EPA. CEMs may also be used to measure CO_2, however, additional adjustments may need to be made to the device (inclusion of a CO_2 or oxygen monitor plus a flow monitor would be necessary to compute emissions in tons per hour). The Climate Registry suggests that you speak directly to EPA's Acid Rain program for answers to technical questions pertaining to CEMs.

It is possible to apply CEMs to any facility that has a stack, however, depending on the size of the emissions output of that stack, it may or may not be efficient to deploy CEMs to every stack. It may be just as effective to use calculation methodologies based on fuel use, efficiency; time operated, etc.

Most single large sources of GHG emissions already have CEMs installed. Since GHGs are ubiquitous and can be produced from a large number of small sources, they are very different in nature from criteria pollutants, and therefore, must be measured and controlled differently. Since GHGs are produced from small sources, it is not feasible, nor cost effective to require CEMs to be installed on all GHG sources. Instead, alternative methods, such as calculations based on a number of relevant parameters must be used instead to quantify GHGs in a meaningful, cost effective way.

Q3. In your written testimony you indicate it would be helpful to develop more industry-specific protocols. Which industries would be the best candidates for these improved protocols?

A3. Since the Subcommittee hearing in February, the US EPA released its Draft Mandatory Reporting Rule for GHG Emissions. This Draft requires a number of specific industries to report their GHG emissions. The following sectors will be required to report to EPA under the Mandatory Reporting Rule:

- Adipic Acid Production

- Aluminum Production
- Ammonia Manufacturing
- Cement Production
- Electric Power Systems
- Electricity Generating Facilities
- Electronic Manufacturing Facilities
- HCFC—22 Production
- HFC 23 Destruction Processes
- Lime Manufacturing
- Manure Management
- Landfills
- Nitric Acid Production
- Petrochemical Production
- Petroleum Refineries
- Phosphoric Acid Production
- Silicon Carbide Production
- Soda Ash Production
- Titanium Dioxide Production
- Underground Coal Mines

Based on EPA's reporting threshold of 25,000 tonnes of CO_2e per year, emissions from these sectors will produce approximately 85–90 percent of total U.S. national emissions. These industries should be the focus of industry specific reporting protocols.

Q4. Your written testimony provides a list of GHG calculation methodologies that require refinement to reduce uncertainty in GHG emission reporting. It appears that some of the items listed might be considered proprietary information by the specific entity involved. Would this concern be a barrier to design of a structured sampling or survey program to develop improved calculation methodologies?

A4. The results of some of the required measurements (amount of coke produced, etc.) may be considered proprietary information, however, it is important that consistent calculation or measurement methodologies exist to determine these results. Therefore, companies should not have a problem using a standardized calculation/measurement method to determine the information necessary to calculate their emissions, but they may not wish to share the resulting raw information publicly in order to protect confidential business information.

It is important to note that all emissions information may not be considered confidential under the *Clean Air Act,* however, raw information used to calculate emissions could be considered confidential.

Q5. During the hearing, it was pointed out that it can take some time for a new member of The Registry to obtain all the necessary information to meet The Registry's requirements for reporting their emissions. About how much time does it require for new members to be able to fully report their emissions in accordance with The Registry's standards from the time an entity indicates their desire to be a member of The Registry?

A5. The time necessary to successfully complete a GHG emissions inventory depends entirely on how much work an organization has done to assemble their inventory prior to joining The Registry. The biggest factors in successfully completing an emissions inventory are: 1) how well the emissions information is organized (management systems, data archiving, measurement practices, documentation, skilled personnel, etc.) and 2) how well the organization's staff understands The Registry's reporting requirements.

Some organizations join The Registry without ever assembling an emissions inventory before. In general, these organizations can collect the basic information necessary to report their annual emissions within a year. Other organizations only join The Registry once they are convinced that their current emission inventory will meet The Registry's reporting requirements. As a result, they could join The Registry and report their emissions immediately.

In general, The Registry believes that most organizations can assemble a reasonable inventory in a year or so. However, to provide organizations with the ability to scale up their inventorying activities over time, The Registry allows organizations up to three years to report their complete North American inventory of all six internationally recognized GHGs.

Questions submitted by Representative Bob Inglis

Q1. How different are the reporting protocols for The Climate Registry compared to other organizations? Has there been an effort made between different organizations (The Climate Registry, the California Registry, and the Chicago Climate Exchange) to standardize these protocols to make it easier on those companies that want to participate in more than one?

A1. The Climate Registry is the only voluntary GHG registry that requires public reporting of all North American emissions. Therefore, it is different and distinct from other voluntary and mandatory GHG programs. The Climate Registry used a series of international GHG standards (World Resources Institute/World Business Council for Sustainable Development's *GHG Protocol* and the ISO 14064 standard) and existing best practice protocols (i.e., the California Registry and other industry publications) as the foundation for its Protocols. The Registry's protocols are therefore consistent with international GHG reporting and verification standards and industry best practices. In addition, The Registry produced its protocols through a public development process that included technical experts, industry representatives, environmental groups, and government agencies.

The California Climate Action Registry was created in 2001, and quickly became known as the model for a rigorous voluntary GHG reporting program. The Climate Registry was incorporated in 2007. The Climate Registry drew from the California Registry's existing protocols to develop its own protocols.

In April, 2009, the California Climate Action Registry officially changed its name to be the Climate Action Reserve (The Reserve). Moving forward, The Reserve will focus its efforts on developing emission reduction protocols and tracking the resulting emission reductions, i.e., "offset projects." The California Registry will continue to collect emissions data for 2009 (reported in 2010), but will then cease collecting emissions data. The California Registry is working with The Climate Registry to transition its members to report to The Climate Registry to continue their entity-wide emission inventory reporting efforts.

The Chicago Climate Exchange (CCX) is a private exchange that works with its members to reduce GHG emissions. CCX develops protocols for emission reduction projects and serves as an exchange for its members to transfer the emission reductions to and from interested parties within the exchange. The Climate Registry focuses on public reporting of a company's GHG emissions inventory and does not require members to reduce GHG emissions. The Registry also does not develop emission reduction protocols. Thus, the Chicago Climate Exchange's work is complementary to The Climate Registry's. In fact, several companies are members of both The Registry and CCX.

The Climate Registry's primary mission is to ensure consistency of GHG calculation, reporting, and verification standards. The Registry is working closely with mandatory GHG programs at the State, regional, and federal level to ensure that at a minimum the calculation methodologies are the same across programs. The Registry's goal is to serve as a central data repository for members to report their emissions (once) to multiple programs, thereby reducing the reporting burden for members, while meeting the various policy needs of different GHG programs.

Q2. How many small businesses are part of The Climate Registry? Do you provide additional assistance to companies who wish to participate and report their greenhouse gas emissions but may not be, able to afford the cost of gathering all the data and go through a third-party verification process?

A2. Approximately one third of The Climate Registry's 330-plus members could be considered small businesses. The Climate Registry provides the same excellent customer service and technical support to all of our members, including the small ones. The Registry offers regular webinars and trainings to help all members assemble their GHG inventory. In addition, The Registry has a "help line" where members can call staff experts to discuss particularly difficult reporting issues.

Small businesses must meet the same reporting requirements as larger organizations. There are not different standards of reporting based on size.

Third-party verification is required for all members, regardless of size. However, The Registry offers a service called "batch verification" for organizations with relatively small and simple inventories (less than 1,000 tonnes of CO_2e per year, no process emissions, etc.).

The purpose of Batch Verification is to help reduce the cost of verification by "batching" together a number of small inventories for one Verification Body to review and verify. The Batch Verification Body is selected by The Registry each year (not the member) and The Registry negotiates one standard rate for verification for each eligible member—which is generally lower than a member seeking verification services directly.

Q3. How long does it take for a third-party verifier to become accredited by your organization? How many are actually accredited?

A3. The Registry does not accredit Verification Bodies itself, but rather uses the American National Standards Institute (ANSI) as its third-party accreditation body.

The amount of time it takes for a Verification Body to become accredited depends on how well organized and prepared the Verification Body is. If a Verification Body has a well defined and documented management system in place the accreditation process should not take more than approximately three months. If a Verification Body's management system is not in place, it could take some time for them to become accredited.

Currently there are seven ANSI-accredited, Registry-recognized Verification Bodies. We anticipate there will be three more accredited Verification Bodies shortly. To see the list of ANSI-accredited, Registry-recognized Verification Bodies, please visit The Registry's website: *http://www.theclimateregistry.org/resources/verification/list-of-verifiers.php*

Q4. If Congress were to enact a mandatory emission reduction program, should the official database/registry be managed directly by the Federal Government? Or would the data be better managed by some outside organization such as The Climate Registry?

A4. Without knowing the specifics of a federal emission reduction program, it is difficult to advise the Subcommittee on how best to manage it. Regardless of the program design, however, it will be important that reporters do not have to enter emissions data in more than one place for more than one use. For example, if a reporter is subject to mandatory reporting at the State, regional, and federal level, reporting the same data three or more times will not be efficient.

There are several ways to address the need for multiple GHG programs that limit the reporting burden for reporters. 1) Congress should ensure that data reported to one program can be exchanged and used by other programs—perhaps through the Exchange Network; or 2) Congress should ensure that there is one central data repository through which reporters may enter their emissions data once to meet all of the necessary reporting requirements for multiple programs. This concept could be achieved by either the Federal Government or through an organization like The Climate Registry.

The Climate Registry is currently developing its "Common Framework for Mandatory Reporting" to serve as the central repository for GHG data to various mandatory reporting programs as well as its voluntary registry.

The Registry will be submitting formal comments to U.S. EPA to further elaborate how data collection between multiple GHG programs could happen. The Registry's comments to the EPA regarding its Mandatory Rule are available on The Registry's website: *http://www.theclimateregistry.org/downloads/Public%20Hearing%20comments%20on%20EPA%20rule.pdf*

Q5. What is currently being done to update obsolete emission factors? Are these calculation methodologies generated by the government alone? Or, do they arise from a collaborative effort from industry which then becomes the de facto standard?

A5. Several government agencies are responsible for updating key emission factors (EIA, DOE, EPA, etc.) necessary for calculating GHG emission inventories. Most default emission factors are developed by government agencies, however, detailed calculation methodologies for specific industries are often developed by industry associations, such as the American Petroleum Institute and others.

Q6. It has been estimated that nearly 20 percent of global greenhouse gas emissions are generated from livestock. Does the agricultural industry participate in The Climate Registry? Does The Climate Registry have a suitable protocol for inventorying emissions from livestock and land use changes, with account for approximately one third of global greenhouse gas emissions?

A6. The Climate Registry's members currently include nine members associated with the food and beverage industry. This ranges from an onion farm, to a dairy operation, to a cheese producer.

The Climate Registry has not yet developed a protocol for livestock management or forestry management. As a result, members with these types of emissions will need to follow industry best practices to calculate their emission inventories.

Please note that livestock management and land use management are both areas where emission reduction activity can occur. The California Climate Action Registry, recently re-named the Climate Action Reserve, has developed emission reduction protocols for both sectors. (*http://www.climateregistry.org/tools/protocols/project-protocols.html*)

Q7. Based on the sentiments expressed by the Senate in the Byrd-Hagel resolution in 9997, any mandatory emission reduction program will surely have an international piece to maintain American competitiveness in international markets. How does The Climate Registry plan on including this type of information? This will be particularly important in the cases of China, India, Brazil, and Mexico because these countries may not develop verifiable climate registries for some time.

A7. The Climate Registry is working with mandatory GHG reporting programs that are being developed by states, regions, and Federal governments to ensure that the calculation, reporting, and verification standards are as consistent as possible. In this capacity, The Climate Registry is not setting climate policy, but rather, informing policy-makers of the need for consistency, and offering its technical tools for use in mandatory programs. It will ultimately be the responsibility of the U.S. Government to define how the Byrd-Hagel resolution will be addressed in any federal program needing Senate approval.

Q8. As Congress considers ways to associate a cost with carbon dioxide emissions, a mechanism to create high quality emissions data is of increased importance. At the federal level, this mechanism will enable us to track progress and economic impacts; at the individual facility level, managers will be able to make better investment decisions with robust emissions data.

Q8a. Should industries be responsible for composing their own reporting standards?

A8a. Industries should not be able to set their own reporting standards. Any federal reporting standards should be based on international standards such as the World Resource Institute/World Business Council for Sustainable Development's GHG Protocol and the ISO 14064 standard, in addition to industry best practices. The Federal Government must define a clear set of reporting standards for all regulated parties that take into account the internationally accepted GHG standards as well as industry best practices.

Q8b. Should NIST play a role in setting reporting standards?

A8b. As indicated above, international GHG reporting standards have already been defined; they just need to be implemented. That said, NIST could play a useful role in helping to develop technologies that increase the ease and accuracy in reporting GHG emissions.

Q8c. Do voluntary emission registry firms like yours supply the protocols and standards to properly capture all emission activities with the same amount of reliability?

A8c. The Climate Registry supplies its members with reporting and verification protocols that explain how GHG emissions must be calculated and verified. Two protocols, the General Reporting Protocol and the General Verification Protocol, address the most commonly occurring emission sources. In addition, The Registry is working to finalize two new industry specific protocols (Electric Power Sector and Local Government Operations), and will continue to develop new industry specific protocols that provide further guidance to reporters in speck sectors.

The level of reliability is determined through The Registry's annual third-party verification process, wherein all reported emissions must meet a materiality threshold of five percent.

Q8d. Is ANSI doing a sufficient job in pushing these standards to a consensus?

A8d. ANSI has designed and implemented a program to meet the needs of ISO 14065. This program accredits Verification Bodies interested in verifying GHG emissions to the international standard and ensures that competent Verification Bodies are conducting verification activities.

The Climate Registry currently uses ANSI as its accreditation body. It is critically important that the Federal Government and other State and regional GHG programs also utilize ANSI in this capacity to ensure one common standard for the accreditation of Verification Bodies in the U.S. As a result, the important push to consensus will be driven by the policy-makers in their decision to *use* ANSI as a third-party accreditation body rather than by ANSI itself.

Q9. Are there any significant obstacles to the monitoring or verifying of emissions that Congress should consider?

A9. While there are many details to consider, it is important to recognize that we currently have the capacity to accurately calculate, report, monitor, and verify GHG emissions from most sectors. While some additional refinements may be needed, we should not delay the start of a robust program until all of the minor details are resolved.

ANSWERS TO POST-HEARING QUESTIONS

Responses by Leslie C. Wong, Director, Greenhouse Gas Programs, Waste Management, Inc.

Questions submitted by Chair Brian Baird

Q1. In your written testimony you describe a process now underway to characterize fugitive methane emissions over the range of conditions characteristic of different landfills, both operating and closed. How does the variability in fugitive methane emissions associated with these factors compare with the variability in estimates for methane emissions using current estimation methods? Do the variations in season, management, and site specific conditions for landfills make these sources candidates for continuous monitoring that would allow for reporting of a range of emissions or a more realistic summation of the actual annual emissions from these facilities?

A1. The U.S. EPA in its proposed mandatory GHG Reporting Rule, reviewed methods for estimating landfill emissions and concluded that direct measurement techniques were not yet available for accurately or reliably measuring landfill emissions. According to EPA in its proposed rule preamble, "the direct measurement methods available (flux chambers and optical remote sensing) are currently being used for research purposes, but are complex and costly, their application to landfills is still under investigation, and they may not produce accurate results if the measuring system has incomplete coverage." Waste Management agrees with EPA's determination that reliable and accurate, direct measurement methods are not now available for continuous greenhouse gas (GHG) emission monitoring at landfills. As the leading researcher employing these methods, WM can confirm that research is continuing, but data sufficient to support their use as tools to generate accurate measurements to serve as the basis for regulatory compliance have not been generated to date.

Instead, EPA proposes that landfill owner/operators use a combination of two approaches: 1) all landfills would use the UN Intergovernmental Panel on Climate Change (IPCC) First Order Decay model to estimate landfill emissions that reflect degradation of wastes in a landfill; and 2) for landfills that operate landfill gas collection and control systems, EPA proposes that these landfills also measure collected landfill gas flow and the methane concentration of the gas flow, with an estimated gas collection efficiency to calculate methane generation. Where landfills have active landfill gas collection and control systems, we are able to directly and continuously monitor total collected landfill gas flow; and, although it is not standard operating practice nor required by the New Source Performance Standards for Municipal Solid Waste Landfills, we can continuously monitor the methane concentration of collected landfill gas.

Coupled with these two measurement approaches, EPA also requires owner/operators to estimate the amount of uncollected methane that is oxidized in the landfill cover material. EPA provides a default factor for methane oxidation or allows reporters to calculate an oxidation factor using site-specific data. A significant number of field studies conducted in the U.S. and Europe have provided good estimates of methane oxidation, in the form of ranges, under differing circumstances of cover type, soil type and climate.

EPA's proposed GHG reporting requirements recognizes that landfills are large non-point sources of GHG emissions and far more similar to a large agricultural operation than to a point source such as a stack on an industrial manufacturing plant. Landfill fugitive GHG emissions, in the form of the uncollected and unoxidized methane component of landfill gas, are neither continuous nor uniform. The volume of fugitive landfill gas emissions, and the methane concentration in the fugitive emissions, varies spatially across the landfill footprint, and varies temporally across the course of a day, across seasons, and by region of the country due to climate, soils, topography and waste types. Based on these conclusions, EPA has proposed a workable approach that we support.

Questions submitted by Representative Bob Inglis

Q1. Ms. Wong, in your testimony you state that in 2007 Waste Management launched a two-year project to inventory emissions in order to account for your carbon footprint. How much has this effort cost your company so far? What will the total cost of this effort be?

A1. In December of 2007, WM formed a multi-disciplinary Carbon Footprint Project Team to better understand our greenhouse gas (GHG) emissions by measuring our company-wide carbon footprint, including direct and indirect emissions from all WM controlled entities. The Team is well on the way to meeting our goal of collecting data for and calculating our 2009 GHG emissions so we can report them in 2010. The Team organized itself around four major tasks:

1. Identifying all WM sources of GHG, and identifying existing or developing new protocols for measuring their emissions;
2. Developing the organizational structure for reporting emissions from individual facilities, up to the company as a whole, and identifying internal means to collect emissions data;
3. Selecting and configuring a software tool for managing GHG emissions data, calculating GHG emissions of various types and reporting WM's GHG emissions, which we have named "Climate Care"; and
4. Communicating to internal and external stakeholders about what we are doing, and developing training for WM staff who will be involved in data collection.

The Team's focus this year will be on collecting and internally validating our 2009 emissions information, uploading it to Climate Care, calculating GHG emissions by pollutant and compiling the WM carbon footprint in early 2010.

Set forth below are some estimates of our internal staff resources, our investment in electronic infrastructure and our consultant costs associated with developing our "Climate Care" GHG data management tool, identifying our sources, gathering information required to calculate emissions and calculating our emissions for calendar year 2009. These cost estimates do not include internal resources or external consulting costs associated with landfill monitoring research, emissions testing, development of the SWICS landfill GHG estimation protocol, or upgrades to existing landfill gas collection monitoring equipment, as we consider these to be long-term investments with benefits reaching beyond facilitation of GHG reporting. Also, these cost estimates do not include the cost of third-party verification, as WM is hopeful that third-party verification will not be required on a federal basis.

However, WM has investigated what the cost of third-party verification would be to the company if The Climate Registry's protocols were adopted on a federal level. Using a cost estimate from a reputable third-party verifier for labor and internal cost estimates for travel expenses to provide cross-country access to that verifier, the total estimated cost for annual third-party verification of WM's GHG reports would be approximately $500,000.

To provide some background on the costs provided below, WM is including in its carbon footprint all six commonly recognized GHGs as emitted by approximately 2,500 sites including open and closed landfills of various types, waste-to-energy facilities, alternative fuel power plants, recycling facilities, transfer stations, hauling companies and office-based operations. This wide variety of operations, however, generates GHGs from only four major sources: direct emissions from landfills; direct emissions from fuel combustion in on-road and off-road mobile sources as well as stationary sources; indirect emissions from use of electricity; and direct emissions of refrigerants from maintenance of our own equipment and processing of discarded refrigeration units at some facilities.

Landfill emissions are calculated using the SWICS protocol (shared with Committee staff). Waste-to-energy facility and power plant emissions are calculated using existing emissions test data and waste/fuel receipt data. On-road and off-road mobile source and stationary fuel-burning source emissions are calculated using TCR/CCAR fuel default emission factors and fuel invoice data. Indirect emissions from use of electricity are calculated using E–Grid default emission factors and electricity invoice data. Refrigerant emissions, which are expected to be well under five percent of WM's GHG emissions, are estimated using company average refrigeration unit usage and management assumptions for each type of site.

The effort associated with our carbon footprint effort is reflected in internal WM staff costs, in external consulting costs of IHS, our equipment vendor, and ERM, who customized the IHS software for use by WM, and in the cost of purchasing software and related operating licenses. Internal staff costs include two full-time managers, one environmental and one IT, technical support from professionals in all WM operations departments, WM legal and financial control support, and data entry personnel.

WM Business Units	*Hours*	*Hourly Rate*	*Internal Staff Costs*	*External Cost*	*Total Cost*
Climate Care Mgmt.*	2,800	$100.00	$280,000.00		
Legal/Financial	300	$100.00	$30,000.00		
Landfill Mgmt.	5,500	$100.00	$550,000.00		
Utility Mgmt (elec.)	400	$100.00	$40,000.00		
Fuels Mgmt	400	$100.00	$40,000.00		
WTE and power plant	200	$100.00	$20,000.00		
Programming & Entry	1,500	$100.00	$150,000.00		
Total Internal Labor			***$1,110,000.00***		***$1,110,000.00***
Consultants					
ERM	2,030	$168		$341,040.00	
IHS	140	$185		$25,900.00	
Total Consultants				***$366,940.00***	***$366,940.00***
Hardware/Software					
IHS				$811,896.00	
Total Hard/Software					***$811,896.00***
Total Internal Costs			***$1,110,000.00***		
Total External Costs				***$1,178,836.00***	
Total Inventory Costs					***$2,288,836.00***

*Climate Care Management includes refrigerants emission estimation

The internal WM staff hourly rate used above represents an average salary plus a standard benefits multiplier for the key staff that worked on this project. It is not a fully loaded rate, and it does not include travel associated with working on the project. The estimates of hours of efforts were obtained from interviewing the staff involved. The ERM and IHS staff hourly rates represent an average of each company's billable rates for the personnel assigned to WM's project. Hours and cost are from the contract between ERM and WM. Hardware and software costs are from invoice data.

Q2. Waste Management is a member of the Chicago Climate Exchange and the California Climate Action Registry. How similar are the reporting requirements of these two organizations? What are the differences between them?

A2. Waste Management, as a founding member of the Chicago Climate Exchange (CCX) and as a member of the California Climate Action Registry (CCAR), has voluntarily reported GHG emissions for a subset of our operations in accordance with the two entities' membership rules and protocols. The protocols for calculating emissions are very similar across the two programs, and the protocols used are consistent with the widely accepted GHG reporting protocol developed jointly by the World Resources Institute and World Business Council for Sustainable Development. The primary difference between the two programs is that CCX focuses solely on the carbon dioxide (CO_2) emissions of its members, while CCAR requires its reporting members to report all six Kyoto GHGs (CO_2, methane, nitrous oxide, HFCs, PFCs, SF6) after a three-year transition period.

CCX specifically requires its members to measure baseline and yearly CO_2 emissions resulting from fossil fuel combustion in stationary and mobile sources. Additionally, WM is required to report CO_2 emissions from its nine wholly owned waste-to-energy plants and five power plants. Because the majority of these plants produce renewable energy, WM reports only the CO_2 emissions resulting from combustion of non-biogenic materials (primarily plastics) contained in the municipal solid waste and from combustion of supplemental and base load fossil fuel. The annual inventory is reported to CCX and is third-party audited by the Financial Industry Regulatory Authority (FINRA formally NASD) at the direction of CCX.

Waste Management, as a transitional reporting member of the CCAR, reports only its CO_2 emissions for the first three years of membership, which concluded with the 2008-reporting year. WM has reported CO_2 direct emissions from fuel combustion in stationary facilities and vehicles, and indirect CO_2 emissions from electricity use in the State of California in accordance with CCAR quantification and reporting rules. The emission reports are third-party verified by CCAR-approved verifiers. With the end of our transition period, WM will for the 2009-reporting year be required to report GHG emissions for all six Kyoto gases from its California facilities and vehicles.

Neither CCX nor CCAR requires reporting of landfill GHG emissions. However, WM has supplied landfill GHG emissions data to CCAR on a voluntary basis, using the Solid Waste Industry for Carbon Solutions (SWICS) protocol.

Q3. Waste Management emits greenhouse gases from many different sources.

a. What percentage of your emissions is tracked by direct monitoring technologies? Can this number be increased?

b. What types of technologies would be needed in order to increase the amount of greenhouse gas emission that are directly monitored? Are any of these technologies currently being developed?

A3a,b. WM, for its company-wide carbon footprint, plans to use The Climate Registry (TCR) or CCAR-approved GHG emission calculation protocols for estimating all of its GHG emissions. The U.S. EPA has proposed the same or very similar protocols for its mandatory GHG Reporting Rule. These calculation methodologies employ scientifically demonstrated mathematical formulas, which are used to estimate GHG emissions associated with landfill emissions, fossil fuel combustion in stationary, off-road mobile and on-road mobile sources, electricity use, and municipal solid waste combustion at our waste-to-energy plants.

For landfill emissions, U.S. EPA in its proposed mandatory GHG Reporting Rule, reviewed methods for estimating landfill emissions and concluded that direct measurement techniques were not yet available for accurately or reliably measuring landfill emissions. Instead, EPA proposes that landfill owner/operators use a combination of two approaches: 1) all landfills would use the UN Intergovernmental Panel on Climate Change (IPCC) First Order Decay model to estimate landfill emissions that reflect degradation of wastes in a landfill; and 2) for landfills that operate landfill gas collection and control systems, EPA proposes that these landfills also measure collected landfill gas flow, the methane concentration of the gas flow, and estimated gas collection efficiency with site-specific data to calculate methane generation. Where landfills have active landfill gas collection and control systems, we are able to directly and continuously monitor total collected landfill gas flow; and, although it is not standard operating practice nor required by the New Source Performance Standards for Municipal Solid Waste Landfills, we can continuously monitor the methane concentration of collected landfill gas.

Coupled with these two measurement approaches, EPA also requires owner/operators to estimate the amount of uncollected methane that is oxidized in the landfill cover material. EPA provides a default factor for methane oxidation or allows reporters to calculate an oxidation factor using site-specific data. A significant number of field studies conducted in the U.S. and Europe have provided good estimates of methane oxidation, in the form of ranges, under differing circumstances of cover type, soil type and climate.

For waste-to-energy plants, EPA's proposed rule asks for an annual measurement of GHG emissions for the facility. WM plans to use an annual stack test (using the EPA-approved methodology) to develop an emissions factor for carbon dioxide, nitrous oxide and methane in pounds per ton of municipal solid waste (MSW) combusted. The emissions factors are then multiplied by the annual throughput of MSW combusted at the facility. For an annual measurement, use of stack tests in this manner will provide as accurate and reliable a measurement as would an annual averaged reading from a continuous emissions monitor. The formalized emission test provides a high degree of accuracy, as does the precise measurement of the mass of MSW input to the system. A continuous emission monitor does not employ the technical finesse of a formalized emission test, and is subject to periodic maintenance and recalibration.

The reporting of GHG emissions associated with fuel use in stationary and mobile sources typically uses a calculation methodology that estimates emissions based on the carbon content of the fuel and the mass of fuel consumed. This is an accurate estimate because carbon is not consumed in the combustion process, but is emitted. Inventorying indirect emissions from electricity use requires the use of estimation techniques based on actual metered use rates combined with GHG emission factors based on the type and proportion of fossil or renewable fuels used to generate electricity in a particular state. The utilities themselves are able to directly measure their stack emissions of CO_2, but users of electricity must calculate their indirect emissions associated with electricity use because they cannot determine the specific power plants providing electricity to the grid at the time power is used.

Q4. You state in your testimony that the solid waste management sector decreased greenhouse gas emissions by more than 75 percent from 1974 to 1997. How were these reductions made? What opportunities exist to further decrease your emissions?

A4. Through improved practices, such as recycling and landfill gas collection and combustion, GHG emissions from MSW management have decreased by over 75 percent from 1974–1997 despite an almost two-fold increase in waste generation.[1] The EPA-sponsored study footnoted below evaluated MSW management practices as they evolved throughout the last several decades. For the baseline year of 1974, MSW management consisted of limited recycling, combustion without energy recovery, and landfilling without gas collection or control. This was compared with data for 1980, 1990, and 1997, accounting for changes in MSW quantity, composition, management practices, and technology. Over time, the United States has moved toward increased recycling, composting, combustion (with energy recovery) and landfilling with gas recovery, control, and utilization.

WM believes that additional opportunities exist for further reducing GHG emissions within our sector. In October of 2007, WM announced a series of environmental initiatives to serve as a platform for sustainable growth, building on a number of innovative technologies WM already employs. They include:

- The operation of landfill gas-to-energy, waste-to-energy and biomass plants that produce electricity and fuels that replace fossil fuel use. We plan to double our output of renewable energy by 2020;
- Saving resources and energy by recovering valuable materials through the Nation's largest recycling program. We plan to triple the amount of recyclable materials we manage by 2020;
- Advancing technology for alternative transportation fuels (e.g., landfill gas to liquefied natural gas) and engine design to lower GHG emissions from our vehicles. We expect to direct capital spending of up to $500 million per year over a ten-year period to increase the fuel efficiency of our fleet by 15 percent and reduce our emissions by 15 percent by 2020;
- The continued recovery and destruction of methane gas from landfills; and
- Development of "Next Generation" technology landfills that offer enhanced collection and beneficial use of landfill gas.

Q5. As Congress considers ways to associate a cost with carbon dioxide emissions, a mechanism to create high quality emissions data is of increased importance. At the federal level, this mechanism will enable us to track progress and economic impacts; at the individual facility level, managers will be able to make better investment decisions with robust emissions data.

a. Should industries be responsible for composing their own reporting standards?

b. Should NIST play a role in setting reporting standards?

c. Do voluntary emission registry firms supply the protocols and standards to properly capture all emissive activities with the same amount of reliability?

d. Is ANSI doing a sufficient job in pushing these standards to a consensus?

A5a,b,c,d. As Waste Management has worked over the last year to develop the tools to measure our company-wide carbon footprint, we have gained an appreciation for the complexity of the effort and the need to ensure our customers, our regulators and ourselves that we have done so correctly. One of the key challenges we have faced is the lack of broadly accepted protocols for measuring GHG emissions from our solid waste management operations, particularly landfills.

To facilitate our voluntary reporting of methane emissions from landfills to the California Climate Action Registry, WM and other public and private owners and operators of landfills formed the Solid Waste Industry for Climate Solutions (SWICS), and commissioned SCS Engineers to conduct an in depth literature review and make recommendations on refining current landfill emissions models. The protocol, which has been shared with EPA, The States of California, Massachusetts, and New Jersey, along with CCAR and the Climate Registry, replaces default values for landfill gas collection efficiency and methane oxidation in existing EPA models with ranges, which better account for effects of climate, landfill design and landfill

[1] K. Weitz et al., The Impact of Municipal Solid Waste Management on Greenhouse Gas Emissions in the United States, *Journal of Air & Waste Management Association,* Volume 52, September 2002.

cover types. The protocol was peer reviewed by a team of landfill academicians and practitioners. The protocol represents a first step in refining existing EPA models and protocols to improve landfill methane estimation. We are pleased that EPA's proposed mandatory reporting rule adopted aspects of the protocol to allow reporters to either use default values supplied by EPA, or to undertake more rigorous emissions estimation using site-specific information on collection system and landfill cover system design and operation.

Our experience with developing a protocol for estimating landfill emissions leads us to believe that a consensus-based standards-setting process would be the most constructive means for developing generally accepted protocols for sectors that now lack such protocols. GHG emissions inventorying and accounting is an evolving art and science. The advent of federal GHG reporting requirements offers an excellent opportunity to develop consensus standards for emissions inventorying for key industry sectors. The *National Technology Transfer and Advancement Act of 1995* (P.L. 104–113) directs federal agencies to use consensus-based standards in lieu of government-unique standards except when inconsistent with law or otherwise impracticable.

The American National Standards Institute (ANSI) process for voluntary standards development is the "gold standard" of such processes. It is guided by the principles of consensus, due process and openness, and depends heavily upon data gathering and compromises among a diverse range of stakeholders. The process ensures that access to the standards development process, including an appeals mechanism, is made available to anyone directly or materially affected by a standard that is under development. WM would welcome and support efforts by NIST and ANSI to develop consensus-based protocols to implement both mandatory and voluntary GHG emissions reporting programs.

Q6. Are there any significant obstacles to the monitoring or verifying of emissions that Congress should consider?

A6. Waste Management does not support a requirement for third-party verification of mandatory GHG emissions reporting. There is no precedent for third-party verification in any federal environmental statute under which we operate. The solid waste management sector is subject to numerous reporting requirements under federal statutory programs including the *Resource Conservation and Recovery Act, Clean Air Act, Emergency Planning and Community Right-to-Know Act,* Spill Containment and Countermeasures Program, the *Clean Water Act,* and Superfund to name a few. None of these programs require third-party verification of reporting, and many do not even require self-certification. All, however, include enforcement provisions, which create significant disincentives for faulty or false reporting. Any GHG reduction regime promulgated at the federal or State level will incorporate similar enforcement mechanisms designed to promote good behavior and penalize violators.

Our experience with third-party verification under the CCX and CCAR, suggests that any requirement for third-party verification in a federal mandatory reporting program will add significant logistical issues and delays to the reporting process without enhancing the quality or reliability of reported data. EPA would have to develop standards for the certification of third-party verifiers, approve a sufficient number to ensure that the thousands of reporters subject to the mandatory reporting rule would have ample access to certified verifiers, and then oversee the verification process. Should disputes arise between reporters and third-party verifiers, the likely venue for negotiation is the court system, which would add profound delays to the confirmation of reported data. The EPA has proposed instead to require GHG emissions reporters to self-certify their emissions reports that EPA will then verify. EPA has outlined robust data requirements to ensure that it has the background information necessary to verify the completeness and quality of the emissions reports. We believe that this approach will avoid delays in program implementation, reduce the number of disputes and the time required to rectify them, as well as reduce costs for reporters who would have had to pay for third-party verification, while still ensuring the completeness and quality of emissions data, which itself in many cases will require the services of a third-party expert.

ANSWERS TO POST-HEARING QUESTIONS

Responses by Rob Ellis, Greenhouse Gas Program Manager, Advanced Waste Management Systems, Inc. (AWMS)

Questions submitted by Chair Brian Baird

Q1. In your testimony, you explain that the fundamental principle of the on-site verification is that an inventory calculation is only as good as the raw data used to make that calculation. In your experience, what are some of the challenges with gathering good quality raw data?

A1. For many companies the process of generating a complete GHG inventory is new. In AWMS' experience the greatest challenge we see is the difficulty of creating a complete inventory. In the cases where a reporter has omitted a GHG source it is impossible for that reporter to go back in time and begin measuring that source. This can result in an unverifiable inventory if that omission exceeds materiality (five percent error) thresholds. This is a key point: a GHG inventory is not one point source, or a "tailpipe" measurement—there are many emissions sources at any given site.

Q2. Can you explain any drawbacks to using the data collected from the Continuous Emissions Monitoring Systems (CEMS)? What are the maintenance requirements for CEMS? Do CEMS measure methane and nitrous oxide or only carbon dioxide? Do you verify the emissions recorded with CEMS?

A2. The primary drawback to using the data collected from CEMS is that it can lead to a false sense that GHG inventories are measurable with a single point source measurement device. As stated, a GHG inventory comprises monitoring and measurement of many GHG sources, most of which will be outside the scope of CEMS. Should a power plant, for example, rely on solely CEMS then data sources such as emergency generator emissions, coal pile emissions, and fugitive emissions will be omitted. The maintenance requirements for CEMS are very specific, and include items such as automated calibrations and periodic stack testing to confirm the accuracy of the CEMS. In AWMS' experience a power plant often will assign staff the specific job of CEMS maintenance full-time. Taken in this context, however, CEMS data provides a very reliable source of data. As a verifier AMWS would accept CEMS data in accordance with the applicable reporting protocol, but would still perform a verification of the data by checking items such as calibration records and the availability records of the CEMS. CEMS can be set to monitor almost any gas, however methane would not likely be one of these. Temperatures in stack gas would be so high any methane would probably combust.

Questions submitted by Representative Bob Inglis

Q1. How many companies in the U.S. at this time are third-party verifiers? How long does it take to get accreditation to be a third-party verifier?

A1. Utilizing the global best management practice of ISO 14065 accreditation, there are eight accredited verifiers (including AWMS). This accreditation program is overseen and managed by the American National Standards Institute (ANSI). ANSI represents the U.S. in the International Accreditation Forum (IAF) that ties this accreditation to the international community. In AWMS' case the process to become accredited by ANSI took about eight months (May 2008 thru December 2008). AWMS was a successful member of the pilot group of verifiers, so some of this time can be attributed to the fact that each step was being performed for the first time.

Q2. How long does it take for you to audit a single company's greenhouse gas inventory? Is your entire staff involved in every audit? What is the average number of staff assigned per audit? How many audits can your company conduct in a single year?

A2. As can be expected, the length of time to perform a verification varies greatly depending on the reporting entity. Having said that, there are a number of key indicators that affect that time. For example, the homogeneity of a reporter's operations drives the level of effort greatly. Reporters utilizing a small number of technologies (e.g., coal fired power plants) require a smaller number of site visits in order to sample the emissions inventory where reporters utilizing a large number of technologies (e.g., coal fired, gas fired, and waste-to-energy) require a larger number of site visits in order to sample the emissions inventory. AWMS does not involve the entire staff in any audit; the average number of staff assigned per audit is two to three (consisting of a Lead Verifier, an additional Verifier when necessary, and a Peer Reviewer). AWMS has not had to turn down any verification work due to a lack of resources.

Q3. Are the verification protocols utilized for auditing greenhouse gas inventories the same as protocols used for determining the validity of off-sets? How are these protocols different?

A3. The protocols for auditing greenhouse gas inventories are slightly different from those used to verify offset projects. The primary reason for this is there are different programs for inventories (e.g., TCR) and offset projects (e.g., CCX). Being different entities, they have developed their own protocols. The protocols differ primarily in the calculation methodologies but are based on international practices. There are key similarities, however, such as the requirement for third-party verification. This is the globally accepted best management practice.

Q4. What is the typical margin of error you have found during auditing? Do you assist companies to reduce this error in reporting? Are there any penalties incurred by the companies that have significant errors in their reporting?

A4. TCR and international practices have set the acceptable error level at five percent (assessed independently against direct and indirect emissions). AMWS has been able to successfully verify reporters against this requirement to-date. A very clear requirement of any third-party verification body is that we will in no way assist companies. AWMS' responsibility is to identify error and maintain our impartiality by not participating in or recommending corrections. Along those lines any assessment of penalty is the responsibility of the relevant program. AWMS does have the responsibility to report our verification findings without consideration of reward or consequence.

Q5. Do you test the monitoring technologies to ensure that the data received from them is accurate?

A5. AMWS verifies whether the reporter assesses themselves to ensure that their data is accurate. This includes actions such as verifying proper maintenance, equipment calibration, placement, and, where required, physical sampling such as stack tests. AWMS reviews the records of these actions to ensure they are being performed.

Q6. As Congress considers ways to associate a cost with carbon dioxide emissions, a mechanism to create high quality emissions data is of increased importance. At the federal level, this mechanism will enable us to track progress and economic impacts; at the individual facility level, managers will be able to make better investment decisions with robust emissions data.

Q6a. Should industries be responsible for composing their own reporting standards?

A6a. In order for any emissions inventory to be accepted at an international level, and thus gain access to the international market, industries need to follow the global best management practices. This necessitates a centralized set of protocols by which industries calculate their inventories. A prime example is that of The Climate Registry that creates a system of comparable inventories, i.e., comparing apples to apples. If industries are asked to compose their own reporting standards there will be no consistency and U.S. companies will be barred from any trading on the international market.

Q6b. Should NIST play a role in setting reporting standards?

A6b. Any role that NIST could play in GHG reporting is already being filled, with the American National Standards Institute (ANSI) being the best example. The unique value that ANSI brings to the role is their membership in the International Accreditation Forum (IAF). IAF is a global unifying body that ensures that accreditation as a verifier under ANSI's program is recognized internationally. This, in turn, ensures that a U.S. company that has their inventory verified by an ANSI accredited verifier will be recognized at the international level. For this reason, ANSI is the best choice to provide oversight of any U.S. GHG program. As far as specific reporting protocols, those have also been developed and are in common use. These protocols, such as The Climate Registry's General Reporting Protocol, have been developed with linkage to international protocols in mind, thus ensuring that U.S. verified inventories would be recognized internationally. Both ANSI and TCR are in practice today; there is no need to recreate these functions within NIST.

Q6c. Do voluntary emission registry firms supply the protocols and standards to properly capture all emissive activities with the same amount of reliability?

A6c. In AWMS' experience the voluntary emission registries in which we participate (TCR, CCX) are producing high quality protocols that do properly capture emissive activities. As with any protocol or standard it is up to the end-user (reporters in this case) to appropriately apply these protocols. That highlights the fact that third-party verification is a critical element; it is in this phase of an inventory program that assurances are made that a reporter appropriately interpreted and applied the protocols and that no emissive activities were omitted. Relative to GHG programs, ANSI utilizes ISO 14065 and ISO 14064–3 which are Standards written and ratified by ISO member nations (159 nations). ANSI ensures that U.S. programs and verifiers operate in a fashion consistent with the international community, thus keeping the link to the international market open.

Q6d. Is ANSI doing a sufficient job in pushing these standards to a consensus?

A6d. Absolutely, ANSI is doing an excellent job in pushing these standards to a consensus. AWMS has experienced a great deal of two-way communication with ANSI, including updates on the status of various U.S. programs utilizing ANSI as the accreditation scheme of choice. Examples grow on a routine basis and ANSI continues to work towards bringing all verifier accreditation under one system. Through ANSI's representation in the IAF this scheme ensures recognition of not only U.S. verifiers on the international level, but also the inventories verified by that same group.

Q7. Are there any significant obstacles to the monitoring or verifying of emissions that Congress should consider?

A7. A very recent obstacle presented itself with the release of the draft EPA mandatory greenhouse gas reporting rule. In this draft EPA recommends bypassing third-party verification in favor of internalizing that function to the EPA. This immediately would place the U.S. program in contradiction to every other GHG program in the world. In so doing, all U.S. reported inventories would be called into question internationally and would prevent U.S. reporters from entering the international trading market. The argument is presented within this draft rule that EPA has experience with this sort of work through the acid rain program. This is not true in that the comparison between monitoring and verifying data for the acid rain program can be linked to CEMS, while those same CEMS comprise only a portion of a GHG inventory. A GHG verification involves much more than checking the data quality of a monitoring device; this is expertise that resides in the public sector with private companies specialized in emissions inventory verification. This relates directly to another argument presented in the draft EPA rule that states that third-party verification is too expensive. Again, this argument is flawed in that third-party verifiers are already operating in the marketplace. There is no ramp-up cost associated with these companies any longer, and third-party verifiers already have trained staff and management systems in place. Should EPA assume the responsibility of verifier at this stage, all that ramp-up, learning, training, and program development will need to be repeated in the EPA. The argument that there is no need for third-party verification and that spot checks by EPA are sufficient is a very shortsighted argument By ignoring the international best practice the U.S. will take itself out of the international carbon market and eliminate the vast potential of earnings for forward-minded companies who build carbon credits. This draft EPA rule poses an obstacle to international recognition and acceptance of a U.S. GHG inventory program and any future cap and trade program, should the decision to eliminate third-party verification stand.

Further, the draft EPA rule replaces globally vetted emissions calculations and emissions factors with EPA's own versions that have never been tested or internationally used. These EPA procedures further require numerous repetitive site and fuel specific calculations, the cost of which would be extreme.

MONITORING, MEASUREMENT, AND VERIFICATION OF GREENHOUSE GAS EMISSIONS II: THE ROLE OF FEDERAL AND ACADEMIC RESEARCH AND MONITORING PROGRAMS

WEDNESDAY, APRIL 22, 2009

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE AND TECHNOLOGY,
WASHINGTON, DC.

The Committee met, pursuant to call, at 10:04 a.m., in Room 2321 of the Rayburn House Office Building, Hon. Bart Gordon [Chair of the Committee] presiding.

BART GORDON, TENNESSEE
CHAIRMAN

RALPH M. HALL, TEXAS
RANKING MEMBER

U.S. HOUSE OF REPRESENTATIVES

COMMITTEE ON SCIENCE AND TECHNOLOGY

SUITE 2321 RAYBURN HOUSE OFFICE BUILDING
WASHINGTON, DC 20515–6301
(202) 225–6375
http://science.house.gov

Hearing on

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

Wednesday, April 22, 2009
10:00a.m. – 12:00p.m.
2318 Rayburn House Office Building

Witness List

Dr. Alexander "Sandy" MacDonald
Director
Earth Systems Research Laboratory, National Oceanic and Atmospheric Administration

Dr. Beverly Law
Professor, Global Change Forest Science, Oregon State University, and Science Chair, AmeriFlux Network

Dr. Richard Birdsey
Project Leader, Climate, Fire, and Carbon Cycle Science, USDA Forest Service, and Chair, Carbon Cycle Scientific Steering Group

Dr. Michael Freilich
Director
Earth Science Division, National Aeronautics and Space Administration

Ms. Dina Kruger
Director
Climate Change Division, Office of Atmospheric Programs, Environmental Protection Agency

Dr. Patrick D. Gallagher
Deputy Director
National Institute of Standards and Technology

Dr. Albert Heber
Professor of Agricultural and Biological Engineering and Science Advisor, National Air Emission Monitoring Study, Purdue University

HEARING CHARTER

COMMITTEE ON SCIENCE AND TECHNOLOGY
U.S. HOUSE OF REPRESENTATIVES

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

TUESDAY, APRIL 22, 2009
10:00 A.M.–12:00 P.M.
2318 RAYBURN HOUSE OFFICE BUILDING

Purpose

On April 22, 2009, the House Committee on Science and Technology will hold a hearing entitled *"Monitoring, Measurement, and Verification of Greenhouse Gas Emissions II: The Role of Federal and Academic Research and Monitoring Programs."* The purpose of the hearing is to examine existing and planned federal programs focused on monitoring, measuring, and verifying sources and sinks of greenhouse gases, their atmospheric chemistry and their impacts on Earth's climate. The Committee will examine both top-down and bottom-up methods for tracking greenhouse gases including: ground-based, tropospheric, and space-based monitoring systems as well as facility-based monitoring systems and inventory and reporting methods.

The Committee seeks to understand how the existing and planned federal measurement and monitoring systems can be utilized to gain greater understanding of sources and sinks of greenhouse gases and to support research on greenhouse gases, evaluation of national and international greenhouse gas mitigation policies, and development of projections of regional climate impacts to inform development and implementation of mitigation and adaptation strategies. The Committee also seeks to identify the key requirements that need to be addressed in developing a scientifically and operationally robust system for verifying compliance with potential climate agreements.

Witnesses

- **Dr. Alexander "Sandy" MacDonald,** Director, Earth Systems Research Laboratory, National Oceanic and Atmospheric Administration (NOAA)
- **Dr. Beverly Law,** Professor, Global Change Forest Science, Oregon State University, and Science Chair, AmeriFlux Network
- **Dr. Richard Birdsey,** Project Leader, Climate, Fire, and Carbon Cycle Science, USDA Forest Service, and Chair, Carbon Cycle Scientific Steering Group
- **Dr. Michael Freilich,** Director, Earth Science Division, National Aeronautics and Space Administration (NASA)
- **Ms. Dina Kruger,** Director, Climate Change Division, Office of Atmospheric Programs, Environmental Protection Agency (EPA)
- **Dr. Patrick D. Gallagher,** Deputy Director, National Institute of Standards and Technology (NIST)
- **Dr. Albert J. Heber,** Professor of Agricultural and Biological Engineering, Director, Purdue Agricultural Air Quality Laboratory, Purdue University, and Science Advisor, National Air Emission Monitoring Study

Background

The Federal Government has a number of programs that gather observations on greenhouse gases, climate, ecosystem function, land use change, and primary production on land and in the oceans using ground-based, aircraft-based, and space-based measurement techniques. These monitoring and measurement programs are integral parts of research and observation programs designed to gain greater understanding of the Earth's carbon cycle, global nutrient budgets, atmospheric chemistry, the fate and transport of air pollutants, and ecosystem health and function.

There are also several monitoring, measurement and reporting activities that are tied to voluntary reporting, regulatory programs, or international treaty obligations. The voluntary emissions reporting program at the Department of Energy (DOE) tracks the emissions of entities that volunteer to provide information about the greenhouse gas emissions associated with their activities. Under the *Clean Air Act,* the Environmental Protection Agency manages cap-and-trade programs to control the emissions of air pollutants from the power generating sector. The U.S. has ratified two international treaties—the U.N. Framework Convention on Climate Change and the Montreal Protocol. Both of these treaties require monitoring and reporting of greenhouse and ozone depleting gases, respectively to ensure compliance and effectiveness of these treaties.

Research efforts are also underway to quantify greenhouse gas emissions from previously unmonitored sources. For example, the National Air Emission Monitoring Study (NAEMS) is continuously monitoring levels of hydrogen sulfide, particulate matter, ammonia, nitrous oxide, volatile organic compounds and greenhouse gases released from lagoons and animal barns at 20 animal feeding operations in the United States. Led by researchers at Purdue University, the 2.5 year study was established in 2006 by a voluntary Air Compliance Agreement between EPA and the pork, dairy, egg, and broiler industries. The study is currently in its second year of monitoring, and once complete will be used to develop protocols for measuring and quantifying air pollutants emitted by animal feeding operations.

Several proposals are under consideration to develop mandatory programs to report and to control the emissions of greenhouse gases associated with the burning of fossil fuels here in the U.S. At the same time, 192 countries are preparing to meet in Copenhagen, Denmark in December of this year to negotiate an agreement on an international framework to control emissions of greenhouse gases.

The monitoring system now in place serves important ongoing functions in the support of research on the Earth's climate and carbon cycling systems. The current observation system also provides us with information about the likely direction and magnitude of changes in climate and other phenomena, such as ocean acidification, that we are likely to experience as concentrations of greenhouse gases in the atmosphere continue to increase.

A different configuration and level of investment may be required if we are to adapt the current monitoring and observation systems to address specific questions about the efficacy and level of compliance we are achieving as a result of a control program for greenhouse gases. This hearing will explore the following three issues:

- Is our current monitoring system being maintained to support research and general information needs to track the Earth's climate and anticipate future impacts?
- What changes need to be made to the current monitoring systems to support the need for verification and compliance with a greenhouse gas control program domestically?
- What is the status of the international effort to monitor greenhouse gases and will the international monitoring effort be able to support compliance with an international greenhouse gas control program?

The specific type of monitoring system needed is dependent upon the nature of the reporting or control program that is ultimately selected. The current observing and monitoring networks include both "top-down" and "bottom-up" measurements in addition to utilizing modeling, accounting, and other estimation methods.

Top-down measures include satellite-based monitoring or ground-based monitoring focused on measurement of aggregate emissions over large areas or global averages such as the concentration of carbon dioxide in the atmosphere. Bottom-up measures include monitoring or reporting of emissions from specific facilities or geographic locations. Both general categories of measurements and observations will be needed. However, the extent and mix of top-down and bottom-up approaches will be different depending upon the design of the control program.

In both cases, key parameters that need to be determined are the baselines from which changes in emissions will be measured. In some instances, these baselines will be relatively easy to determine. For example, the measurement of carbon dioxide (CO_2) emissions associated with fossil fuel based electric generation has been directly measured using continuous emission monitors for some years. The determination of baseline emissions for a forest or an agricultural area is much more challenging.

While CO_2 is the most prevalent greenhouse gas of concern, there are five other greenhouse gases that are included in reporting programs and are likely to be included in a greenhouse gas control program. These are methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulphur hexafluoride (SF6). These gases, the dynamics of their sources and sinks, and the monitoring and measurement of them is less well-developed than the systems for CO_2.

The witnesses will discuss the specific types of monitoring programs, how these are being used, and how they may need to be altered to provide information to verify compliance and effectiveness of a greenhouse gas control program.

In addition to his role at the U.S. Forest Service, Dr. Richard Birdsey serves as Chair of the Carbon Cycle Scientific Steering Group which provides scientific advice to the North American Carbon Program and the Carbon Cycle Science Program. Interagency coordination of the research, observation, and monitoring efforts is done through the U.S. Global Change Research Program and is essential to this effort.

The information in the Appendix that follows provides a brief overview of key programs supported by the Federal Government. They include programs of the National Oceanic and Atmospheric Administration (NOAA), the Environmental Protection Agency (EPA), the National Institute of Technology and Standards (NIST), the U.S. Department of Agriculture Forest Service, and the National Aeronautics and Space Administration (NASA). In addition, two monitoring efforts managed by the academic community are also included. These programs are supported with federal funds provided by multiple agencies.

APPENDIX

INTERAGENCY RESEARCH AND MONITORING COORDINATION

Climate Change Science Program (CCSP)

The major goal of the CCSP initiatives to study and understand key aspects of the climate system, including the global carbon cycle. According to *Our Changing Planet: The U.S. Climate Change Science Program for Fiscal Year 2009,* the strategic research questions for the global carbon cycle are:

- *What are the magnitudes and distributions of North American carbon sources and sinks on seasonal to centennial time scales, and what are the processes controlling their dynamics?*
- *What are the magnitudes and distributions of ocean carbon sources and sinks on seasonal to centennial time scales, and what are the processes controlling their dynamics?*
- *What are the effects on carbon sources and sinks of past, present, and future land-use change and resource management practices at local, regional, and global scales?*
- *How do global terrestrial, oceanic, and atmospheric carbon sources and sinks change on seasonal to centennial time scales, and how can this knowledge be integrated to quantify and explain annual global carbon budgets?*
- *What will be the future atmospheric concentrations of carbon dioxide, methane, and other carbon-containing greenhouse gases, and how will terrestrial and marine carbon sources and sinks change in the future?*
- *How will the Earth system, and its different components, respond to various options for managing carbon in the environment, and what scientific information is needed for evaluating these options?*

To address these questions, federal agencies, including the Department of Energy, NASA, the National Institute of Standards and Technology, the National Oceanic and Atmospheric Administration, the National Science Foundation, the U.S. Department of Agriculture's Agricultural Research Service, Cooperative State Research, Education, and Extension Service, Forest Service, and Natural Resources Conservation Service, and the U.S. Geological Survey contribute to and coordinate carbon cycle research.

The major elements of the U.S. Carbon Cycle Science Program are:

- The North American Carbon Program (NACP). The NACP addresses some of the strategic questions on the global carbon cycle noted above. The goal is to better characterize and understand the factors that influence changes in the concentrations of carbon dioxide and methane in the atmosphere and the amount of carbon, including the fraction of fossil fuel carbon, being taken up by North America's ecosystems and adjacent coastal oceans.

- The Ocean Carbon and Climate Change (OCCC) Program. The OCCO addresses specific aspects of the global carbon cycle associated with ocean processes. The OCCC and the NACP are complementary programs with a focus on understanding the exchanges of carbon between terrestrial and coastal ocean systems.

There are several interagency working groups with the larger interagency effort that are focused on the carbon cycle and on the coordination of climate observations. These include the Carbon Cycle Interagency Working Group and the Observations Working Group of the U.S. Climate Change Science Program.

U.S. observation and research efforts are linked to the broader international scientific community through our participation in international organizations associated with the World Meteorological Organization (WMO) including the Global Climate Observing System (GCOS) and the Intergovernmental Panel on Climate Change (IPCC).

MONITORING NETWORKS AND PROGRAMS

The AmeriFlux Network

The AmeriFlux network is a ground-based, terrestrial carbon observing system that measures the exchange of carbon dioxide, water vapor and energy between the atmosphere and terrestrial ecosystems. The 90 sites are located in different ecosystems throughout North, Central, and South America and consist of towers equipped with instruments at various heights above ground level. These sites adhere to common protocols across the network to produce continuous, long-term measurements of temperature, wind, water, energy, and carbon dioxide. Using these measurements, researchers estimate terrestrial carbon sources and sinks, the responses of these sources and sinks to climate and land use change, and test models of the carbon cycle and the climate system. Data from ground-based sensors is also needed to calibrate remote sensing and space-based monitoring systems.

The AmeriFlux Network is supported by a number of federal agencies. The Department of Energy's Office of Biological and Environmental Research supports approximately 20 of the sites, measurement and data quality assurance, and data archiving activities for the network. The network's science office is funded by the National Science Foundation and the remaining sites are funded individually by other agencies such as the National Aeronautics and Space Administration, the National Oceanic and Atmospheric Administration, the United States Geological Service, the Forest Service, the Agricultural Research Service, and the National Science Foundation.

The AmeriFlux Network's carbon dioxide flux observations and carbon cycle modeling are important contributions to other national and international observation networks. The Network's information is linked to other federal agencies' observing systems (i.e., NASA, NOAA, NSF, USDA Forest Service) through the North American Carbon Program's (NACP) research plan. The NACP plan for research on the carbon cycle is focused on measuring and understanding the permanence of North American carbon sinks, and the AmeriFlux Network is an integral component of this effort.

The AmeriFlux Network is linked to international carbon flux measurement networks (i.e., CarboEuroFlux, FluxNet-Canada, AsiaFlux and OzFlux) through the National Science Foundation's global carbon flux network known as FluxNet. FluxNet provides infrastructure for managing, archiving and distributing data collected at FluxNet sites to the science community. FluxNet also supports efforts to calibrate observations collected at different sites and to ensure data from these sites are inter-comparable. FluxNet also provides forums for exchange of research findings and facilitates communication among scientists working in related fields. The goal is to build an integrated global network of information from the regional networks in place on each continent to better understand the carbon, energy and water balance of ecosystems and how they fluctuate seasonally and in response to changes in climate.

Monitoring Networks Managed by the National Oceanic and Atmospheric Administration (NOAA)

NOAA's climate observations are extensive and support a number of atmospheric measurement platforms. The majority of atmospheric measurements are conduced by NOAA's Earth System Research Laboratory (ESRL), located in Boulder, Colorado. ESRL's Global Monitoring Division (GMD) conducts long-term continuous measurements on atmospheric gases, aerosols, and solar radiation to inform research on source and sink strengths, global climate forcing, stratospheric ozone depletion, and baseline air quality. The Division has a number of measurement capabilities. However, the global baseline observations and the carbon cycle observations are most likely to have a role in verifying the effectiveness of emission reduction strategies. The programs which support these observations will be examined briefly below.

Global Atmospheric Baseline Observatories

ESRL/GMD supports the Global Atmospheric Baseline Observatories in five locations around the world: Barrow, Alaska; Mauna Loa, Hawaii; Cape Matatula, American Samoa; the South Pole, Antarctica, and Trinidad Head, California. Up to 250 different atmospheric parameters relevant to the study of climate change and ozone depletion are measured at each of these locations. Measurements are made to determine baseline greenhouse gas levels and are critical to the collection and continuity of the world's atmospheric measurements. The first continuous carbon dioxide measurements, for example, were taken in 1958 by Dr. Charles David Keeling at the Mauna Loa Observatory in Hawaii. The Mauna Loa observations are now the longest record of continuous monthly mean carbon dioxide measurements in the world and were the basis for the now-famous Keeling Curve. The Keeling Curve showed the first significant evidence of increasing carbon dioxide levels in the atmosphere and was instrumental in showing that human activity is changing the composition of the atmosphere through the combustion of fossil fuels.

Carbon Tracker and Related Observations

ESRL/GMD also conducts a number of greenhouse gas measurements through its observation networks. The Division's Carbon Cycle Greenhouse Gases Group conducts measurements that document the spatial and temporal distributions of carbon-cycle gases and provide essential constraints to our understanding of the global carbon cycle. The Group conducts in-situ and flask sampling of CO_2 and other atmospheric trace gases using platforms such as: tall towers and existing television, radio and cell phone towers; ships; cooperative fixed sampling sites; and aircraft.

These observations are linked with other agencies' and international observation networks to support the ESRL's research and visualization projects. One of ESRL/GMD's programs that could have a role in verifying the effectiveness of emission reduction strategies is its CarbonTracker program. Launched in 2007, the Carbon Tracker a visualization tool for biological carbon flux on a regional and global basis. Carbon tracker uses the aforementioned measurement networks, other NOAA and DOE sampling sites, and sampling sites operated by Australia and Canada. The measurements are fed into a model with 135 ecosystems and 11 ocean basins worldwide. The model then calculates carbon release or uptake by oceans, wildfires, fossil fuel combustion, and the biosphere and transforms the data into a color-coded map of sources and sinks.

ESRL is also planning to support a future project known as CALNEX. CALNEX 2010 is a joint NOAA, California Air Resources Board, and California Energy Commission field study of atmospheric processes over California and the eastern Pacific coastal region set to begin in 2010. Direct emissions of a wide range of species will be studied, including aerosol, gas-phase ozone, aerosol precursors (e.g., VOCs, NO_X, SO_2, CO, etc.) and greenhouse gases (CO_2, CH_4, etc.). The top-down approach that that will be used is expected to provide an independent assessment of existing inventories.

Carbon Inventory, Management, Monitoring and Reporting by the USDA Forest Service

The Forest Inventory and Analysis (FIA) Program is one of the longest running and oldest research programs of the U.S. Forest Service. The U.S. program was modeled on inventory programs established in Scandinavian countries in the 1920s. The first comprehensive inventory of forests in the U.S. began in the early 1930s but was not completed until the 1960s. The need for more current information led to direction in the 1998 Farm Bill to the Forest Service to adopt a continuous annual inventory system. The information in the inventory is used to estimate the greenhouse gas emissions associated with U.S. forest lands. These estimates are incorporated into the National Inventory of Emissions for the U.S. reported to the U.N. Framework Convention on Climate Change.

In addition, the Forest Service has an active research program on carbon cycling in forests that includes more specific direct measurements of the flux of greenhouse gases from forest vegetation and soils and change in these in response to changes in ecosystem conditions or management practices.

Compilation of the National Emissions Inventory and Monitoring by the Environmental Protection Agency (EPA)

EPA is the lead agency charged with compiling the U.S. National Greenhouse Gas Emissions Inventory. Data from DOE, USDA, and other federal agencies are compiled to provide an annual accounting of U.S. greenhouse gas emissions. This Inventory is submitted to the U.N. Framework Convention on Climate Change in accordance with our obligations under this treaty.

EPA receives data on carbon dioxide emissions from electric power generation facilities from continuous emission monitors at these facilities. These data are collected as part of the cap-and-trade systems for controlling emissions of sulfur dioxide and nitrogen oxides in accordance with the Clean Air Act. The carbon emissions are monitored as a means of verifying individual facility emissions and ensuring compliance with the cap-and-trade program.

National Institute of Technology and Standards (NIST)

NIST's role is to develop standard reference materials and assist with calibration and characterization of the instruments used to observe and monitor greenhouse gases. Because these measurements are made over long period of time and from many sources and by many different groups and individuals, NIST's role of ensuring comparability and accuracy of these measurements is very important. NIST works with federal agencies to ensure the quality of the data gathered through our monitoring and observation networks. In addition, NIST serves as the official U.S. representative in international efforts to ensure quality and comparability of data contributed by different nations to global data repositories.

Observations and Monitoring Programs of the National Aeronautics and Space Administration (NASA)

The Advanced Global Atmospheric Gases Experiment (AGAGE)

The Advanced Global Atmospheric Gases Experiment (AGAGE) network is sponsored by NASA's Atmospheric Composition Focus Area in Earth Science. AGAGE and previous experiments that measure the composition of the global atmosphere have been in place since 1978. The ground-based network supports high frequency measurements of gases specific to the Montreal Protocol—chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons—and non-CO_2 gases specific to the Kyoto Protocol (hydrochlorofluorocarbons, methane, and nitrous oxide). AGAGE includes stations in non-U.S. countries and is part of a collaboration with the System for Observation of Halogenated Greenhouse Gases in Europe (SOGE).

NASA Space-Based Greenhouse Gas Sensors

NASA satellite and airborne data has in the past had an influence on environmental policy, specifically in the case of the Montreal Protocol. NASA Earth observing data helped develop the scientific basis that led to the Montreal Protocol and contributes to the subsequent ozone monitoring program to support the Protocol.

Data from existing NASA sensors on orbit are already being used to study GHGs. Planned satellites are expected to have a greater contribution. Satellites are expected to be a critical component in obtaining the measurements needed to support potential climate policies.

- Tropospheric Emission Spectrometer (TES) on NASA's Aura spacecraft. TES is a high-resolution infrared spectrometer that makes direct measurements of the ozone globally and of other gases, including carbon monoxide and methane. TES takes a global survey on a 16-day repeat cycle. TES' measurements of ozone at different altitudes are used to create an ozone profile.
- Atmospheric Infrared Sounder (AIRS) on NASA's Earth observing Aqua satellite. AIRS measures temperatures, humidities and other properties to help researchers understand the climate system and to improve weather forecasting. Included in its measurements are global data on CO_2 in the mid-troposphere (about five miles above Earth). Researchers also use AIRS data to measure ozone, carbon monoxide, carbon dioxide, methane, sulfur dioxide, and dust particles. AIRS, however, does not measure CO_2 near the surface where it is emitted and absorbed into the land and ocean. To detect the sources of emissions and the absorption of CO_2 near the surface, a different

type of sensor was required; that requirement led to the development of the Orbiting Carbon Observatory.

- The Ozone Monitoring Instrument (OMI) on NASA's Aura spacecraft continues the record of ozone measurements collected by the Total Ozone Mapping Spectrometer (TOMS) instrument and other ozone measurements collected from previous NASA satellites in support of the Montreal Protocol. OMI also measures nitrogen dioxide (NO_2), sulfur dioxide (SO_2), bromine monoxide (BrO), and OCIO among other aspects of air quality.

Orbiting Carbon Observatory (OCO)

The Orbiting Carbon Observatory (OCO), which was launched on February 24, 2009 and failed to reach orbit, *"is the first spacecraft dedicated to studying atmospheric carbon dioxide,"* according to a December 2008 NASA publication entitled, *"Orbiting Carbon Observatory: Science Writer's Guide."* OCO carried three spectrometers and would have detected CO_2 at the level of one to two parts per million—an increase of three times the precision of any earlier satellites that had trace gas sensors. *"The surface footprint of each measurement is [was to have been] about 1 square mile . . .."* OCO was to have collected eight million measurements of CO_2 atmospheric concentration every 16 days. The small size of the footprint and the number of measurements are important for achieving the quality and accuracy of OCO measurements, which are *"accurate to 0.3 to 0.5 percent on regional to continental scales,"* according the OCO Science Writers Guide. The Guide also notes that the level of precision at which OCO's instrument was designed was necessary, *"because atmospheric carbon dioxide concentrations rarely vary by more than two percent from one pole to the other."*

Better understanding of the absorption and emission of carbon and the variation of those changes over time, would have provided researchers with new knowledge about how carbon dioxide emissions contribute to climate change, the efficiency of carbon sinks, and helped researchers forecast changes in atmospheric carbon dioxide. This fundamental knowledge will be important for designing strategies to manage carbon emissions, according to researchers involved in the OCO project.

The Ice, Cloud and land Elevation Satellite (ICESat)

ICESat is the satellite used to measure the mass balance of ice sheets, cloud and aerosol heights and variations in land elevation and vegetation cover. This satellite provides global coverage of topography and vegetation. This satellite also provides specific observations of the major polar ice sheets in Greenland and Antarctica. A follow-on mission is planned to provide continuity for the study of the major ice sheets.

Other Federal Agency Satellite and Airborne Measurement Projects

The Landsat 5 and Landsat 7 satellites were developed by NASA and launched in 1985 and 1999 respectively. The satellites continue the space-based Landsat observations of the Earth's land cover, which began in 1972. The Landsat satellites are currently operated by the Department of Interior's U.S. Geological Survey. NASA is developing the Landsat Data Continuity Mission (LDCM)—the follow-on to Landsat 7—for the USGS. A proposed 2007 plan for a National Land Imaging Program, which would sustain U.S. long-term space observations of the land has thus far not been implemented.

A 2006 report, *Reducing Greenhouse Gas Emissions from Deforestation in Developing Countries: Considerations for Monitoring and Measuring,* noted that Landsat and other remote sensing data can be used to identify deforestation. Landsat data have also been used in studies to identify selective logging in the Brazilian Amazon. (Selective logging affects the carbon storage of tropical forests.) In addition, Landsat data have been applied to research on the use of satellite images for monitoring and verifying agricultural practices related to soil carbon sequestration.

NASA was one of several agencies including the U.S. Department of Energy's Lawrence Berkeley National Laboratory, the National Oceanic and Atmospheric Administration, the University of California, and the California Air Resources Board that participated in an airborne research campaign to measure GHGs over California. According to a June 2008 news release from the Berkeley Lab, the goal was to gain knowledge about how much California's greenhouse gas emissions are contributing to the overall GHG total worldwide.

The flight was linked to the NASA ARCTAS (Arctic Research in the Composition of the Troposphere from Aircraft and Satellites) program. ARCTAS connects to the broader International Polar Year effort known as Polar Study using Aircraft, Remote Sensing, Surface Measurements and Models (POLARCAT), which is an international initiative to employ aircraft and remote sensing platforms to investigate climate change, air pollution, and atmospheric chemistry.

In addition, the High Performance Instrumented Airborne Platform for Environmental Research (HIAPER) Pole-to-Pole Observations (HIPPO) project is an example of an airborne carbon measuring project that involved other research institutions and facilities. With funding support from NSF and NOAA, researchers from the National Center for Atmospheric Research (NCAR), Scripps, and Harvard teamed-up to develop a project that would investigate whether northern forests were absorbing less carbon than had been estimated and tropical forests were absorbing more than estimated.

The project used an NSF/NCAR Gulfstream V jet, which has long-range and high-flying capabilities that suited the project. Repairs and spare parts were easily obtained because Gulfstream is a commercial aircraft that is used around the world. In addition to carbon dioxide, HIPPO measured other greenhouse gases at one- to ten-second intervals.

Key Non-U.S. Satellites and Sensors

Europe's key greenhouse gas monitoring sensor is known as SCIAMACHY on the European Space Agency's Envisat satellite. The SCIAMACHY instrument measures trace gases, including carbon dioxide, methane, and carbon monoxide in the troposphere and the stratosphere.

Japan's Greenhouse Gas Observing Satellite (GOSAT), named "Ibuki," was developed to detect atmospheric carbon dioxide and methane to support compliance monitoring of the Kyoto Protocol. The Protocol is an international and binding agreement under the United Nations Framework Convention on Climate Change and establishes targets for reducing greenhouse gas emissions during the 2008–2012 period.

Ibuki, which was launched on a Japanese H2–A rocket on January 23, 2009, includes an infrared spectrometer to detect carbon dioxide (CO_2) and methane (CH_4) concentrations and a cloud/aerosol sensor.

Japan also operates the Advanced Land Observing Satellite (ALOS) and its Phased Array L–Band Synthetic Aperture Radar (PALSAR) is an advanced imaging radar which is particularly suited for forest and wetland observations. PALSAR measurements are strengthening the satellite capabilities for mapping tropical forests for initiatives such as Reduced Emissions from Deforestation and Degradation (REDD).

Finally, University of Toronto's Canadian Advanced Nanospace eXperiment (CanX) program is a technology demonstration project. The CanX–2 micro-satellite includes an Argus spectrometer which was designed to record greenhouse gas constituents in the near infrared band at a surface resolution of one kilometer.

Chair GORDON. Good morning and welcome to the Committee's second hearing to examine the systems we have to track the emissions, sequestration, and transport of greenhouse gases in the atmosphere, on land, and on the oceans. We welcome our witnesses. We will be having more Members; this is like a lot of times in this committee, a busy day, but we are being televised so some of our Members are watching us, and we have our staff here watching here and in the back. And so we want to get all this information down. This is very important.

In our first hearing we examined the greenhouse gas reporting systems and the methods used to verify the information reported to greenhouse gas registries. Today we will hear about federally-sponsored programs to monitor greenhouse gases.

Monitoring and verification of greenhouse gases doesn't sound like a very exciting topic. It is a little like housekeeping; it is an essential task that goes unnoticed until it isn't done well or isn't done at all.

So without robust monitoring and verification systems we cannot understand the sources and sinks of greenhouse gases. We cannot detect changes in atmospheric or ocean chemistry or understand the potential impacts of these changes, and we cannot evaluate the effectiveness of policies to control emissions of greenhouse gases. Equally important, we cannot verify compliance with emission reductions agreements.

Our nation is a leader in these areas of research. Some of the satellite observations that enable us to track Earth's heat budget are available only because of our investment in science programs at NASA. The ground and satellite observations that we gather tell us a lot about local weather and climate patterns, air quality, and the health of ecosystems and the oceans.

The monitoring and measurement systems that we have today serve primarily a research function. Some, such as the monitoring system associated with EPA's Acid Rain Program serve as a regulatory purpose, and we also track emissions to meet our reporting obligations under international agreements: the United Nations Framework Convention on Climate Change and the Montreal Protocol.

Our colleagues on Energy and Commerce have begun their work to develop a plan to reduce our nation's greenhouse gas emissions. In December, 192 countries will meet in Copenhagen to forge an international agreement to reduce emissions.

We will need a robust monitoring system that is capable of telling us whether we are reducing emissions and meeting our policy goals, and we need to know how the earth's climate system is responding. Of course, the specific design of the monitoring system will depend upon the type of emissions control policy we ultimately decide upon.

We have an excellent panel of witnesses with us here this morning who will offer constructive suggestions on how we can best utilize the assets we already have in place and make strategic investments where necessary to develop a robust and reliable monitoring system.

At a time when warming appears to be accelerating and people are experiencing regional climate impacts already, we need to ensure that we have the information we need on a sustained basis to implement the most effective policies.

So thank you all for participating in this important hearing.

The Chair now recognizes Mr. Hall for an opening statement.

[The prepared statement of Chair Gordon follows:]

PREPARED STATEMENT OF CHAIR BART GORDON

Good morning and welcome to the Committee's second hearing to examine the systems we have to track the emissions, sequestration and transport of greenhouse gases in the atmosphere, on land, and in the oceans.

In our first hearing, we examined greenhouse gas reporting systems and the methods used to verify the information reported to greenhouse gas registries. Today, we will hear about federally sponsored programs to monitor greenhouse gases.

Monitoring and verification of greenhouse gases doesn't sound like a very exciting topic. It's a little like housekeeping—it is an essential task that goes unnoticed—until it isn't done well or it isn't done at all.

Without robust monitoring and verification systems, we cannot understand the sources and sinks of greenhouse gases. We cannot detect changes in atmospheric or ocean chemistry or understand the potential impacts of those changes. And, we cannot evaluate the effectiveness of policies to control emissions of greenhouse gases. Equally important, we cannot verify compliance with emissions reductions agreements.

Our nation is a leader in these areas of research. Some of the satellite observations that enable us to track Earth's heat budget are available only because of our investments in science programs at NASA. The ground and satellite observations that we gather tell us a lot about local weather and climate patterns, air quality, and the health of ecosystems and oceans.

The monitoring and measurement systems we have today serve primarily a research function. Some, such as the monitoring system associated with EPA's acid rain program, serve a regulatory purpose. And we also track emissions to meet our reporting obligations under international agreements—the United Nations Framework Convention on Climate Change and the Montreal Protocol.

The Intergovernmental Panel on Climate Change's recent reports tell us that we must control greenhouse gas emissions if we are to avoid future accelerated warming and its most devastating consequences.

Our colleagues on the Energy and Commerce Committee have begun their work to develop a plan to reduce our nation's greenhouse gas emissions. In December, 192 countries will meet in Copenhagen to forge an international agreement to reduce emissions.

We will need a robust monitoring system that is capable of telling us whether we are reducing emissions and meeting our policy goals. And, we need to know how the Earth's climate system is responding.

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At a time when warming appears to be accelerating and people are experiencing regional climate impacts already, we need to ensure that we will have the information we need on a sustained basis to implement the most effective policies.

Thank you all for participating in this important hearing.

Mr. HALL. Mr. Chairman, I thank you, on I thank you for holding the hearing here and measuring and verifying greenhouse gas emissions, and I appreciate your leadership on this very, very important topic.

While this may not be the most exciting part of the climate change debate that Congress is going to have this year, I truly believe it is one of the most important and appreciate those of you who have prepared for this, who have traveled for this, and who are giving us your time, because we listen to you because you know more about what we are talking about than we do, and we base the law on what you tell us, the part we believe and understand.

So speaking as American as you can for those of us that are not physicists or didn't have the grade average that most of you had. I wouldn't have liked any of you in college because you ruined the curve for guys like me, but I appreciate you being here.

And while it is said it is not the most exciting part of the climate debate, but knowing exactly how many pollutants are being emitted into the environment and establishing a verifiable baseline as a requirement for virtually every environmental law our country has ever passed, and without knowing the current state of things, it is impossible for us to truly assess the impact that we are having on the environment, whether that is good or whether it is bad. And if we don't know where we are starting, how can we prove that we have made any progress?

Mr. Chairman, you and I both sit on another committee that is focusing heavily on the climate change debate. The entire premise of this debate in the Energy and Commerce Committee is based on the idea that we can accurately measure, we can accurately monitor, and accurately verify greenhouse gas emissions coming from all sectors of the economy.

And it is also based on the idea that we can accurately measure, monitor, and verify greenhouse gases removed from the atmosphere through offsets. Setting a cap implies that we know where we currently stand. The trade part implies that we know where it is all coming from. We are betting the entire U.S. economy on the assumption that verifiable data collection and monitoring is as simple as some of the authors say it is going to be.

The hearing we are having this morning demonstrates that we do not have these abilities yet. Our witnesses are going to tell us about the need for greater scientific information, about the need for an accurate emissions baseline in order to implement any regulatory scheme, about the necessity of developing tools and protocols for verifying sources and sinks of greenhouse gases. The fact that we are still early on in the research and development phase of these methods and monitoring technologies means that we cannot in good faith assure the American people that any regulatory framework designed to regulate greenhouse gas emissions based on such methods and technology will not be harmful to the economy.

Accurate measurements, verifiable data, and the integrity of methodology are the very things that form the foundation of any regulatory scheme and are the instruments necessary for responsible governance. Albert Einstein once said, and my kids think I knew Albert Einstein, and he wasn't a bad guy. "If we knew what we were doing, it would not be called research, would it?"

Mr. Chairman, I couldn't agree more with Albert. He was a friend of mine, a good guy.

Our committee has to continue to be at the forefront of this debate because the work we do here is the groundwork needed by other committees to do their own work, so I have to thank you once again for holding the hearing, Mr. Chairman, and I look forward to hearing from these very distinguished witnesses, and I yield back my time, sir.

[The prepared statement of Mr. Hall follows:]

PREPARED STATEMENT OF REPRESENTATIVE RALPH M. HALL

Thank you, Mr. Chairman. I would like to thank you for holding this hearing today on monitoring, measuring and verifying greenhouse gas emissions. I appreciate your leadership on this very important topic.

While this may not be the most exciting part of the climate change debate the Congress will have this year, I truly believe it is one of the most important. Knowing exactly how many pollutants are being emitted into the environment and establishing a verifiable baseline is a requirement for virtually every environmental law our country has passed. Without knowing the current state of things, it is impossible for us to truly assess the impact we are having on the environment, good or bad. If we don't know where we are starting, how can we prove that we have made any progress?

Mr. Chairman, you and I both sit on another committee that is focusing heavily on the climate change debate. The entire premise of the debate in the Energy and Commerce Committee is based on the idea that we can accurately measure, monitor, and verify greenhouse gas emissions coming from all sectors of the economy. It is also based on the idea that we can accurately measure, monitor and verify greenhouse gases removed from the atmosphere through off-sets. Setting a cap implies that we know where we currently stand; the trade part implies that we know where it is all coming from. We are betting the entire U.S. economy on the assumption that verifiable data collection and monitoring is as simple as wanting it to be.

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Accurate measurements, verifiable data and the integrity of methodology are the very things that form the foundation of any regulatory scheme and are the instruments necessary for responsible governance. Albert Einstein once said, "If we knew what we were doing, it would not be called research, would it?" Mr. Chairman, I couldn't agree more with this sentiment.

Our committee must continue to be at the forefront of this debate because the work we do here is the groundwork needed by other committees to do their own work. So I have to thank you once again for holding this hearing, and I look forward to hearing from our distinguished witnesses.

Chair GORDON. Thank you, Mr. Hall, and we will try to get it in Texan so we can both understand it.

If there are other Members who wish to submit additional opening statements, your statements will be added to the record at this point.

[The prepared statement of Mr. Costello follows:]

PREPARED STATEMENT OF REPRESENTATIVE JERRY F. COSTELLO

Good Morning. Thank you, Mr. Chairman, for holding today's hearing to discuss the monitoring and measuring of greenhouse gas emissions.

President Obama has made addressing climate change and greenhouse gas emissions a priority for the 111th Congress. As we prepare to tackle this major piece of legislation, it is imperative that we understand where and how we produce greenhouse gases in the United States and around the world. A strong system for measuring and monitoring greenhouse gas emissions will help ensure compliance with any emissions reduction programs and measure our progress towards decreasing our greenhouse gas emissions.

I would like to hear from our witnesses today how our current array of measurement systems can be most effectively and efficiently used to develop baselines and ensure compliance with a new greenhouse gas emissions reduction program. Further, I would also like to know what new monitoring and measurement technologies will be necessary as we reduce our emissions to lower levels and how the Federal Government and U.S. academic research centers can remain on the forefront of this important technology.

As we all know, the U.S. is not the sole producer of greenhouse gas emissions, and we will not be the sole country to establish a program to reduce greenhouse gases. I am interested to hear how our systems can work internationally, especially as the United Nations prepares to consider a new climate change agreement in January.

I welcome our panel of witnesses, and I look forward to their testimony.

[The prepared statement of Ms. Johnson follows:]

PREPARED STATEMENT OF REPRESENTATIVE EDDIE BERNICE JOHNSON

Good morning, Mr. Chairman.

I would like to welcome today's panel to our hearing, focused on federal programs for monitoring, measuring, and verifying sources and sinks of greenhouse gases.

Today's hearing will also examine greenhouse gas impacts on Earth's climate.

The United States is the world's biggest emitter of greenhouse gases. We are thus in the prime position to lead by example in mitigating those emissions.

Doing so will not only improve our environment, but it may also influence the world's biggest economies to do similar good.

While the federal agencies are already utilizing various strategies to monitor and quantify greenhouse gas emissions, we are thinking towards the future.

Today's hearing will examine the status of our current monitoring systems.

It will also help guide Members of Congress on changes that should be made to fulfill the need for verification and compliance with a greenhouse gas control program.

Mr. Chairman, it is my sense that our Administration and the American public favor progressive greenhouse gas mitigation policies.

Also, I believe that other nations are waiting for our leadership in this area.

Currently, the Department of Energy has a voluntary emissions reporting program in place.

It tracks the emissions of entities that volunteer to provide information about greenhouse gas emissions associated with their activities.

A voluntary system has not worked to sufficiently bring down greenhouse gas emissions. The result is a slow up-tick in global warming.

While I know that some fellow Members of this committee and a minority of scientists may not agree, the consensus is that global warming is happening.

At a local level, we have a problem with greenhouse gas and other harmful pollutants that are emitted by a company just to the west of Dallas.

This company has been authorized by the state to burn hazardous waste as fuel.

The result is terrible air quality and a public health hazard. The jet stream carries it into my district.

According to the Environmental Protection Agency's toxic release inventory, this entity more than doubled the release of toxics into the air between 1994 and 1995.

During 1995, the company discharged 11,000 pounds of chromium, 2000 pounds of butadiene, 7000 pounds of benzene, 255 pounds of methyl ethyl ketone, 3000 pounds of toluene, 750 pounds of xylene and 250 pounds of cyclohexane.

While emitting "probable carcinogens" such as benzene, butadiene and chromium, this entity also releases toxic heavy metals including arsenic and mercury.

The Environmental Protection Agency has determined that this business is the second largest source of dioxin emissions in the U.S.

Mr. Chairman, clean air is a serious concern that is literally "close to home" for me.

Thank you for hosting today's Full Committee hearing to learn more about greenhouse gas emissions.

It is my hope that we can move forward proactively to devise policies for verification of compliance and effectiveness of a greenhouse gas control program.

[The prepared statement of Mr. Carnahan follows:]

PREPARED STATEMENT OF REPRESENTATIVE RUSS CARNAHAN

Chairman Gordon, Ranking Member Hall, thank you for hosting this important hearing on "Monitoring, Measurement, and Verification of Greenhouse Gas Emissions II: The Role of Federal and Academic Research and Monitoring Programs." Thank you to the witnesses for appearing before the Committee today.

As Congress considers legislation this year to address the emissions of greenhouse gasses, collecting accurate and comprehensive scientific data about the progress and potential effects of climate change has become ever more important. I am pleased that the scientific infrastructure we have developed in response to previous international agreements, such as the Montreal Protocol and the U.N. Framework Convention on Climate Change, has enabled us to chart the disturbing trends in our climate. However, we must further develop our scientific capacity if we are to collect the information necessary to implement and monitor comprehensive policy solutions to climate change.

Today, I am interested in learning more about the efforts of our witnesses to collect the data we need and what Congress can do to help. I am disheartened by the recent failure of the Orbiting Carbon Observatory to reach orbit, and I would like to know more about NASA's plans to compensate for the loss of this critical tool. As a member of the Subcommittee on Research and Science Education, I am particularly interested in the role universities have to play in researching climate change, and I would be glad to hear the panelists' opinions with regard to streamlining the flow of our scarce research dollars to the most promising projects. Finally, as Vice Chairman of the Subcommittee on International Organizations within the Foreign Affairs Committee, I am interested in learning more about opportunities to facilitate cooperation and coordination with international scientific bodies on climate science research.

In closing, thank you again, Chairman Gordon, for calling this important hearing, and thank you to the witnesses for offering your testimony.

Chair GORDON. At this time I would like to introduce our witnesses. Dr. Alexander MacDonald is the Director of the Earth Systems Research Laboratory at the National Oceanic and Atmospheric Administration. Dr. Richard Birdsey is the Project Leader of the Research Work Unit, Climate, Fire, and Carbon Cycle Systems at the Northern Research Station of the U.S. Forest Service and the Chair of the Carbon Cycle Scientific Steering Group. Dr. Michael Freilich is the Director of the Earth Science Division at NASA. Ms. Dina Kruger is the Director of the Climate Change Division in the Office of Atmospheric Programs at EPA. Dr. Patrick Gallagher is the Deputy Director of NIST, and Dr. Albert Heber is the Professor of Agriculture and Biological Engineering at Purdue University and the Science Advisor to the National Air Emissions Monitoring Study.

At this point I would like to recognize my friend from Oregon, Representative David Wu, to introduce our last witness.

Mr. WU. Thank you very much, Mr. Chair. I would like to welcome Dr. Beverly Law for being here today. Dr. Law is a Professor of Global Change Forest Science at Oregon State University and currently serves as the Science Chair of the AmeriFlux Network and as a member of the Science Steering Groups of the U.S. Carbon Cycle Science Program and the North American Carbon Program. She is also serving on the National Research Council, Committee on Methods for Estimating Greenhouse Gases. Her research is on the effects of climate and disturbances on carbon, water, and energy exchange between terrestrial ecosystems and the atmosphere and methods for integrating observations and modeling to quantify and understand regional carbon balances. Dr. Law has been an author of over 100 journal articles. We welcome you, and we are glad that we could turn out some Oregon weather for all the witnesses today.

I yield back the balance of my time, Mr. Chair.

Chair GORDON. Thank you, Mr. Wu, and Dr. Law, we hope you will take it back to Oregon with you.

As our witnesses know, we try to limit our oral testimony to five minutes. But we are on a short track here. This is very important, and we want to hear from you, and we appreciate your earlier written testimony, and I would encourage you when this is over if you have additional thoughts as we prepare legislation—Mr. Hall mentioned that we also serve on Energy and Commerce Committee, and so we will be a part of it there, but we want to be sure the monitoring is right, and we need your help in doing that.

And so your written testimony will be included as a part of the record, and when you have completed your testimony, we will start questions. Each Member will have five minutes to ask their questions.

So we will start now with Dr. MacDonald.

STATEMENT OF DR. ALEXANDER E. "SANDY" MACDONALD, DEPUTY ASSISTANT ADMINISTRATOR FOR LABORATORIES AND COOPERATIVE INSTITUTES, OFFICE OF OCEANIC AND ATMOSPHERIC RESEARCH, NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION, U.S. DEPARTMENT OF COMMERCE

Dr. MACDONALD. Good morning, Chair Gordon, Ranking Member Hall, and Members of the Committee. Thank you for inviting me to discuss the key role that NOAA plays in monitoring greenhouse gases and aerosols.

Emissions are the result of human activities, particularly of carbon dioxide, are changing the Earth's environment. The unequivocal warming of the atmosphere and ocean, along with increasing ocean acidity, are serious challenges to our future.

In addressing this threat it is important to assess the effectiveness of potential mitigation programs. This will be complex because in addition to fossil fuel emissions, soil and vegetation exchange CO_2 at the atmosphere. We are fortunate that our advanced technical civilization has both the tools and expertise needed to implement the monitoring systems we will need.

NOAA has decades of experience monitoring greenhouse gases. The current global system for monitoring can be traced back to the 1950s when the first observations were made at the South Pole and Mauna Loa, Hawaii. NOAA has six comprehensive atmospheric observatories and routinely measures greenhouse gases at over 100 sites worldwide with an accuracy of a 0.10 percent. Aircrafts, ship, and satellite measurements are also used to get global scale distributions.

NOAA and its partners occasionally conduct field programs where they deploy aircraft with sensitive instruments. Here is a picture of our NOAA P–3, the flying chemistry lab, measuring aerosols and gases in an experiment conducted over Houston in 2006.

NOAA could improve its North American monitoring to provide a check on the success of the mitigation effort. It is helpful to think of greenhouse gases like one thinks about a bank account. The total amount of CO_2 in the air, roughly three trillion tons, is the equivalent of the bank balance. Emissions increase the balance, which is bad, and when CO_2 goes from the atmosphere into the ocean or land, it decreases the amount in the atmospheric bank.

So there is two ways to check your bank balance. One is to track the income and outgo in your checkbook. Another way is to call the bank and say, how much money do I have? There are also two ways to calculate how much CO_2 is in the air. First we would add the emissions, subtract the CO_2 going into the land and ocean, and we call this the bottom-up approach. The top-down method would be to simply measure, using our tools, the amount of carbon dioxide in the air.

In the mitigation program it is very important that we do both of these. By carefully tracking total amounts we can independently check the emissions and tell us whether the mitigation efforts are working. This would also allow us to monitor the progress of the global program and see what other countries are doing.

NOAA's carbon tracker is a sophisticated computer program that measures the distribution and total amounts of carbon dioxide. On this poster carbon tracker is showing areas of high carbon dioxide in red. You see those in southern U.S., and areas with low amounts in blue, and in this case the blue is because the air flowed over Siberia and Canada, and the leaves were soaking up the carbon dioxide, so that is why that blue area northern U.S. is there.

Programs like AmeriFlux tell us the biological sources, while fossil fuel emissions give us the human contribution. History shows that accounting through self-reporting is not adequate. Carbon trackers' top-down estimates are the ideal compliment to the bottom-up emissions measurements. In the end we count on the atmosphere to tell us the complete story.

Mitigation will require a more comprehensive program. Our system for monitoring greenhouse gases was designed for research understanding on planetary and continental scales and wasn't designed for the regional scale that we will need for national mitigation. Fortunately, the system can be enhanced in the coming decade to meet our needs. Our surface networks, our satellites, and things like the orbiting carbon observatory of NASA would give us the horizontal coverage while aircraft and other instruments could give us the vertical coverage. A robust and complete emissions inventory will need to be implemented by EPA and Department of Agriculture.

In conclusion, NOAA has a broad mission to understand and predict the atmosphere and global ocean. We can serve as the honest broker to determine how well our mitigation policies are working and how they can be improved. We look forward to the role NOAA will play in this important endeavor.

Thank you.

[The prepared statement of Dr. MacDonald follows:]

PREPARED STATEMENT OF ALEXANDER E. "SANDY" MACDONALD

INTRODUCTION

Good morning Chairman Gordon, Ranking Member Hall, and other Members of the Committee. I am Alexander MacDonald, Deputy Assistant Administrator for Laboratories and Cooperative Institutes in the Office of Oceanic and Atmospheric Research at the National Oceanic and Atmospheric Administration (NOAA), in the Department of Commerce. Thank you for inviting me to discuss NOAA's research and monitoring programs that support our understanding of greenhouse gases in the atmosphere, as well as the country's needs with respect to monitoring of greenhouse gases and aerosols in light of potential future mitigation policy and overall advancement of climate science and research.

NOAA's mission is to understand and predict changes in Earth's environment and conserve and manage coastal and marine resources to meet our nation's economic, social, and environmental needs. In support of its mission, NOAA has developed a long-standing capability to monitor and understand climate and climate change. From observatories and cooperative sampling sites and satellites around the world, NOAA measures virtually all greenhouse gases, ozone-depleting gases, and aerosols to understand their trends, distributions, and fluxes. NOAA, in cooperation with other agencies, conducts intensive research campaigns to understand the impacts of regional emissions on climate and air quality. Oceanic distributions and exchange of carbon dioxide (CO_2) and other gases with the atmosphere are monitored intensively by NOAA scientists. From these measurements and models to support them, NOAA scientists quantify and improve our understanding of the sources, sinks, and trends of a host of related greenhouse gases (including CO_2, methane, and nitrous oxide), aerosols, and atmospheric tracers. These continuing data records, maintained by NOAA and its interagency partners (e.g., National Aeronautics and Space Administration (NASA), Department of Energy (DOE), U.S. Department of Agriculture (USDA), et al.), reflect the U.S. scientific leadership in this area, and are essential to diagnose current global climate trends and project future climate impacts, including effects on global weather extremes. NOAA's field missions and global networks for long-term monitoring of greenhouse gases, ozone, ozone precursors, ozone-depleting compounds, aerosols, aerosol precursors and surface radiation produce the highest quality atmospheric data. These data provide a reference for accurate climate model initialization and validation necessary to develop credible scenarios for the future, and for developing national and international emission management strategies.

In this testimony, I will briefly describe the issues related to reducing greenhouse gas emissions, identify some of the needs and collaborative efforts underway for science-based support of emission reduction efforts, summarize NOAA's capabilities and expertise in providing information on greenhouse gases and aerosols, and address what NOAA can do to provide the information society will need for reducing emissions in this century.

WHAT ARE THE ISSUES?

The carbon cycle and influences of greenhouse gases are complex and dynamic. An efficient emissions policy requires a robust bottom-up and top-down monitoring approach. Identifying and quantifying human and natural emissions of these climate forcing agents, such as CO_2, methane, nitrous oxide, several halocarbons, and certain aerosol and ozone-forming agents is necessary for informing emission reduction strategies. We must understand where the emissions are coming from in order to reduce their quantity. We also must be able to identify which areas act as carbon "sinks," removing CO_2 from the atmosphere and possibly offsetting CO_2 emissions, and which areas act as "sources," adding CO_2 to the atmosphere, e.g., areas of oceanic up-welling. To answer these questions and ensure effective, efficient policy requires monitoring and validation of emissions from specific sources and projects. In addition, monitoring the concentrations of gases in the atmosphere for verification with reported emissions is critical to understand whether policies are having the desired result.

According to the IPCC Assessments, the increase of CO_2 in the atmosphere is the single largest contributor to observed climate change. Increasing atmospheric CO_2, mainly from burning of fossil fuels, has not only substantially altered global climate, but has also increased the acidity of the oceans. This trend will continue as long as humans continue to increase atmospheric CO_2. It is well understood that CO_2, once emitted, remains in the atmosphere and oceans for a very long time—many thousands of years. Thus, the changes induced today will have a long-term impact on climate and ocean acidity. For these reasons, reduction of CO_2 emissions is often the primary focus in discussions about mitigating climate change; urgency in doing so is well understood throughout the scientific community.

Other greenhouse gases and aerosol influences must be considered in any emission reduction strategy. Although gases such as methane and nitrous oxide are not rising as fast as CO_2, they still contribute substantially to climate change, and their future growth rates are uncertain. Anticipated changes in climate are likely to affect the emission from land and water surfaces. Some aerosols, such as black carbon, have a warming effect and others, which are mostly associated with poor air quality, have a cooling effect. Aerosols, for the most part, are partly offsetting the warming caused by greenhouse gases. Therefore, it is important to know how changes in emissions will alter atmospheric concentrations of greenhouse gases and aerosol.

There is a definite urgency to reduce greenhouse gas emissions, but we cannot expect to see the effects of reduced emissions immediately on the rate of climate change. There are various reasons as to why this is the case: (1) many greenhouse gases, especially CO_2, persist in the atmosphere long after emissions are reduced or halted; (2) even though the emissions are local, the climate change they bring about is global and takes time to realize; (3) links between trends in greenhouse gas concentration and North American weather extremes, including hurricanes, tornadoes, damaging winds, floods, droughts, cold waves, and heat waves have not been fully established; (4) there are natural variations in climate and it will take time before we have the necessary data to show that changes in climate have grown larger than the natural variation (i.e., to establish statistical significance between what we are experiencing and what is part of natural variation); and (5) since climate change is a global problem, the actions of other nations also have an effect on climate. In the short-term, then, we must rely on reporting and measurement of human-caused emissions and observations of the greenhouse gas and aerosol abundances in the atmosphere to provide the sole basis for evaluating the effectiveness of actions to mitigate climate change.

Greenhouse gas emissions are generated by practically all economic sectors, including energy, agriculture, manufacturing, transportation, housing and urban planning, and public health.

A NEED FOR SCIENTIFIC INFORMATION

NOAA maintains a widespread global monitoring network, including a dense observation system in North America, and an ability to measure many atmospheric tracers to characterize the origins of greenhouse gases. NOAA works in partnership with many federal agencies and international organizations, and has been providing greenhouse gas information on global, hemispheric, and continental scales for a long time. NOAA's observation systems and partnerships have evolved over several decades around the goal to resolve scientific questions about the global carbon cycle and climate change. But today the question has become, "How can we provide scientific information to support and enhance emission reduction efforts?" An observation and analysis system developed to effectively support and enhance emission reduction efforts would have significant economic and environmental value, and would support the efforts of decision-makers at all levels of government. At regional levels, verification that reported emission reductions are consistent with what is observed in the atmosphere will require many more observations of greenhouse gases and tracers (including those from satellites like those currently being built or planned at NASA), improved and higher resolution modeling, and an enhanced understanding of biospheric responses to climate change. It will require the expertise contained in several federal agencies, especially DOE, NASA, USDA, the Environmental Protection Agency (EPA), and the National Institute of Standards and Technology (NIST).

The need for sound scientific information regarding climate change mitigation will accelerate. The Committee has identified several questions with respect to greenhouse gas emissions, climate change, and the research endeavors and capabilities currently underway in our nation. Chosen courses of action will require a firm grounding in science and a reasonable expectation of success. Taking action to mitigate climate change is followed by the need to answer questions of accountability—Are the actions working as intended? Do we need to do something different? Do we need to accelerate or can we relax emission reduction efforts? How do these reduction efforts affect other air pollutants and solid and liquid effluents? The lead-up to actions, and the follow-through of determining the effectiveness of those actions, are both rooted in science.

Science-based information is needed to support greenhouse gas emission reduction policy and includes knowledge of the current emissions and atmospheric composition of greenhouse gases, on-going verification that emission reduction efforts are having their intended effect, and an understanding of how natural greenhouse gas emissions and uptake are impacted by climate change.

History shows that emission measurements are most reliable when there is a robust verification process. Reported emissions (i.e., emissions inventories) are necessary for regulation and initiating emission models, but we will have to verify that reported emissions are consistent with what is observed in the atmosphere. No large-scale emission reduction effort has succeeded without independent verification of its progress, whether it is ozone depletion, air quality, acid rain, or wastewater management. For example, such efforts by NOAA and NASA, required by the *Clean Air Act Amendments of 1990,* has been critical to verifying the success of emission reductions related to stratospheric ozone depletion. This and other efforts, however, are simple compared to what lies ahead with climate change forcing agents. The complexity and variability of the carbon cycle alone present a challenging task of verifying that reported emission reductions are consistent with what we observe in the atmosphere. In the end, the atmosphere tells the story—do observed changes in the atmospheric levels reflect calculated emissions?

Objective, credible, and specific information about the effectiveness of mitigation efforts undertaken, and about the response of the natural carbon cycle to climate change itself, will be necessary to guide policies. Given the sustained investments required to meet this challenge, it is critical that efforts to reduce emissions be verifiable at local, regional and national levels and consistent with evidence in the atmosphere. It is also possible that potential feedbacks in the climate system could exacerbate the problem. For example, there is a real possibility that the melting of Arctic permafrost soils in response to global warming will liberate enormous amounts of methane and CO_2, and would be at that time out of our control. Aerosols also need to be watched, as they can have both warming and cooling effects and are linked to some potential greenhouse gas emission reduction strategies. Thus, in addition to verification of the efficacy of emission reduction programs and offsets, based on observed atmospheric conditions, we must focus on climate information at regional and local levels to confirm the effectiveness of any efforts or policies to mitigate climate change, and understand distributions, trends, and Earth-system impacts of increasing CO_2 and other greenhouse gases in the atmosphere. For management to be effective, society will require the best information that research can deliver.

It is also important to clarify the limits to what monitoring (and efforts to verify that reported emissions are consistent with what is observed in the atmosphere) at the local and regional level can accomplish. A comprehensive climate policy will require compliance at the individual source level and a "bottom-up" reporting approach. NOAA's capabilities will not verify emissions at individual sources, this will be the responsibility of the EPA through compliance assistance efforts. However, at the aggregated level, the information NOAA can provide will serve to inform EPA's efforts.

WHAT ARE NOAA'S CAPABILITIES?

NOAA's capabilities span a range of activities relevant to climate science, including observations, analysis, modeling, prediction and assessment. NOAA maintains global observational networks and numerous field programs, and works closely with partnering agencies, institutes, and universities across the Nation and around the world. NOAA is well-poised to work with key federal agencies and other partners to determine the effectiveness of mitigation efforts, and to integrate new information into its natural resource management efforts.

Measurements and products of NOAA's research contribute significantly to the U.S. Global Change Research Program. NOAA is active with 12 other agencies in the Carbon Cycle Science Program (now part of the U.S. Climate Change Science Program, CCSP). This is coordinated through the NASA/USDA-led Carbon Cycle Interagency Working Group (CCIWG), which meets tri-weekly and sponsors the North American Carbon Program and Ocean Carbon Biogeochemistry Program. Research in these programs, involving both agency and university scientists, is coordinated through separate CCIWG-sponsored Scientific Steering Groups that meet twice yearly. The CCIWG also sponsors biennial all-investigators meetings, workshops at national conferences, and the development of the First State of the Carbon Cycle Report, 2007 (CCSP Synthesis Report 2.2) for North America. This report summarized our current understanding of the sources and sinks of carbon in North America, based primarily upon bottom up (i.e., ecosystem measurements and calculations) approaches which are compared to top down (i.e., atmospheric measurement and analysis) approaches, driven mainly by NOAA's measurements and CarbonTracker. Currently the CCIWG agencies are working with carbon cycle scientists across the Nation to develop a new Carbon Cycle Science Program for the coming decade. Efforts coordinated through the CCIWG have been extraordinarily successful in bringing the diverse research capabilities of scientists and organizations across the country to understand how human and natural systems contribute to CO_2 and related greenhouse gases in the atmosphere. NOAA is proud of its on-going role at all levels in this effort.

On a global basis, NOAA's observations of greenhouse gases and aerosols form the backbone of the World Meteorological Organization's (WMO) Global Atmosphere Watch Programme. NOAA's carbon cycle monitoring network currently constitutes two-thirds of the atmospheric monitoring sites reporting to the WMO Greenhouse Gas Data Centre (WDCGG). Data from the WDCGG are a primary component of the Global Climate Observation System. Updated and displayed daily, NOAA's high-quality measurements of carbon cycle and other greenhouse gases from all of its sites are available worldwide to all interested parties. Because of this strong global role, NOAA has leadership positions on the GEO (Group on Earth Observations) Task Team for Carbon and the WMO Scientific Advisory Groups for greenhouse gases, aerosols, and ozone.

Greenhouse Gas and Aerosol Monitoring. NOAA has monitored all of the major greenhouse gases, along with aerosols, for nearly 40 years at its baseline observatories and its cooperative sampling sites. This long-term commitment to monitoring these substances has required detailed, accurate measurements, high quality research, and technological advancement over the decades. NOAA's skills and commitment in this effort are unsurpassed. For example, the measurement of CO_2 in the atmosphere and oceans has flourished under NOAA since its work began several decades ago. This science-based effort requires sustained, comparable measurements at an accuracy level of 0.05 percent or better. NOAA's capabilities and commitment is acknowledged by the scientific community throughout universities, federal agencies, and international organizations. Scientists researching the carbon cycle or conducting climate research depend upon NOAA to provide the world calibration scale and to deliver consistent, accurate field measurements of CO_2 and other climate-relevant gases. The significance of NOAA's capabilities is exemplified by the agency's high level of quality control and assurance (e.g., ongoing, long-term comparisons of field measurements), its involvement in national and international planning and execution, and its leadership role in the world community—via the WMO—for calibration.

Oceanic Measurements. The largest, active reservoir of CO_2 is the ocean, which accumulates 40–50 percent of the CO_2 emitted into the atmosphere. Processes in the ocean constitute the ultimate sink for atmospheric CO_2, though those removal processes take thousands of years. Understanding the cycling of carbon in the ocean has been at the core of NOAA's mission for decades. NOAA scientists provide about half of the Nation's measurements of CO_2 in both deep and surface waters globally and are leaders in understanding the processes that drive gas exchange between the ocean and atmosphere. NOAA scientists also are leaders in understanding ocean acidification, which is driven by increasing CO_2 in the atmosphere, and they are major players in the international effort to monitor, understand, and assess the trends of carbon in the ocean and its impacts on ocean habitat and living resources.

Satellite Observations. NOAA retrieves data on CO_2 and other greenhouse gases and aerosols from NASA satellites. NASA and international satellites complement NOAA's global *in situ* observing system for greenhouse gases by providing global coverage, high-spatial resolution and vertically integrated measurements. To ensure data comparability, it is critical that the satellite retrievals be consistent in form with long-standing, high quality, accurate measurements made on the ground or from aircraft and with reanalysis output such as that of NOAA's CarbonTracker. Data comparability requires a coherent, on-going research effort among groups involved in both ground-based and remote measurements and traceability to international standards such as provided by NIST; these efforts provide NOAA with an opportunity to work closely with national and international partners in this endeavor.

Intensive Field Campaigns. NOAA has a demonstrated capability of carrying out intensive observational campaigns using NOAA aircraft as a "flying chemistry laboratory" to measure all the major greenhouse gases, tracers that help ascertain the origin of the gases, tropospheric ozone and its precursors, and aerosols and their precursors (Figure 1). This capability can be deployed anywhere in the U.S. and in most places in the world to "spot check" emissions of climate forcing agents from specific regions and establish internal relationships among emissions of different gases. Suitably planned observational campaigns can help quantify emissions of climate-forcing agents and identify their locations and emission sectors. NOAA's capability can help establish a reasonably useful baseline of emissions from various parts of the country.

Process Understanding. NOAA has a demonstrated capability in carrying out research to understand and quantify the transformation of chemicals to climate relevant agents such as ozone and aerosols. NOAA also is a leader in seeking to understand and quantify the transport of chemicals. These capabilities enable NOAA to translate observations into information that can be used in models to predict what actually happens in the Earth system.

Integration of Observations through CarbonTracker. NOAA's CarbonTracker tool is widely acknowledged as the most open and effective reanalysis approach to date for estimating CO_2 emissions and uptake (Figure 2), particularly at large spatial scales. When fully developed, CarbonTracker will make it possible to track regional emissions of CO_2 over long periods of time and to determine which areas are absorbing CO_2 from the atmosphere. CarbonTracker uses an existing land model, recognized as the best for this work. The land model is informed in part by measurements carried out in the DOE's Ameriflux Network, which provides information on ecosystem function on kilometer scales. (Augmenting Ameriflux sites in the future would allow for incorporation of additional atmospheric measurements into CarbonTracker and help improve its resolution, particularly near Ameriflux sites.) The land model also is informed by NASA and NOAA satellite observations of land surface and biosphere characteristics. CarbonTracker uses a transport model with satellite-supported meteorological fields that can exploit the current distribution of observing sites. Finally, CarbonTracker incorporates global fossil emission estimates

(DOE), fires (NASA MODIS instruments on NASA Aqua and Terra satellites) and a modification of NOAA's world-class ocean circulation model. Because CarbonTracker constrains the model results with atmospheric observations, it was able to identify the impact of the 2002 drought on North American absorption of CO_2. This suggests that, under its current configuration, CarbonTracker is effective in capturing large-scale, North American phenomena. There is not, however, a current greenhouse gas monitoring network large enough for CarbonTracker to provide fine scale resolution with low uncertainty.

An important role that a "top down" system like CarbonTracker plays is to independently validate the combined fluxes calculated from "bottom up" efforts such as estimated fossil fuel emissions and biological sources. If estimates of sources and sinks do not agree with measured atmospheric concentrations, the "top down" approach provides the information needed to continually improve our understanding of the carbon cycle.

Analysis of data to predict climate change and its impacts. NOAA has a demonstrated capability in climate and chemistry modeling. Such modeling is essential for providing information about why past changes occurred, knowing what the "climate baseline" is now, and identifying what can be expected when emissions are altered. These models can quantify consequences of changes in emissions on both climate and air quality. They also are useful in predicting what will happen in the future and how ecosystems and human systems will respond, with and without emission regulations—information that will be important for decision-makers.

WHAT NOAA CAN DO TO HELP VERIFY EMISSION REDUCTIONS

Based on the capabilities described above, NOAA will play a central role providing in scientific information that will be necessary to verify whether reported greenhouse gas emission reductions are consistent with what is observed in the atmosphere. NOAA can help, along with other agencies, in characterizing a baseline for atmospheric composition, supporting EPA's development of greenhouse gas emission inventories, and setting up a greenhouse gas information system for the 21st century. NOAA, along with other agencies, can provide timely analyses on the impacts of the proposed regulatory action by verifying reported emissions at the aggregated level, assessing the effectiveness of offsets, and characterizing the impacts of emission reduction efforts across sectors and regions of the Nation and world.

Upgrade the Greenhouse Gas and Aerosol Monitoring System. The current greenhouse gas monitoring systems implemented by the federal science agencies are designed to support research to understand the role of gases and aerosols in climate forcing. The growing need to provide scientific verification and support to efforts to *mitigate* climate change through changes in human-caused emissions requires a more comprehensive monitoring system. Such a system will need to be developed over the next decade with cooperation among federal agencies, particularly NOAA, NASA, National Science Foundation (NSF), Environmental Protection Agency (EPA), Department of Transportation (DOT), and DOE, and with our international partners. Global measurements of CO_2, such as those NASA's Orbiting Carbon Observatory (recently lost on launch), would have made is one example of the new capabilities that will be needed. NASA's and NOAA's roles in verifying NASA satellite data through comparisons with CarbonTracker profiles and with direct measurements by aircraft and ground-based facilities will be critical for demonstrating the potential for incorporating satellite measurements into a comprehensive system of observations. NOAA and NASA have recently developed a method to measure mid-troposphere CO_2 from the NASA Atmospheric Infrared Sounder instrument on NASA's Aqua satellite. NOAA is investigating other new technologies, including use of manned and unmanned aircraft, commercial aircraft, and tall towers to sample air above the surface. We are also working on exciting new possibilities, such as the Air Core, a method of bringing air from all altitudes (a chemical sounding) back to the laboratory for analysis. Air Core was invented by Dr. Pieter Tans of NOAA's Earth System Research Laboratory. A major advantage of retrieving air samples is that it allows the measurement of many tracers which can be used to attribute sources and sinks of CO_2.

Establish a Greenhouse Gas Information System for the 21st Century. The ability of the United States and other nations to effectively implement policies for limiting atmospheric greenhouse gas concentrations would benefit considerably by ensuring that reported emission reductions and offsets are consistent with atmospheric observations at regional and national scales. A U.S. program to reduce human-caused concentrations of CO_2 that incorporates such a system would help guarantee an efficient, effective, and economic approach to emission reduction. It would have considerable value for improving our approach to reducing emissions and verifying treaty agreements.

Such a system would combine ground-based, air-based, ocean-based, and space-based measurements with facility and site-specific measurements, carbon-cycle modeling, fossil-fuel emission inventories, land-use data, and an extensive distribution system for information about sources and sinks of greenhouse gases at policy-relevant temporal and spatial scales. A greenhouse gas information system would need to be linked to enhanced capabilities for seamless weather-climate modeling and prediction across timescales.

A global greenhouse gas information system would build from existing capabilities and require collaboration to expand and develop improved ground, sea, and air-based measurements; sustained space-based observations; and measurements of non-CO_2 short-lived gases for fossil-fuel combustion attribution. Ground-based observations must be focused on accuracy as well as long-term continuity to be of value to the climate record. Deriving actionable information from these observation sources further requires coordinated efforts in carbon-cycle modeling, data assimilation, and data analysis—spanning several networks, spatial scales, disciplines, and agencies. The specific requirements of such a system would be dictated by policy objectives and by the degree of international cooperation.

This information system could build on NOAA's current global leadership, observation, modeling, prediction, and analysis capabilities and would involve coordination with other federal agencies, national and international partners, and the private sector. This information system also would be a structural, operational, and research backbone in a global effort to verify reduction of CO_2 and other greenhouse gas and certain aerosol emissions and quantify changes in emissions or uptake by natural systems. Such a system would have lasting value for national and international assessments and would serve as the ultimate tool for guiding these efforts globally. To successfully simulate the atmospheric CO_2 record, a reanalysis tool like CarbonTracker must work with the most advanced models of the coupled oceanic and terrestrial carbon cycle, which would require collaborations with federal and State agencies, universities, and international partners. A dense observing network and targeted field campaigns combined with a data assimilation capability would provide an objective check on efforts to track emissions and the contributions of fossil fuel use.

Deliver early information to establish a baseline characterizing the influence of current and past emissions on atmospheric composition. There are near-term opportunities for helping establish a baseline of current emissions and providing process information in support of model development. Verification of emissions from some individual sources can be started almost immediately. Climate change forcing agents, their precursors, and related tracers can be measured with existing instruments placed on NOAA's aircraft, ships, and ground-based stations. This early information would aid in evaluating overall emission reduction strategies. Such measurements can be coordinated with those from other agencies (e.g., NASA, DOE, NSF, DOT, and EPA) to provide a more comprehensive coverage of sources, geographic regions, and temporal characteristics for providing baseline information on emissions as quickly as possible.

Support development of robust emission inventory of climate forcing agents for the country. A systematic, up-to-date inventory of emissions, their distributions, and their variations will help decision-makers base their decisions on accurate information, climate scientists more accurately model future climate and its impacts, and stakeholders feel confident of the consequences of the emission changes. A robust, accurate, updated, emissions inventory can be developed, refined, and maintained through close interaction with other agencies, most notably by supporting EPA, DOE's Energy Information Administration, and others maintaining accounting registries. Development of an improved inventory would go hand-in-hand with development of a greenhouse gas information system for the 21st century, as improvements in emission estimates inform model development and vice-versa.

Model, predict and analyze the impacts of proposed mitigation actions on climate change. NOAA has the capability to make climate predictions, and this capability is being continually improved. NOAA's capabilities will be critical for predicting the consequences of any actions taken to reduce emissions. Such information will be essential to support the best possible decisions.

CONCLUDING REMARKS

In conclusion, I have described the issues involved in dealing with reduction of emissions for the benefit of climate, the science-based information needs for dealing with reductions, the expertise NOAA currently has to address some of the issues, and what more NOAA—in conjunction and coordination with other federal agencies—can do to provide science-based information for emission reductions.

NOAA—with its broad mission responsibilities for physical and life sciences, and its stewardship responsibilities—and its national and international partners have the technological prowess to implement the comprehensive and highly sophisticated global information systems needed to measure the effectiveness of greenhouse gas mitigation strategies. Such a system should include new satellite sensors, an improved monitoring network in the atmosphere and oceans, and powerful new techniques to analyze the data in support of policy. We look forward to the role NOAA will play in providing the information society will need for reducing emissions in this century.

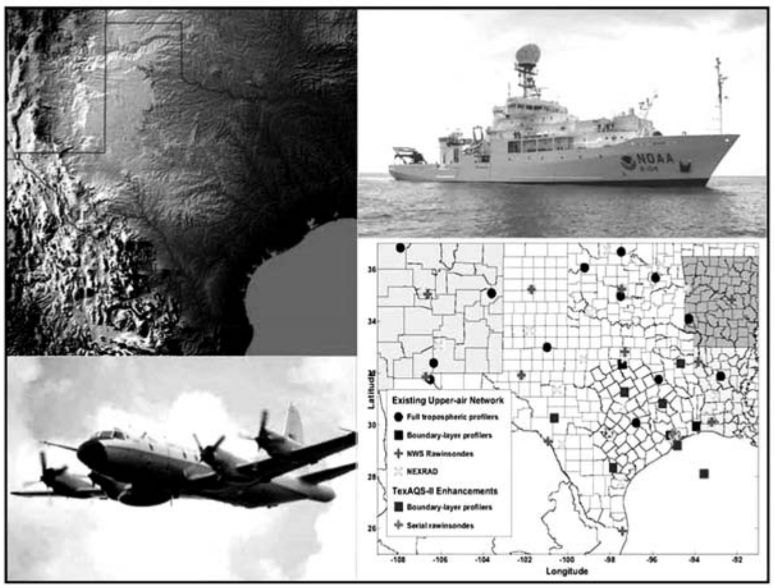

Figure 1. Measurements of various chemicals such as greenhouse gases, precursors of ozone (a potent greenhouse gas), reactive chemicals, tracer chemicals, and aerosols (including black carbon) were carried out using a flying "chemical laboratory" (a NOAA WP-3 aircraft) and a "floating chemical laboratory" (a NOAA ship) over and around Texas in 2000 and 2006. Such measurements combined with meteorological data allowed quantification of emissions of various chemicals from different locations in Texas. It was shown from these studies that emissions of olefins- highly reactive chemicals that produce ozone- from petrochemicals were major sources of ozone over Houston.

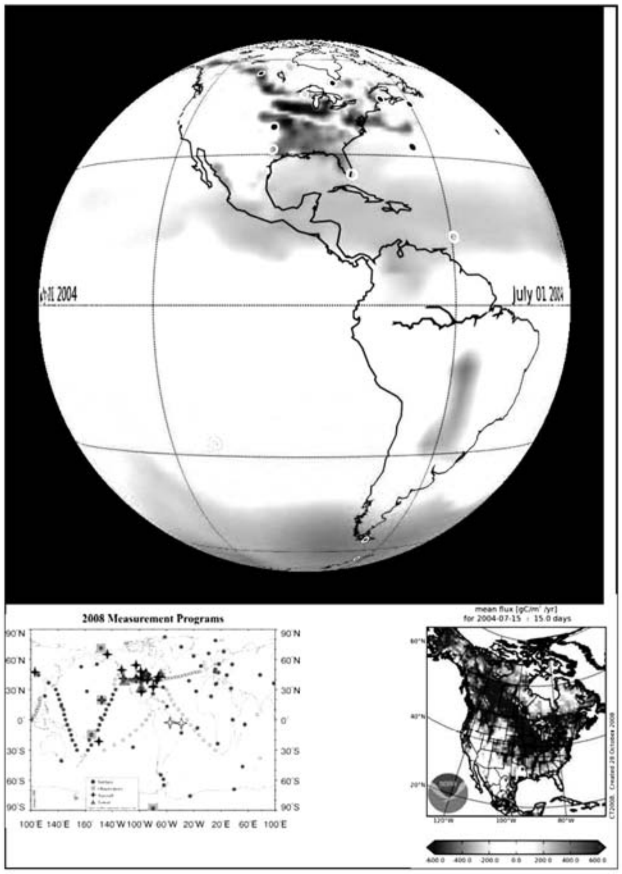

Figure 2. NOAA's CarbonTracker is a system to keep track of carbon dioxide (CO2) uptake and release at Earth's surface over time. It is constrained by NOAA's highly accurate observation system (lower left), produces maps of biosphere emission and uptake of CO2 (lower right), and provides vertical profiles of CO2 everywhere all the time (upper figure). Blue indicates net uptake by the biosphere (lower right) or a CO2 deficit in the air (upper figure), red indicates net emission or excess. Data are for July 2004.

BIOGRAPHY FOR ALEXANDER E. "SANDY" MACDONALD

Dr. Alexander E. (Sandy) MacDonald was named the first Director of the Earth System Research Laboratory and first Deputy Assistant Administrator for NOAA Research Laboratories and Cooperative Institutes on July 27, 2006. Dr. MacDonald served as Acting Director for the Earth System Research Laboratory and Director of the ESRL Global Systems Division during the consolidation of the Boulder Laboratories into the Earth System Research Laboratory in 2006. Prior to the consolidation, Dr. MacDonald led the Forecast Systems Laboratory.

Dr. MacDonald was the Director of the Program for Regional Observing and Forecasting Services (PROFS) from 1983 to 1988. From 1980–1982, he was Chief of PROFS' Exploratory Development Group and from 1975–1980 he was a Techniques Improvement Meteorologist in the Scientific Services Division, Western Region, National Weather Service in Salt Lake City, UT. He was an Air Force Officer while a member of the U.S. Air Force from 1967–1971.

Chair GORDON. Thank you, Dr. MacDonald. I agree. NOAA is a very important player in this equation.

Dr. Law, you are recognized for five minutes.

STATEMENT OF DR. BEVERLY LAW, PROFESSOR, DEPARTMENT OF FOREST ECOSYSTEMS AND SOCIETY; SCIENCE CHAIR, AMERIFLUX NETWORK, OREGON STATE UNIVERSITY

Dr. LAW. Chair Gordon, Ranking Member Hall, and Members of the Committee, thank you for inviting me here today to talk about the AmeriFlux Network and the potential to quantify fluxes from natural and managed systems in the context of greenhouse gas emissions.

The AmeriFlux Network has about 90 flux sites currently, and it has great potential to improve understanding of the carbon cycle and land-based contributions to greenhouse gases. AmeriFlux provides ecosystem-level measurements of the net of ecosystem carbon processes that produce a source or a sink to the atmosphere. The data are used to calibrate remote sensing data and models. Carbon cycle and climate system monitors use flux data to characterize land sources and sinks for carbon and to understand ecosystem responses to climate and land use.

So the most effective tool to measure the net carbon fluxes from natural and managed systems is an array of flux sites. The most powerful tool to produce spatial estimates of fluxes from ecosystems is a bottom-up process model that ingests the flux data as well as data from inventories and remote sensing of land characteristics, and this is used to map the carbon stocks and fluxes for every square kilometer.

The output of a bottom-up process model could be used to constrain estimates of the terrestrial portion of the observed greenhouse gases. Continuity of AmeriFlux needs to be ensured. The network is built on a model of cooperating investigators, primarily university professors. The AmeriFlux records are now seven to fifteen years in length and are beginning to show long-term trends. AmeriFlux sites are supported by multiple agencies with the Department of Energy funding about half the sites.

I am in the unique position of heading a regional project that uses observations and models that are going to be discussed today. To develop a sustained and robust carbon monitoring system, I think it is necessary to enhance the AmeriFlux Network, intensify the greenhouse gas concentration network, improve crop and forest inventories, ensure continuity of critical remote sensing data, including Landsat and MODIS for the land or bottom-up approach, provide more resources for coordinated data management for assimilation in models, and accelerate data availability and analysis for a more comprehensive modeling and assessment.

For AmeriFlux some required resources would be to add sites in under-represented regions and disturbances classes of forests, add measurements of methane fluxes and isotopes for identifying sources, and add well-calibrated CO_2 concentration measurements to augment NOAA's CO_2 observations. Additional resources are required for AmeriFlux data management and data processing and regional to global analysis. The resources needed for a robust monitoring system are about the same as that for carbon cycle research.

The effects mechanism for communication between academic community and federal agencies are the science steering groups of the North American Carbon Program and the Carbon Cycle Science Program. The NACP is the best organizing mechanism for developing an integrated national network of observations and modeling the challenges implementing an integrated national system quickly.

Mechanisms for international coordination of infrastructure and analysis could build on the NACP and the new European infrastructure called the International Carbon Observation System. ICOS is a system for carbon monitoring and verification based on observations and modeling of ecosystem fluxes to assess terrestrial sources and sinks and greenhouse gases to quantify anthropogenic sources.

FluxNet is a network of networks, and FluxNet and the FAO Global Terrestrial Observing System could operate within this framework. To ensure that data collected by different nations are comparable, institutional support is required for coordinating observation systems and developing high-quality data systems.

In summary, the tools and communication mechanisms exist for monitoring, measuring, and understanding greenhouse gas sources and sinks. Each of the agencies has been working on their piece of the puzzle. Now what is required is a high level of commitment and coordination to build an integrated national system.

Thank you.

[The prepared statement of Dr. Law follows:]

PREPARED STATEMENT OF BEVERLY LAW

Introduction

Good morning Chairman Gordon, Ranking Member Hall, and other Members of the Committee. I am Dr. Beverly Law, Professor of Global Change Forest Science at Oregon State University, and Science Chair of the AmeriFlux Network. Thank you for the opportunity to appear before you today to discuss the AmeriFlux Network, and the potential to quantify GHG fluxes from natural or managed ecosystems with respect to potential mitigation strategies and advancing carbon cycle science.

Purpose and Status of the AmeriFlux Network

AmeriFlux was initiated in 1996. It currently consists of 90 research sites that measure biology properties, meteorology, and carbon, water vapor and energy exchanges between terrestrial ecosystems and the atmosphere. The sites are in different vegetation types, climatic conditions, and stages of response to natural events and management. Most of the sites are in the lower 48 states, with a few sites in Alaska, Central and S. America (Fig. 1). Similar networks exist on other continents and are loosely coordinated through FLUXNET (Baldocchi, 2008), with over 500 sites from the tropics to high northern latitudes.

The aim of AmeriFlux is to:

- quantify and explain the amounts and variation in carbon storage and the exchanges of carbon dioxide, water vapor and energy at multiple timescales, and
- provide systematic data and analysis that has value for monitoring climate variables and change in terrestrial ecosystem processes in response to climate, land use and management

The AmeriFlux records are now seven to fifteen years in length and continuation is essential for understanding long-term trends in ecosystem response to climate and management. Support for AmeriFlux is currently provided on a site-by-site basis, and is funded by multiple agencies, with DOE funding about half of the sites.

Some long-term, high-quality records are endangered by lack of continued support. Most of the sites are run by academic researchers.

The network plays a major role in the North American Carbon Program (part of the U.S. Climate Change Science Program), where flux data are used to test model assumptions, or to optimize models and apply them spatially. The models also require inputs of remote sensing data on land surface characteristics (Law et al., 2004). Carbon cycle and climate system modelers use the flux data to characterize terrestrial sources and sinks for carbon, effects of climate and land use change on ecosystem fluxes, and effects of ecosystems on climate.

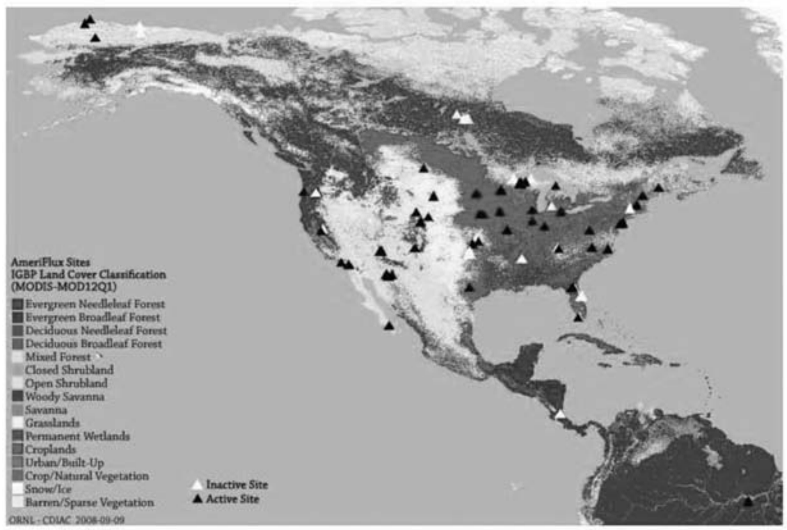

Figure 1. Current status and distribution of AmeriFlux sites

Potential to Improve Understanding of the Carbon Cycle and Accuracy of GHG Inventories

The AmeriFlux Network has great potential to improve understanding of the carbon cycle, and land-based contributions to greenhouse gases (GHG). Response of ecosystems to management can be detected by AmeriFlux measurements, which provide direct measurements of net carbon dioxide exchange at the stand-scale that represents the integrated effect of various ecosystem processes. The area coverage of a flux site is the appropriate scale for understanding the effects of climatic events and management activities on terrestrial sources and sinks, such as the outcome of mitigation strategies. For example, the effects of thinning 30 percent of tree biomass in a forest stand were evaluated using net carbon dioxide exchange measurements in the years before and after the thinning (Misson et al., 2006).

Models optimized with flux data can be used to test scenarios of response to mitigation actions. Mitigation actions cannot be detected by top-down methods that incorporate atmospheric CO_2 concentration observations, but this role can be filled by AmeriFlux, which was designed to be a land-based observation network.

Long-term flux data at individual sites show trends that allow one to identify the relative importance of factors influencing carbon uptake. For example, at Harvard Forest, annual net carbon uptake over 15 years has averaged ~2.5 tons carbon/hectare/year, and has increased at an average rate of ~0.2 tons carbon/hectare/year. The 15 years of data track changes in net carbon uptake driven by long-term increases in tree biomass, successional change in forest composition, and climatic events, processes not well represented in current models (Urbanski et al., 2006). Along with the energy fluxes, the data have proven valuable in evaluating and improving carbon cycle and climate system models, as indicated in many publications and model comparisons.

The potential to improve accuracy of GHG inventories relies on increasing the density of GHG measurements across the continent. A small subset of AmeriFlux sites measure well-calibrated carbon dioxide concentration profiles in an above the vegetation canopy, and more sites could be augmented. These data would improve the density of GHG concentration measurements made by NOAA over the continent so that it might become possible to resolve regional GHG sources and sinks.

Potential to define reliable baselines of GHG fluxes from natural or managed ecosystems

The most effective tool to measure the effect of natural events and management at annual timescales is an array of flux sites. The most powerful tool to produce spatial estimate of GHG fluxes from ecosystems is a bottom-up process model that ingests these data. A bottom-up approach starts with measurements where the action is taking place. For example, a regional project uses observations from forest and agricultural inventories, AmeriFlux sites, and Landsat data in a process model to produce estimates of terrestrial carbon stocks and fluxes for every square kilometer (Law et al., 2004, 2006). The model grows forests after disturbances and data compare well with forest biomass from inventories. This type of approach can be applied across the U.S. to track changes in terrestrial sources and sinks at a resolution appropriate for the scale of spatial variability that exists. The output of bottom-up process models could be used in CarbonTracker to improve its estimates of the terrestrial contributions to observed greenhouse gas concentrations.

The potential of the network to define reliable baselines of sources and sinks in the U.S. is high in the near future, but it will require enhancements and a more coordinated effort of the different science communities and agencies. The coordination could be improved through the North American Carbon Program (NACP), part of the Carbon Cycle Science Program.

Internationally, the potential to define baselines of GHG fluxes from natural or managed ecosystems using tower flux measurements is low in the next few years. The distribution of sites is variable, with a sufficient density of sites in Europe and Japan, but no sites in some countries. China and India recently started their own networks. In the past 10 years, the global network of sites has mushroomed from about 100 sites to over 500 flux sites in the regional international networks, so it is possible that the status will change quickly. However, continuity of existing observations remains threatened in some countries, like Canada. In addition, it requires technical expertise both in instrument maintenance and data analysis that isn't likely to be available everywhere.

Additional resources required to develop and sustain a robust carbon monitoring system

This is something that is required; the details are yet to be determined. It would be necessary to enhance the AmeriFlux Network, intensify the CO_2 concentration network, enhance the crop and forest inventory programs, ensure continuity of critical remote sensing data, provide more resources for coordinated data management systems for data assimilation, and accelerate analysis of available data for more comprehensive modeling and assessment.

Continuity of the AmeriFlux sites needs to be ensured. Improvements in the AmeriFlux Network would require adding new sites in under-represented biomes, eco-climatic regions, and early stages of forest growth following disturbance events and management/mitigation actions. In 2005, an analysis indicated locations where new towers were needed (Fig. 2 and Hargrove et al., 2003); gaps have since been filled in the SE and SW U.S. Sites should be enhanced with measurements of methane fluxes, another carbon source from land surfaces. New measurements could include isotopes for distinguishing sources and well-calibrated CO_2 concentration measurements that could augment NOAA's GHG observations. The required resources for a robust monitoring system are the same as if the primary purpose of the network remains focused on carbon cycle research.

More resources are needed for AmeriFlux data management to serve a broad user community. Increased computational resources are needed for data processing and modeling for regional, continental and global scale analysis (e.g., distributed computer clusters, and time on a super computer).

Many of the products needed for integrating AmeriFlux observations with other data and models are provided by individual investigators or programs with other missions, some with significant lags (years) in data availability and others lacking continuity. Additional resources are required for more rapid delivery of upstream data products that are critical to modeling and assessment, such as the State of the Carbon Cycle Report (CCSSP, 2007). Examples are Landsat data products, spatially derived weather data, and inventory estimates of biomass and productivity.

Figure 2. Representativeness of AmeriFlux sites of major biomes and climate zones in 2005. The black areas show the Pacific Northwest, Sierra Nevada Mountains, and Sonoran desert region were poorly represented by the AmeriFlux towers in 2005. Since then, sites were added in the SE and SW US. (http://www.esd.ornl.gov/research/terrestrial_ecology/carbon_flux_ecoregions.shtml).

Relationship between academic community involved in carbon cycle research and regional to continental mapping of fluxes of GHG, and the federal agencies supporting this work

There are existing mechanisms for communication between the academic community and the federal agencies supporting the work. The academic community involved in NACP projects is using the range of observation networks and models to produce maps of fluxes of GHG. The observation and modeling communities are represented on the steering groups. The Science Steering Groups of the NACP and Carbon Cycle Science Program meet a couple of times a year with the program managers in the Interagency Working Group. This has proved to be an effective way for scientists to discuss current gaps in observations or knowledge, and future research needs. The challenge is in responding to these needs in a timely manner.

Mechanism for Coordinating Efforts with Other Nations to Better Understand Carbon and GHG

A mechanism for coordinating observation networks among nations could build on the NACP and the Integrated Carbon Observation System (ICOS), a new European Research Infrastructure for quantifying and understanding the greenhouse balance of the European continent and of adjacent regions. ICOS aims to build a network of standardized, long-term, high precision integrated monitoring of (1) atmospheric greenhouse gas concentrations to quantify the fossil fuel component; (2) ecosystem fluxes of carbon dioxide, water vapor and energy and ecosystem variables (*http://icos-infrastructure.ipsl.jussieu.fr/*). The ICOS infrastructure would integrate terrestrial and atmospheric observations at various sites into a single, coherent, highly precise database, which would allow a regional top-down assessment of fluxes from atmospheric data, and a bottom-up assessment from ecosystem measurements and fossil fuel inventories. This is similar to aspirations of the U.S. North American Carbon Program (NACP).

One of the activities of the North American Carbon Program is ongoing coordination with Canada and Mexico on carbon observations and modeling. Here, the framework and science plan are under development, but again, there aren't enough resources for a high degree of coordination. Additional support necessary to ensure that data collected by different nations are comparable includes institutional support for coordination of observation systems, interchange of standards, and development of curated, active data management systems for data assimilation.

Within the frameworks of NACP/ICOS, a mechanism for coordinating tower flux work with other nations is the scientific bodies FAO Global Terrestrial Observing System—Terrestrial Carbon (GTOS–TCO) and FLUXNET. These frameworks exist, but there isn't enough support for a high degree of coordination. GTOS is supported by the Food & Agricultural Organization, and the role of GTOS–TCO is to organize and coordinate reliable data and information on carbon, linking the scientific community with potential end users. One important recent product is the guidelines for terrestrial carbon measurements and global standardization of protocols for submitting data to a database for international comparisons (Law et al., 2008).

The FLUXNET project is a "network of regional flux networks," serving a synthesis coordination role rather than primary data collection. The intent is to stimulate regional and global analysis of observations from tower flux sites. It is operated from the U.S., and has functioned intermittently depending on grants (*http://www.fluxnet.ornl.gov/fluxnet/index.cfm*). Through FLUXNET, we produced a global database using the data standardization protocols we developed for AmeriFlux (and published in the GTOS document, Law et al., 2008). However, the FLUXNET database is currently static and no one is responsible for continually updating it. To continue these developments and building international continuity in methods and databases, it would make sense for the community to have FLUXNET regularly funded. Along with guidelines for instrumentation and calibration we provide on the AmeriFlux web site, we have the templates for international coordination; they just need to be implemented.

Summary

The AmeriFlux Network of 90 sites has great potential to improve understanding of the carbon cycle, and land-based contributions to GHG. AmeriFlux provides direct measurements of net carbon dioxide exchange at the stand-scale that represents the integrated effect of various ecosystem processes. The area coverage of a tower is the appropriate scale for understanding the effects of climatic events and management activities, such as the outcome of mitigation strategies.

The network plays a major role in the North American Carbon Program, where modeling approaches use the flux data to test model processes, or to optimize the models and apply them spatially with inputs of weather data and remote sensing data on land surface characteristics (e.g., Landsat products, MODIS; Goward et al., 2008). Carbon cycle and climate system modelers use flux data to characterize terrestrial sources and sinks for carbon, responses of carbon and energy fluxes to climate and land use change, and resulting radiative forcing feedbacks to climate.

The potential of the network to define reliable baselines of sources and sinks in the U.S. is high in the near future, but it will take enhancements and a more coordinated effort of the science communities and federal agencies. Critical to this effort is timely availability of upstream observations and data products that are used in terrestrial models to map fluxes. The coordination could be improved through the North American Carbon Program.

Internationally, the potential to define baselines of GHG fluxes from natural or managed ecosystems using tower flux measurements is low in the next few years. The distribution of sites is variable, with a sufficient density of sites in many developed countries, but no sites in some countries. It also requires technical expertise both in instrument maintenance and data analysis that isn't likely to be available everywhere. Continuity of existing observations remains threatened in countries like Canada.

Additional resources will be required to develop and sustain a robust carbon monitoring system. It would be necessary to enhance the AmeriFlux Network, intensify the GHG observation network, improve terrestrial inventories, ensure continuity of remote sensing data, develop coordinated data management, and accelerate analysis of available data for more comprehensive modeling and assessment.

Additional resources are needed to ensure continuity of the AmeriFlux sites. Required resources would fill gaps in coverage by existing AmeriFlux sites, particularly in under-represented regions and biomes, and in different stages of forest growth such as following management/mitigation actions. The sites should be enhanced with additional measurements to include methane fluxes (another GHG), isotopes for distinguishing sources, and well-calibrated CO_2 concentration measurements. NOAA CO_2 concentration measurements and CarbonTracker would benefit from addition of well-calibrated CO_2 concentration measurements on more of the AmeriFlux towers. More resources are needed for AmeriFlux data management, data processing and modeling for regional to global scale analysis (e.g., distributed computer clusters, and access to super computers). The required resources for a robust monitoring system are the same as if the primary purpose of the network remains focused on carbon cycle research.

There are existing mechanisms for communication between the academic community and the federal agencies supporting the work. The observation and modeling communities are represented on the steering committees of the Carbon Cycle Science Program and NACP, and meet regularly with the Interagency Working Group of the federal agencies to identify gaps and needs. The challenge is meeting those needs in a timely manner.

Mechanisms for international coordination of infrastructure and analysis could build on the NACP and the new European infrastructure called the International Carbon Observation System (ICOS). FLUXNET, a 'network of regional flux networks,' and the FAO Global Terrestrial Observing System would operate within this framework. Additional support necessary to ensure that data collected by different nations are comparable includes institutional support for coordination of observation systems, interchange of standards, and development of high quality data management systems.

In summary, the tools and communication mechanisms exist for monitoring, measuring and understanding GHG sources and sinks. Each of the agencies has been working on their piece of the puzzle. Now what is required is a high level of commitment and coordination to build an integrated national system. For successful implementation, the observation networks, analysis teams, and data management need to be enhanced in the near term to develop and sustain a robust carbon monitoring system.

Citations

Baldocchi, D.D. 2008. 'Breathing' of the Terrestrial Biosphere: Lessons Learned from a Global Network of Carbon Dioxide Flux Measurement Systems. *Australian Journal of Botany* 56:1–26.

CCSP. 2007. *The First State of the Carbon Cycle Report (SOCCR): The North American Carbon Budget and Implications for the Global Carbon Cycle.* Anthony W. King, Lisa Dilling, Gregory P. Zimmerman, David M. Fairman, Richard A. Houghton, Gregg Marland, Adam Z. Rose, and Thomas J. Wilbanks, editors, 2007. A report by the U.S. Climate Change Science Program and the Subcommittee on Global Change Research, Washington, DC.

Goward, S.N., J.G. Masek, W. Cohen, G. Moisen, G.J. Collatz, S. Healey, R.A. Houghton, C. Huang, R. Kennedy, B.E. Law, S. Powell, D. Turner, M. Wulder. 2008. Forest Disturbance and North American Carbon Flux. *EOS Transactions* 11:105–106.

Hargrove, W.W., F.M. Hoffman, B.E. Law. 2003. New Analysis Reveals Representativeness of AmeriFlux Network. *EOS Transactions* 84:529.

Law, B.E., T. Arkebauer, J.L. Campbell, J. Chen, M. Schwartz, O. Sun, C. van Ingen, S. Verma. 2008. Terrestrial Carbon Observations: Protocols for Vegetation Sampling and Data Submission. Report 55, Global Terrestrial Observing System. FAO, Rome. 87 pp.

Law, B.E., D. Turner, J. Campbell, O.J. Sun, S. Van Tuyl, W.D. Ritts, W.B. Cohen. 2004. Disturbance and climate effects on carbon stocks and fluxes across western Oregon USA. *Global Change Biology* 10:1429–1444.

Law, B.E., D. Turner, M. Lefsky, J. Campbell, M. Guzy, O. Sun, S. Van Tuyl, W. Cohen. 2006. Carbon fluxes across regions: Observational constraints at multiple scales. In J. Wu, B. Jones, H. Li, O. Loucks, eds. *Scaling and Uncertainty Analysis in Ecology: Methods and Applications.* Springer, USA. Pages 167–190.

Misson, L., J. Tang, M. Xu, M. McKay, A.H. Goldstein. 2005. Influences of recovery from clear-cut, climate variability, and thinning on the carbon balance of a young ponderosa pine plantation. *Agricultural and Forest Meteorology* 130:207–222.

Urbanski, S., C. Barford, S. Wofsy, C. Kucharik, E. Pyle, J. Budney, K. McKain, D. Fitzjarrald, M. Czikowsky, J.W. Munger 2007. Factors Controlling CO_2 Exchange on timescales from hourly to decadal at Harvard Forest. *Journal of Geophysical Research* 112: G02020, doi:10.1029/2006JG000293.

BIOGRAPHY FOR BEVERLY LAW

Dr. Beverly Law is Professor of Global Change Forest Science at Oregon State University. She currently serves as the Science Chair of the AmeriFlux Network, and as a member of the Science Steering Groups of the U.S. Carbon Cycle Science Program and the North American Carbon Program. She is also serving on the National Research Council Committee on Methods for Estimating Greenhouse Gases. Her research is on the effects of climate and disturbances on carbon, water, and energy exchange between terrestrial ecosystems and the atmosphere; and methods for integrating observations and modeling to quantify and understand regional carbon balances. Dr. Law has been an author or co-author on over 100 refereed journal articles, including lead author on a World Meteorological Organization Norbert Gerbier-MUMM International Award for meteorology publication of the year (2004).

Chair GORDON. Thank you, Dr. Law.

And Dr. Birdsey, you are recognized for five minutes.

STATEMENT OF DR. RICHARD A. BIRDSEY, PROJECT LEADER AND SCIENTIST, USDA FOREST SERVICE; CHAIR, CARBON CYCLE SCIENTIFIC STEERING GROUP

Dr. BIRDSEY. Thank you, Mr. Chair and Members of the Committee. Thanks for inviting me here. I appreciate the opportunity to talk for a little while about monitoring, measuring, and verifying greenhouse gas emissions. I will talk a little bit about USDA inventory and monitoring programs, about how they may be used to verify greenhouse gas mitigation activities, and then about some interagency activities we are involved in.

First I want to spend a minute discussing the role of U.S. forests in the climate system. U.S. forests currently take up about 12 percent of the carbon dioxide emissions from the United States. This is a terrific service that these forests provide. We are not sure how that will evolve in the future, but it is something we want to take a good track of. We want to maintain these forests in a healthy way so that as climate changes they are adaptable and can continue to provide these ecosystem services.

Department of Agriculture has conducted inventories of the land for about 75 years, and we have a network of experimental forests and ranges that have been continuously collecting data for in some cases more than 100 years. These information systems are the basis for the U.S. Greenhouse Gas Inventory, the Forestry Sector, and this—these inputs are reviewed periodically, and based on these reviews we do thinks some improvements are needed.

USDA also provides data for land managers to use. We have developed very practical and cost-effective methods for estimating greenhouse gas sources and sinks at the level of farms or forestry projects. So these are very small-scale activities that we provide services to those land owners.

We also have developed some user-friendly estimation tools so that private owners and land managers can have a little easier time developing estimates that are specific for their circumstances.

Our ground-based observation systems are also essential for detecting the signs of climate change and eventually for monitoring our ability to respond to climate changes. For interagency and academic collaborations the U.S. Department of Agriculture and the Forest Service works closely with Environmental Protection Agency, NOAA, NASA, DOE, and other agencies and universities to develop the state-of-the-art greenhouse gas inventories.

The Carbon Cycle Interagency Working Group coordinates carbon cycle research under the U.S. Climate Change Science Program. I have been associated with this group for something like eight years. I find it quite fascinating how they are able to bring ten or more different agencies together to the table periodically to talk about the research that is going on, to do the best job they can to coordinate it, and then go back to their individual agencies and departments and work through those systems. I think it has been very effective.

The Carbon Cycle Steering Group that I chair provides input about carbon cycle science and particularly its relevance to the various stakeholder communities so we can assure that science is meeting the needs of society.

We have found that key elements of a national observation network are lacking or at risk of loss, and you are hearing about some of those from the other witnesses today.

As I mentioned at the beginning, U.S. forests provide a tremendous service of taking up a large percentage of our greenhouse gas emissions. The future of this is somewhat uncertain. There are many threats to the forests; climate change, land use change, fire, insects, and so forth, as well as the opportunity to manage those forests to remain healthy and continue to provide this service. Properly-managed forests across all ownerships; public, private, and in urban and rural areas can make a big difference in the future of mitigating and adapting to climate change.

These forests in rural areas and communities can really help improve people's lives, and we appreciate the opportunity to discuss the role of monitoring and ensuring that these forests continue to provide those services.

Thanks for the opportunity, and I will be glad to answer any questions that you have.

[The prepared statement of Dr. Birdsey follows:]

PREPARED STATEMENT OF RICHARD A. BIRDSEY

Mr. Chairman and Members of the Committee, thank you for inviting me today to discuss monitoring, measuring, and verifying greenhouse gas emissions. I am the Project Leader of the Research Work Unit "Climate, Fire, and Carbon Cycle Sciences" in the Northern Research Station of the U.S. Forest Service. In addition, I currently Chair the Carbon Cycle Science Steering Group. This Steering Group, comprised of about 20 experts involved in carbon cycle research and application from federal, State, university, and non-government organizations, reviews the status of carbon cycle science sponsored by U.S. agencies and departments. I will focus my remarks on the purpose and current status of USDA inventory and monitoring programs, their use in verifying greenhouse gas mitigation activities, and relevant federal interagency activities regarding carbon cycle research and monitoring.

Status of USDA Inventory and Monitoring Programs

Forestry, agriculture, and other land uses may either contribute to or remove greenhouse gases (GHG) from the atmosphere. Land use practices have affected GHG levels in the atmosphere through management of perennial systems and forests, land use changes, cultivation and fertilization of soils, production of ruminant livestock, management of livestock manure, and fuel consumption. Carbon is accumulating in U.S. forests, wood products, croplands, and urban lands, offsetting overall U.S. GHG emissions by about 12 percent.[1]

USDA conducts critical research, observation, survey, and analysis needed to assess greenhouse gas emissions and carbon storage on U.S. lands. We work closely with our partners in the Environmental Protection Agency and the Department of Energy on national, regional, local, and entity scale greenhouse gas inventories and methods.

USDA also maintains critical observation and data systems that will be needed to monitor and track changes in climate and the implications of climate change. USDA contributions include:

- Providing the greenhouse gas estimates from land use, land use change, and forestry and agricultural statistics to EPA for the Official U.S. Greenhouse Gas Inventory.
- Periodically producing a stand-alone inventory of greenhouse gas sources and sinks from the forestry and agriculture sectors to accompany the Official EPA inventory.

[1] *http://epa.gov/climatechange/emissions/usinventoryreport.html*

- Preparing project and farm-scale methods for estimating greenhouse gas sources and sinks for the Department of Energy's Voluntary Greenhouse Gas Reporting System.
- Creating user-friendly estimation tools for private landowners and land managers. These tools are designed to provide a "greenhouse gas footprint" of individual forest lands and farms.

These systems include: the U.S. Forest Inventory (FIA), the National Resources Inventory (NRI), the Census of Agriculture, climate and weather observations, Experimental Forests and Ranges, and various surveys of cropping and management practices.

The Forest Inventory and Analysis Program (FIA) of the Forest Service has tracked the condition and changes in vegetation on public and private lands for more than 75 years, and is the longest running forest inventory program if its kind in the U.S. The nationwide network of experimental forests and ranges provides up to 100 years of data on vegetation, climate and hydrology. Scientific support comes from partnerships with universities, federal and State agencies, non-governmental organizations, and the forest industry. Scientists and managers are using this information and working together to develop strategies for managing our changing forests and rangelands.

FIA data has been the basis of the reported changes in carbon stocks of the forestry sector of the U.S. Greenhouse Gas Inventory, as reported annually to the United Nations Framework Convention on Climate Change by the Environmental Protection Agency.[2] This is the national monitoring baseline for carbon in forests and wood products, following international reporting requirements and guidelines, and undergoing annual review by an international panel of experts. Its basis in the existing forest inventory program has advantages because of the extensive sample plot network which confers the ability to attribute observed changes geographically (e.g., by state), by broad ownership category (e.g., public, private) and by other characteristics of the land such as forest type or productivity class. Since the estimates are based on a statistical sampling approach involving remote sensing and direct field observations, the error of the reported estimates can be statistically described. The extensive FIA data, inventory, and analytical framework has the capacity to answer questions now that will arise as actions are implemented to increase carbon storage.

To improve the data from forest inventories as a basis for monitoring carbon, additional sampling is needed for carbon in soils, dead wood and down woody debris. Areas recently disturbed from events such as hurricanes and large wildfires need additional sampling to assess impacts. If reports are required for areas smaller than states, such as groups of counties or specific national forests, remote sensing augmented with intensified sampling density will be required. Movement of carbon in wood products from specific regions and ownerships are important but are not tracked through the chain of custody. Land-use and land-cover changes are not estimated accurately for small areas, which could be resolved with enhanced use of remote sensing and better coordination between agricultural and forest inventories. Some U.S. regions important to understanding forest carbon dynamics are currently under-sampled, such as Alaskan boreal forests and forested urban areas. Implementing these changes would improve the U.S. greenhouse gas inventory and provide additional capability to report estimates for specific land areas of interest.

The National Resources Inventory (NRI) is a statistically-based, longitudinal survey administered by the USDA Natural Resources Conservation Service (NRCS) that has provided conditions and trends for multiple environmental resources on non-federal U.S. lands since 1956 (known as the Conservation Needs Inventories until 1977). The National Resources Inventory samples more than 800,000 points nationally; each year 210,000 of these are studied remotely and 5,000 to 10,000 field-visited. Much of the sampling relies heavily on information provided by Natural Resources Conservation Service Soil Survey databases. Soil carbon is estimated from biomass production, disturbance (e.g., tillage, grazing or timber harvest) and loss by erosion, decomposition or removal of plant material. Effects of soils, landscape position and climate are factored into the estimates. Scientists from Natural Resources Conservation Service and Agricultural Research Service (ARS) are using National Resources Inventory data to assess the effectiveness of conservation practices in the Conservation Effects Assessment Project (CEAP).

In 2006, USDA prepared the only set of comprehensive landowner-scale greenhouse gas inventory methods available in the U.S. These methods were established by USDA for use the Department of Energy's Voluntary Greenhouse Gas Reporting

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[2] *Id.*

Registry.[3] Uniform standards and definitions provide consistent assessments of greenhouse gases at the landowner scale. To accompany these methods, the USDA Forest Service and Natural Resources Conservation Service provide decision-support tools. The COLE[4] and COMET–VR[5] models are examples of on-line estimators that support greenhouse gas registries and markets. Another example is i-Tree,[6] the Forest Service's suite of on-line tools developed to measure urban forestry benefits.

Section 2709 of the 2008 Farm Bill authorized the Secretary of Agriculture to establish technical guidelines for science-based measurement of environmental services benefits derived from conservation and land management activities. The Farm Bill specifically directs the Secretary to give priority to the establishment measurement standards—in consultation with research community and others—for carbon credits in order to facilitate landowner participation. The Secretary has established the Office of Ecosystem Services and Markets as a separate agency and is proceeding to staff the office to accomplish this work.

The Forest Service is an active participant in the U.S. network of flux towers (known as AmeriFlux) along with other sponsoring agencies such as Department of Energy. We have found that locating these intensive measurement systems in areas where other kinds of data collection takes place, such as our network of long-term Experimental Forests, facilitates integration of data across space and time, which improves verification as well as providing critical parameters for models that are used to diagnose the causes of current changes in carbon flux and to project changes under future climate scenarios. Integration of data and models can improve annual estimates and help attribute observed annual changes in carbon stocks to natural causes such as climate variability.

Other Forest Service monitoring and mapping programs are becoming highly relevant for understanding and monitoring changes and impacts on forest carbon stocks. For example, under the National Fire Plan, annual mapping of burned areas and intensity of wildfires provides critical data to estimate the contribution of fire emissions to the overall carbon budget of the Nation's forests. Mapping for the entire U.S. is currently incomplete, and there could be some improvement in linking maps of burned areas with vegetation classifications and better estimates of emissions based on fire intensity.

In addition to the National Resources Inventory, the Soil Survey Division of the Natural Resources Conservation Service routinely samples soils and measures soil organic carbon. This information is available for about 30,000 sites through the U.S. and its territories.[7] Nearly 650 sites are added annually. Land use data is available for many of these sites along with soil landscape attributes.

Characteristics of a Robust Carbon Monitoring System for GHG Mitigation

Project Monitoring

Monitoring needs for GHG mitigation projects are highly dependent on the specific reporting requirements, which are currently inconsistent among emerging GHG registries and markets. Critical determinants of monitoring needs are the definition of the reporting entity, and optional requirements to separate out changes in carbon stocks caused by natural events from those caused by human activities.

Reporting entities may be defined as any legally defined entity; examples include individuals, businesses, non-profit organizations, or government entities such as cities or states. Some of the registries and markets allow reporting by one entity on behalf of others. These organizations are known as "aggregators" because their purpose is to work with groups of reporters and thus achieve some efficiency in monitoring and reporting costs. There are 10 million family forest landowners in the U.S.[8] For a small landowner who wishes to participate in a carbon program, the monitoring and reporting cost per acre may be high, or they may lack the technical skills to perform the monitoring. But if the landowner is willing to be grouped with others, aggregators can serve their needs.

At the project or landscape level, we have the technology to measure and monitor changes in carbon stocks using remote sensing and field sampling. Most of the cur-

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[3] Smith, James E.; Heath, Linda S.; Skog, Kenneth E.; Birdsey, Richard A. 2006. Methods for calculating forest ecosystem and harvested carbon with standard estimates for forest types of the United States. Gen. Tech. Rep. NE–343. Newtown Square, PA. USDA NE–343: 216 p.

[4] *http://ncasi.uml.edu/COLE/*

[5] *http://www.cometvr.colostate.edu/*

[6] *http://www.itreetools.org/*

[7] National Soil Survey Center *http://ssldata.nrcs.usda.gov/*

[8] NRS–INF–06–08. May 2008. Who owns America's Forests? Family Ownership Patterns and Family Forest Highlights from the National Woodland Owner Survey.

rent and proposed markets and registries rely on sampling and measurements, which may be coupled with predictive models, to track or project changes in carbon emissions or sequestration. These approaches are practical and cost effective, and can be independently verified by a third party.

It may be difficult to separate human-induced causes from natural causes of observed changes at the project level. This is because inventory approaches measure the changes in ecosystem carbon that result from all causal factors combined. For example, if tree growth rates increase as a result of both physiological response to increasing atmospheric carbon dioxide and nitrogen fertilization, inventory measurements will not separate the effects of these two causes. Currently, the only ways to separate such causes are to conduct controlled experiments in the ecosystems of interest or to employ ecosystem process models which may or may not be available.

National-scale Monitoring: Capabilities and Gaps[9]

Successful CO_2 management requires robust and sustained carbon cycle observations, yet key elements of a national observation network are lacking or risk displacement on the basis of competing priorities.

Major threats to existing programs involve sustainability of the National Aeronautics and Space Administration (NASA) high accuracy well-calibrated satellite observations of land and oceans, and continuity of land/atmosphere CO_2 flux measurements. Major gaps include an improved spectral range and resolution for satellite measurements of oceans, sustained field observations at sea, insufficient density of atmospheric observations, incomplete geographic coverage of land inventories, lack of soil carbon monitoring, and lack of observations of the terrestrial-ocean interface. Steps could be taken to better integrate monitoring programs, and close current data gaps.

Since 1972, the Landsat series of satellites has provided spatial and temporal representation of land cover/land use change, classification of vegetation, and detection of natural disturbances. Landsat enables quantification of land vegetation and soil carbon fluxes to and from the atmosphere by providing spatially continuous and extensive estimates of above-aground biomass and/or land cover type that aid in the extrapolation of *in situ* measurements over large regions. The critically important Landsat data are expected to continue without a data gap, or if one should develop it is expected to be very brief, until the Landsat Data Continuity Mission (LDCM). The Landsat 5 and Landsat 7 satellites are very resilient. Refined projections of fuel usage computed by the United States Geological Survey (USGS), which operates the NASA-developed Landsat 5 and Landsat 7 satellites, suggest that Landsat 5 and Landsat 7 could have sufficient fuel to operate at least through 2012, exceeding previous expectations. The NASA and USGS LDCM has a launch readiness data of December 2012.

The NASA Moderate Resolution Imaging Spectroradiometer (MODIS) instruments on NASA's Aqua and Terra satellites, which were launched in May 2002 and December 1999, respectively, produce crucial global observations of primary production and vegetation phenology. A continuous record of primary production and phenology started with the National Oceanic and Atmospheric Administration (NOAA) Advanced Very High Resolution Radiometer (AVHRR) instruments in 1981 and continues with higher accuracy measurements by MODIS. This information is used in combination with ground observations and models to provide regional estimates and maps of carbon stocks and fluxes.

The global network of inter-calibrated measurements of atmospheric carbon dioxide (CO_2) and methane (CH_4) concentrations has been central to climate and carbon cycle studies for decades. These properties reflect the net effect of all global carbon sources and sinks to the atmosphere (anthropogenic, terrestrial and aquatic fluxes). The observational system also provides trace gas measurements (e.g., O_2, $^{13}CO_2$, CO, and other species) indicative of carbon sources. Current *in situ* measurements are made in limited areas from aircraft, towers, and marine, mountaintop and coastal observatories. NASA Aqua and Aura satellites measure global distributions of CO, CO_2, CH_4, and a myriad of greenhouse gases.

Land-based inventories periodically quantify carbon stocks and fluxes for biomass, soil, and fossil fuel emissions, but as already noted, there are some gaps in sampling of carbon pools and some geographic regions are under-sampled. Expanded forest inventories, if deemed necessary, could provide sampling of carbon in soils, dead wood and down woody detritus, especially areas where incidents of natural disturbance have accelerated and where large quantities of soil carbon are vulnerable. Agricultural inventories primarily focus on non-federal lands—federal rangelands are

[9] From the U.S. Carbon Cycle Science Steering Group.

under-sampled. Data on land use management and management history, both of which significantly influence changes in carbon, are lacking. The fate of carbon as it is transported across the landscape and accumulates in other terrestrial or aquatic systems is largely unknown. With a coordinated and consistent suite of core observations, forest and agriculture inventories would be integrated and better positioned to inform emerging policies and actions.

Soil carbon monitoring has large spatial and temporal gaps; this is significant because soil carbon is the largest terrestrial carbon stock and highly vulnerable to loss with warming. If determined to be necessary, a multi-agency supported network of soil carbon observations, with the capacity for performing measurements over decades and associated with other networks of terrestrial observations and inventories, would radically improve estimates of soil and ecosystem carbon dynamics at multiple scales.

Direct observations of CO_2 fluxes over decades are necessary to capture terrestrial carbon and water cycle responses to climate variability and to improve carbon and climate system model simulations. The AmeriFlux Network, initiated in 1996, currently has more than 100 sites observing biological properties, meteorology, and carbon, water and energy exchanges between terrestrial ecosystems and the atmosphere. Continuation would provide understanding of long-term trends in response to climate, yet support for AmeriFlux is currently provided on a site-by-site basis, and some long-term, high-quality records are endangered.

Rivers and groundwater at the land-ocean margins play a central role in linking terrestrial and marine cycles of carbon. The magnitude of weathering and erosion processes on land, sediment storage within the river system, and transport, transformation and burial processes in adjacent ocean margins demonstrate that these systems are an important part of the global carbon cycle. Existing research plans stress the importance of examining both the terrestrial and oceanic sinks for organic and inorganic carbon; however, the primary connection between these two environments is not adequately addressed. Despite a long history by the U.S. Geological Survey of gauging U.S. rivers and streams, there has been a gradual loss of long-term discharge monitoring stations and decreased number of annual carbon measurements. These long-term measurements provide understanding of anthropogenic changes to the hydrologic cycle.

Observational network design will need to respond in an effective and highly coordinated fashion among agencies, closely integrated with policy, land management, and scientific communities. Long-term global carbon observations can inform climate change mitigation policy and management decisions, and permit steps to be taken to close critical current gaps and avoid future gaps in observation continuity.

Verifying Compliance with Potential Climate Agreements

International climate treaties are likely to require monitoring and verification at the national scale; therefore, the discussion of gaps and threats contained in the previous section is most relevant. However, individual projects and activities that collectively affect national estimates and that may be governed by programs or markets also need monitoring and verification at much more detailed scales. As previously described, at the field plots or small watersheds scale of a project, there are published and practiced methods for sampling and measuring ecosystem carbon pools and how they change over time. At more regional scales such as a state or country, there are ongoing inventories and direct observations of CO_2 flux that form an internationally accepted basis for estimating ecosystem carbon and changes over time.

The difference between detection capabilities of atmospheric measurements and project-level measurements is one of scale. The current level of greenhouse gas mitigation would not produce an effect on the atmosphere that is detectable by direct atmospheric measurements, especially considering that there are other causes of atmospheric CO_2 changes that cannot be easily factored out (e.g., climate variability). Eventually, under a larger global offset program, such changes should be detectable by atmospheric measurements of CO_2 concentrations, and the sum of direct observations of activities on the land would add up to the aggregate observations of effects on the atmosphere.

Federal Interagency Activities Regarding Carbon Cycle Research and Monitoring

The Carbon Cycle Interagency Working Group (CCIWG), currently co-chaired by USDA and NASA, coordinates carbon cycle research under the U.S. Climate Change

Science Program (CCSP).[10] This entails coordinating research programs within and across agencies, coordinating the solicitation and review of research proposals (when appropriate), implementing targeted research, providing an interface with the scientific community conducting carbon cycle research, updating needs assessments, working to secure resources for new activities, and reporting results and accomplishments. The CCIWG is comprised of members from 10 participating federal agencies and departments that support and execute U.S. carbon cycle science research.

In order to both improve scientific knowledge and understanding of the carbon cycle and support application of this scientific knowledge to societal needs, a number of strategic research questions are used to guide the efforts of the Carbon Cycle Science Program. These research questions are part of the U.S. Climate Change Science Program strategic plan and indicate the complete scope of the research coordinated by the Carbon Cycle Interagency Working Group.[11]

- What are the magnitudes and distributions of **North American carbon sources and sinks** on seasonal to centennial time scales, and what are the processes controlling their dynamics?
- What are the magnitudes and distributions of **ocean carbon sources and sinks** on seasonal to centennial time scales, and what are the processes controlling their dynamics?
- What are the effects on carbon sources and sinks of past, present, and future **land-use change and resource management practices** at local, regional, and global scales?
- How do **global terrestrial, oceanic, and atmospheric carbon sources and sinks** change on seasonal to centennial time scales, and how can this knowledge be integrated to quantify and explain annual global carbon budgets?
- What will be the **future atmospheric concentrations of carbon dioxide, methane, and other carbon-containing greenhouse gases,** and how will terrestrial and marine carbon sources and sinks change in the future?
- How will the Earth system, and its different components, respond to **various options for managing carbon in the environment,** and what scientific information is needed for evaluating these options?

The Carbon Cycle Science Steering Group reviews the status of carbon cycle science. As mentioned earlier, I currently Chair this Steering Group, comprised of about 20 experts involved in carbon cycle research and application from federal, State, university, and non-government organizations. The function of this group is to provide individual as well as broad scientific and application input to the U.S. Climate Change Science Program about the direction of carbon cycle science and its relevance to the various stakeholder communities, and to identify gaps and potential new areas of emphasis. One of the main recent activities of this group has been to charter a team to update the U.S. Carbon Cycle Science Plan which is now about 10 years old.

One of the principal coordinated interagency activities with a very strong observing component is the North American Carbon Program. The North American Carbon Program is designed to address the strategic research question:

- What are the magnitudes and distributions of **North American carbon sources and sinks** on seasonal to centennial time scales, and what are the processes controlling their dynamics?

Scientists participating in the North American Carbon Program work in a coordinated fashion to assess the status of understanding of the magnitudes and distributions of terrestrial, freshwater, oceanic, and atmospheric carbon sources and sinks for North America and adjacent oceans; enhance understanding of the processes controlling source and sink dynamics; and produce consistent analyses of North America's carbon budget that explain regional and continental contributions and year-to-year variability. This program is committed to reducing uncertainties related to the increase of carbon dioxide and methane in the atmosphere and the amount of carbon, including the fraction of fossil fuel carbon, being taken up by North America's ecosystems and adjacent oceans, including uncertainty regarding the fraction of fossil fuel carbon.

[10] Additional information about U.S. carbon cycle science is available at: *http://www.carboncyclescience.gov/programs.php*

[11] *http://www.climatescience.gov/Library/stratplan2003/final/default.htm*

Similarly, the Ocean Carbon and Climate Change (OCCC) program was designed as an ocean component of the U.S. Carbon Cycle Science Program. A strategic plan provides the scientific rationale for coordinated ocean surface and space observations, experimental study, numerical modeling, and data assimilation efforts for the coastal ocean, ocean basins and atmospheric components of the carbon cycle over North America and adjacent coastal ocean and ocean basins.[12] The strategy consists of several coordinated and integrated elements on global ocean carbon observing networks, multi-disciplinary process studies, data fusion and integration, synthesis and numerical modeling, and new technological development. While the program encompasses a wide breadth of ocean biology, chemistry, and physical research, the program promotes linkages and interactions with related ongoing oceanographic, climatic, and carbon cycle programs to address the full range of scientific elements relevant to marine carbon dynamics and climate change.

One of the major products of the Carbon Cycle Science Program is the CCSP *Synthesis and Assessment Product 2.2, The First State of the Carbon Cycle Report (SOCCR): North American Carbon Budget and Implications for the Global Carbon Cycle.*[13] This report involved dozens of scientists from many disciplines interacting with stakeholders to assess knowledge and progress in understanding and managing the carbon cycles. The report highlighted the magnitude and sources of carbon emissions and sinks for North America, how they are changing, and what options are available to reduce emissions or enhance sinks. The future of this North American terrestrial sink is highly uncertain because we lack sufficient predictive capability to know how regrowing forests and other sinks will respond to changes in climate and CO_2 concentration in the atmosphere.

Summary and Conclusions

- USDA plays a leadership role in assessing land based greenhouse gas sources and sinks. U.S. forests currently offset about 12 percent of all U.S. greenhouse gas emissions.
- Forest Inventory and Analysis data has been the basis of the reported changes in carbon stocks of the forestry sector of the U.S. Greenhouse Gas Inventory, as reported annually to the United Nations Framework Convention on Climate Change.
- Improvements are needed in forest inventories for monitoring carbon: additional sampling is needed for some carbon pools and areas recently disturbed from events such as hurricanes and large wildfires; uncertain estimates of land-use and land-cover changes could be resolved; and some critical U.S. regions important to carbon dynamics are currently under-sampled, such as Alaskan boreal forests and forested urban areas.
- National Resources Inventory data estimates soil carbon from biomass production, disturbance and loss. An expansion of efforts to collect agricultural land management data could provide information for modeling carbon dynamics.
- At the smaller scale of a project, there are published and practiced methods for sampling and measuring ecosystem carbon pools and how they change over time.
- USDA has defined the accounting rules and guidelines for forestry and agriculture in a national greenhouse gas registry. This work may inform development of a federal program under which forestry and agriculture carbon credits could be generated.
- Successful CO_2 management requires robust and sustained carbon cycle observations, yet key elements of a national observation network(s) are lacking or at risk of loss. These gaps and threats limit ability to estimate current carbon budgets or to make projections of baselines.
- Threats to existing monitoring programs involve continuity of satellite observations of land and oceans, and continuity of land/atmosphere CO_2 flux measurements.
- Major gaps in existing carbon cycle monitoring include a need for improved spectral range and resolution for satellite measurements, insufficient density of atmospheric observations, incomplete geographic coverage of land inventories, lack of land use and management histories, lack of long-term soil carbon monitoring, and lack of observations of the terrestrial-ocean interface.

[12] *http://www.carboncyclescience.gov/documents/occc_is_2004.pdf*
[13] *http://www.climatescience.gov/Library/sap/sap2-2/final-report/default.htm*

- International climate treaties are likely to require monitoring and verification at the national scale; however, individual projects and activities that collectively affect national estimates and that may be governed by programs or markets also need monitoring and verification at much smaller scales.
- Carbon cycle research under the U.S. Climate Change Science Program is coordinated by the Carbon Cycle Interagency Working Group.
- The Carbon Cycle Science Steering Group is a group of about 20 experts involved in carbon cycle research and application from federal, State, university, and non-government organizations. The function of this group is to provide individual as well as broad scientific and application input to the U.S. Climate Change Science Program.
- One of the principal coordinated interagency activities with a very strong observing component is the North American Carbon Program. The North American Carbon Program is designed to improve monitoring of the magnitudes and distributions of North American carbon sources and sinks on seasonal to centennial time scales, and improve understanding of the processes controlling their dynamics.
- There are globally important carbon sinks in North America in plant material and soil organic matter. The future of this North American terrestrial sink is highly uncertain because we lack sufficient predictive capability to know how regrowing forests and other sinks will respond to changes in climate and CO_2 concentration in the atmosphere.

Thank you for the opportunity to discuss these issues with the Committee. I would be happy to answer any questions that you have.

BIOGRAPHY FOR RICHARD A. BIRDSEY

Dr. Richard Birdsey is Project Leader of Research Work Unit "Climate, Fire, and Carbon Cycle Sciences" in the Northern Research Station of the U.S. Forest Service. The mission of the Work Unit is to develop and provide the basic science, quantitative methods, and technology needed to make decisions about forest ecosystems and the atmosphere related to climate change, fire, and carbon. Dr. Birdsey is currently Chair of the Carbon Cycle Science Steering Group. This Steering Group, comprised of about 20 experts involved in carbon cycle research and application from federal, State, university, and non-government organizations, reviews the status of carbon cycle science sponsored by U.S. Agencies and Departments. Dr. Birdsey is a specialist in quantitative methods for large-scale forest inventories and has pioneered the development of methods to estimate national carbon budgets for forest lands from forest inventory data. He has compiled and published estimates of historical and prospective U.S. forest carbon sources and sinks, and analyzed options for increasing the role of U.S. forests as carbon sinks for offsetting fossil fuel emissions. Dr. Birdsey has coordinated a national effort to update accounting rules and reporting guidelines for U.S. forests in the national greenhouse gas registry, and identified forest management strategies to increase carbon sequestration. He manages a research program involving several U.S. Forest Service Laboratories and Experimental Forests, and cooperating Universities and other institutions, with research emphases on basic plant processes, ecosystem nutrient cycling, and measurement and modeling techniques.

Chair GORDON. Thank you, and Dr. Freilich, you are recognized for five minutes.

STATEMENT OF DR. MICHAEL H. FREILICH, DIRECTOR, EARTH SCIENCE DIVISION, SCIENCE MISSION DIRECTORATE, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION (NASA)

Dr. FREILICH. Chair Gordon, Members of the Committee, thank you for the opportunity to discuss NASA's greenhouse gas measurements and analysis activities conducted in conjunction with other federal agencies.

NASA develops satellites to make global measurements of greenhouse gases and many other environmental quantities. NASA Research and Applied Sciences Program coordinated with other agencies to analyze space-born, aircraft, and ground-based measurements to advance our understanding of greenhouse gases and their impacts on climate.

As a result of efforts by NASA and our sister agencies we know beyond a doubt that nearly half of human CO_2 emissions remain in the atmosphere with the other half removed from the atmosphere into the ocean and the land biosphere. When accumulated over large areas such as ferial forests, these natural exchange processes clearly have considerable impact, but we have much to learn about their details and about how they will evolve as the climate changes.

We are measuring aspects of the carbon cycle from space today. Data from the MODIS instruments are used to estimate regional carbon uptake by terrestrial and aquatic vegetation. The AIRES instrument on the ACWA Mission and the ORA spacecraft test instrument measure upper-air profiles of CO_2. However, elucidating air sea and air land exchange processes requires accurate CO_2 measurements near the surface. This is what the Orbiting Carbon Observatory, OCO, would have accomplished.

In February, as you know, NASA's OCO Mission crashed due to a launch vehicle failure. OCO would have acquired global, accurate, near-surface measurements of atmospheric carbon dioxide. A comprehensive validation activity was planned and funded using ground-based instrumentation from NASA and auxiliary measurements from NOAA, NSF, and other agencies. OCO would have provided unique global information on spatially-extensive regional scale, natural sources, and sinks of carbon.

We have been investigating recovery approaches. A team of imminent U.S. and international researchers has assessed the state of carbon cycle science and considered whether a new space mission is warranted now in light of present and planned NASA and international missions. They conclude that an OCO re-flight or an equivalent mission will, indeed, advance carbon cycle science and could provide a basis for thoughtful policy decisions and long-term monitoring.

NASA engineering teams, in parallel, are examining mission options including a near identical carbon copy mission and combining a copy of the OCO instrument with a thermal infrared sensor on a single spacecraft to fly in constellation with the Landsat Data Continuity Mission. It is our objective to have solid technical and programmatic understandings of both the carbon copy and the combined OCO thermal infrared missions by the end of May.

We have also been coordinating with our Japanese colleagues to expand previously-planned U.S. validation contributions to their GOSAT Ibuki Mission and to utilize data from that mission to test the existing OCO algorithms. The use of the GOSAT measurements, while they can't address all of the science issues that had been planned for OCO, will accelerate the production of quality products from any future NASA mission.

U.S. interagency groups like the CCSP Program Office, the Climate Change Technology Program, U.S. Ocean Action Plan Committees, and USGEO, the group on earth observations, coordinate many agency activities. NASA relies on DOE, USDA, NOAA, and other agencies for critical *in situ* and airborne observations of greenhouse gases and carbon storage in soil and plants, and of course, they rely on NASA for high-quality global remote sensing products to extend the reach and resolution of the existing networks.

Together we have developed vastly-improved understanding of the atmosphere and carbon cycle that can now inform climate policy and carbon management approaches.

Uncertainties of climate predictions for the 21st century are driven as much by our inability to quantify the feedback between biogeochemical cycles and climate change as by the uncertainty in the physical models of the climate and water vapor feedback of economic projections of fossil fuel emissions.

However, sustained, accurate, space-based observations are now improving the science of climate change and enabling better resource management and decision-making. *In situ* and airborne observations, research activities, and technology advancement are increasing our understanding of the carbon cycle. All of the agencies must continue our collaborations to achieve these ends.

The potential benefits are immense, coupling our present knowledge of emission inventories with new understanding of fluxes will not only support policy development and evaluation but may also identify areas for mitigation efforts and lower the cost of compliance.

Thank you very much.

[The prepared statement of Dr. Freilich follows:]

PREPARED STATEMENT OF MICHAEL H. FREILICH

Good morning Chairman Gordon, Ranking Member Hall and Members of the Committee. Thank you for the opportunity to appear today to discuss NASA activities in conjunction with other federal agencies in the measurement and monitoring of atmospheric greenhouse gases and the exchange processes between the atmosphere, the oceans, and the land.

As the Nation's civil space agency and as a leader in Earth System Science, NASA develops and flies instruments and missions to measure greenhouse gases—and a host of other vitally important environmental quantities—globally, from the vantage point of space. Through our vigorous research program, NASA uses measurements from space, air, and land to advance our understanding of key natural processes that determine amounts, transports, and climate impacts of the greenhouse gases in the atmosphere, with particular attention paid to the ways in which these gases are exchanged between the air, the land, and the sea. The quantitative knowledge we gain through the measurements and research is codified in numerical models, which can then be combined with future measurements to provide predictions of future conditions and to anticipate the effects of different policies and mitigation approaches. Through our Applied Sciences program, NASA develops products that combine the measurements with the understanding to provide information required by stakeholders and in particular by other federal agencies. Once developed and demonstrated by NASA, space-borne measurement approaches can be used to monitor greenhouse gases and their impacts over the entire globe and for long periods of time. The satellite data, in conjunction with essential ground-based and airborne measurements acquired by many agencies and combined in an integrated, coordinated way, provide critical information related to verification and to the efficacy of policy decisions.

Greenhouse gases, and especially carbon dioxide (CO_2), are extremely important components of the Earth system. They play key roles in determining the Earth's energy balance—how much of the incoming energy from the Sun is trapped within the Earth system of atmosphere, land, and ocean, and how much of that energy is reradiated back out to space. In contrast with other greenhouse gas species which are broken down by chemical reactions in the atmosphere, CO_2 is not destroyed; rather, the carbon is primarily cycled between the atmosphere, the surface layers of the ocean, and terrestrial vegetation over time scales of a few centuries. Therefore, decisions that we make today, and mitigation approaches that we take today, will still be determining conditions on Earth many generations into the future. As another consequence of long residence times and relatively rapid transport within the atmosphere, emissions originally localized at specific geographic locations influence environmental conditions around the entire globe. The distributions and concentrations of CO_2 and other greenhouse gases must thus be measured and predicted globally—a job that requires the global coverage and high spatial resolution of satellite measurements, combined with ground-based and airborne data and the use of comprehensive numerical Earth system models.

As will be discussed later in my testimony, we know beyond a doubt that over periods of a few years, about half of the CO_2 emissions remain in the atmosphere and the remainder of the emitted CO_2 is removed from the atmosphere and goes into the ocean and the land for long time periods. While the localized magnitudes of these natural exchange processes are small, their overall impacts can be considerable when accumulated over huge areas such as boreal forests and the oceans. While we know the global net effects of these exchanges over time scales of a few years, we must make and analyze new measurements of near-surface atmospheric greenhouse gas mixing ratios and land use/land cover conditions in order to understand the details of the processes, and to be able to make accurate predictions as to how the processes will change as the Earth's climate evolves.

Make no mistake about it, however: the measurements of greenhouse gases that are necessary to accurately define important, spatially extensive, natural atmosphere-land and atmosphere-ocean exchange processes are difficult to make and require the Nation's cutting edge technological as well as scientific skills. The benefits, however, are immense. Coupling our present extensive knowledge of emission inventories with new information and understanding we will gain on the magnitudes and uncertainties of natural and human-induced fluxes from land use changes and management practices will not only provide additional information to support policy development and evaluation, but also may identify additional areas for mitigation efforts and lower the cost of compliance.

NASA's Existing Capabilities for Measuring Carbon

Climate encompasses more than Earth's physical climate and physical observations. Greenhouse gases include carbon dioxide (CO_2), methane (CH_4), chlorofluorocarbons (CFCs), nitrous oxide (N_2O), ozone, and water vapor. These gases play key roles in climate change, which involves the biogeochemistry of Earth's atmosphere and biosphere (land and ocean). NASA's satellites, along with coordinated *in situ* and remote sensing networks and airborne science programs established and operated by many other agencies, help to quantify, characterize, and improve the accuracy and precision of greenhouse gas measurements over the land, as well as in the atmosphere and ocean. NASA ground-based networks provide critical long-term data for the validation of remote observations and contribute to national and international observational databases. NASA modeling activities along with measurements synthesize our understanding of the importance of greenhouse gases to climate change. While NASA does not have an operational aspect to its mission for monitoring practices, NASA data are utilized by partners in other agencies for operational activities.

Given the importance of understanding how CO_2 cycles through the environment, the NASA Earth Science Division maintains a vigorous research program through its carbon cycle and atmospheric composition focus areas to study the distribution and the forces determining the atmospheric concentrations of carbon dioxide and other key carbon-containing atmospheric gases (especially methane), as well as carbon-containing aerosols. Data from NASA satellites are studied, and observations are also made from airborne platforms and surface-based measurements in ways that can be used to validate and complement space-based observations. Satellite data are obtained for land cover and terrestrial and oceanic productivity, as these are critical in providing quantitative information about the distribution of the biosphere and the biospheric activity that exchanges carbon-containing gases between the land, ocean surface and the atmosphere. They can also provide critical information about the distribution and impact of fires, which play an important role in adding carbon-containing (and other) trace gases into the atmosphere. Models are then used to assimilate observations to produce accurate yet consistent global data sets, to infer information about sources and sinks, and to simulate future concentrations of atmospheric greenhouse gases that contribute to, and are affected by, climate change.

Through a series of direct measurements and models, NASA helps to characterize and quantify greenhouse gases and related controlling processes in the terrestrial, near-surface aquatic, and atmospheric environments. Data from the Atmospheric Infrared Sounder (AIRS) on the Aqua spacecraft delivers ozone, water vapor, methane, and CO_2 concentrations. The Aura spacecraft's Tropospheric Emission Spectrometer

(TES) provides information on ozone, CO_2, methane, and water vapor, while its Microwave Limb Sounder (MLS) provides ozone, nitrous oxide, and water vapor mixing ratios and the Ozone Monitoring Instrument (OMI) measures Nitrogen Dioxide (NO_2), ozone, Sulfur Dioxide (SO_2), and aerosols. However, the policy and science issues associated with methods for enhancing carbon uptake in forest and agricultural land, and with spatially extensive air-land/air-sea exchange processes, require accurate measurements near the surface. Because of the techniques used to make the measurements, both the AIRS and the TES CO_2 data correspond to upper-level concentrations (above about 13,000 to 36,000 feet), while the MLS measurements correspond to even higher levels in the stratosphere. Had the Orbiting Carbon Observatory (OCO) been successful, the combination of its accurate surface CO_2 measurements and the upper-level profiles obtained by AIRS would have provided a valuable component of a global data acquisition capability.

The NASA airborne fleet can detect and help quantify all of the aforementioned greenhouse gases in the atmosphere. For the ocean, Moderate Resolution Imaging Spectrometer (MODIS) data from the Terra and Aqua spacecraft can be used to estimate CO_2 exchange between the ocean and atmosphere. MODIS data are also used to estimate annual carbon uptake by terrestrial and aquatic vegetation over broad regions.

These observations are particularly powerful when the measurements from multiple assets are combined. One recent example of NASA's activity in this area is the Arctic Research of the Composition of the Troposphere from Aircraft and Satellites (ARCTAS) field campaign carried out in the spring and summer of 2008. In the ARCTAS campaign, data from three NASA aircraft based in Canada and Alaska, making flights as far away as Greenland, studied the gas phase and particulate composition of the troposphere, emphasizing their distribution in the atmosphere over North America and the Arctic. In particular, in the summer campaign, numerous observations of air affected by forest fires were made. By combining data from aircraft and satellites, scientists are now better able to understand the regional scale impacts of fires and long-range pollutant transport on air quality and the implications for climate.

Within planned future missions, the Deformation, Ecosystem Structure and Dynamics of Ice (DESDynI) mission, and to a lesser extent the Ice, Cloud, and land Elevation Satellite-II (ICESat-II), will contribute to improved estimates of above-ground carbon storage in vegetation that can be used to monitor the activity of forest carbon sinks and quantify carbon losses from them to the atmosphere due to major disturbances (storms, harvest, fire, etc.). Among later Decadal Survey-recommended missions presently under study, the Active Sensing of CO_2 Emissions Over Nights, Days, and Seasons (ASCENDS) mission will measure CO_2, the Geostationary Coastal and Air Pollution Events mission (GEO–CAPE) will measure ozone and CO_2 exchange between atmosphere and ocean, the Aerosol-Cloud-Ecosystems (ACE) will be used to estimate annual carbon uptake by aquatic vegetation, and the Global Atmospheric Composition Mission (GACM) will measure ozone, water vapor, and aerosols.

The NASA Earth Science Research Program goals in carbon cycle science are to improve understanding of the global carbon cycle and to quantify changes in atmospheric CO_2 and CH_4 concentrations as well as terrestrial and aquatic carbon storage in response to fossil fuel combustion, land use and land cover change, and other human activities and natural events. NASA carbon cycle research encompasses multiple temporal and spatial scales and addresses atmospheric, terrestrial, and aquatic carbon reservoirs, their coupling within the global carbon cycle, and interactions with climate and other aspects of the Earth system. The primary disciplinary research programs that support carbon cycle science at NASA are conducted within its Carbon Cycle and Ecosystems, and Atmospheric Composition focus areas (including the Upper Atmosphere, Tropospheric Chemistry, Atmospheric Chemistry Modeling, analysis, and Prediction, Ocean Biology and Biogeochemistry, Radiation Sciences, Terrestrial Ecology, Land Cover/Land Use Change, the Modeling Analysis and Prediction, Interdisciplinary Science, Carbon Cycle Science, Ozone Trends, Earth Observation Satellites Science, Aura Science programs, and to some extent, Physical Oceanography programs).

A focus on observations from space pervades carbon cycle research by NASA and is a basis for partnerships with other U.S. Government agencies and institutions. NASA carbon cycle research contributes toward the goals of major U.S. Climate Change Science Program (CCSP) activities, including the U.S. North American Carbon Program (NACP) and the Ocean Carbon and Climate Change Program (OCCC).

As an example, NASA working with other agencies and Departments under the NACP is working to improve estimates of carbon storage in forests and the impacts of disturbance (fire, insects and pathogens, severe storms, etc.) on this carbon storage. Other NASA NACP studies are developing regional carbon budgets, documenting year-to-year variations in sources and sinks, and attempting to attribute those changes to particular factors. Other NASA satellite studies are documenting changes in growing season length and the occurrence of critical seasonal events in ecosystems (e.g., budburst, flowering, leaf fall, algal blooms) that also affect carbon dynamics. All of these studies are advancing our scientific understanding and monitoring capacity—as well as advancing our abilities to evaluate the carbon cycle implications of land management practices.

NASA research has also focused on developing the scientific foundation for sound decision-making with respect to climate policy and the management of carbon in the environment. NASA's current and future well-calibrated measurements from space facilitated by NIST standards, in combination with decades of scientific understanding achieved through such studies, and the Agency's experience in demonstrating new decision support capability put NASA in a strong position to contribute to the Nation's responses to climate change. NASA's global observations and global modeling capabilities also will help to reduce regional and global climate and carbon cycle science model uncertainties.

The NASA Applied Sciences Program projects extend the products of Earth science research and the tools associated with that research, including observations, measurements, predictive models, and systems engineering, to meet societal needs beyond NASA Earth Science Research Program objectives. The Applied Science Program also addresses carbon management. For example, projects exploit NASA carbon cycle research results and related capabilities to enhance decision-making within agencies responsible for resource management and policy decisions that affect carbon emissions, sequestration, and fluxes among terrestrial, aquatic, and atmospheric environments.

NASA can provide its research observations, well-calibrated and well-validated for assessment and quantification of greenhouse gases and of aggregate changes in carbon sources and sinks on the land and in the ocean. Space-based measurements of greenhouse gases in the atmosphere are available now, albeit limited in utility, and will only improve in the future (with potential recovery from OCO and future development of ASCENDS, and ACE). Current observations of land cover, vegetation dynamics and ocean color, as well as numerous climate variables, allow for the identification and characterization of terrestrial and aquatic carbon sources and sinks as well as for attribution of some of the processes controlling their dynamics. Future observations of vegetation canopy height profiles will demonstrate and prove new abilities to support the estimation of carbon sequestration in forests.

The Role of the Orbiting Carbon Observatory (OCO)

On February 24, 2009, NASA's Orbiting Carbon Observatory (OCO) failed to reach orbit after liftoff from Vandenberg Air Force Base in California due to a launch vehicle mishap. This mission was designed to make near-global measurements of atmospheric carbon dioxide mixing ratios (approximately equivalent to the CO_2 concentration in a vertical column of the atmosphere) over the sunlit hemisphere of the Earth. The OCO measurements were designed to have high precision and dense spatial sampling. Indeed, OCO was designed to make the most challenging atmospheric trace gas measurements ever made from space.

The OCO measurement approach was designed to be most accurate in the lower troposphere close to the air-sea and land-air interface, which is where the transfers of atmospheric CO_2 to the ocean and the terrestrial biosphere take place. OCO was thus optimized to allow study of the CO_2 transfer processes, and quantification of the spatially extensive, regional-scale (several hundreds of miles in extent) sources and sinks of carbon in the natural system, and to allow their monitoring on seasonal time scales. To accomplish these tasks, OCO was designed to measure total column CO_2 with a precision of almost one part per million (ppm), spatial resolution less than one mile for instantaneous measurements, and a sampling pattern (a combination of orbit and swath width) that allowed global coverage on approximately monthly time scales. The on-orbit measurement strategy for OCO would have allowed accurate data to be obtained both over land and over the harder-to-measure, but larger, areas of the global oceans. The relatively small spatial footprints (high resolution) would have allowed measurements through clear-sky regions even in the presence of broken clouds. The OCO measurements would have been more accurate, had higher spatial resolution, and had greater coverage than those of any other existing space-borne trace gas measurement system. A comprehensive validation activity was planned and funded as part of the OCO mission. Using precisely calibrated measurements from upward-looking, ground-based instruments in the multi-agency Total Carbon Column Observing Network (TCCON) along with auxiliary information from NOAA, NSF, and other agency programs, residual errors in the OCO measurements were to have been identified and removed, resulting in a calibrated OCO data set referenced to the World Meteorological Organization standard. Indeed, the OCO mission activity has contributed three of the primary TCCON sites (Park Falls, Wisconsin; Lamont, Oklahoma; and Darwin, Australia) in this global network.

As a research, science, and technology demonstration agency, NASA rarely plans from the start to build multiple copies of instruments or missions. Given the importance of making multiple simultaneous measurements of many different quantities in order to understand the interactions between processes that define the Earth as a complex but integral system, the NASA Earth Science Division has historically focused on breadth of missions and measurements, rather than building multiple copies of instruments and missions in order to proactively assure rapid replacements in the event of launch catastrophes or early mission failures. Indeed, our careful design, construction, and extensive testing at every step of the process have resulted in spectacular success rates and long lifetimes for many of our Earth missions.

Prior to February 24, 2009, NASA had neither plans nor resources to build a replacement mission, either as a “carbon copy” of OCO itself or as a functional equivalent mission or instrument.

Following the launch failure, the NASA science and engineering teams have been actively investigating recovery from many different approaches. From the start, NASA has ensured that the OCO Science Team, augmented with researchers from our Research and Analysis programs and international scientists, have been kept intact and funded to investigate the state of carbon cycle science, whether the present key issues should or must be addressed through space-based measurements, and whether a new space mission was warranted in light of the present on-orbit assets of NASA and our international partners.

On April 9, 2009, the science team’s thoughtful, well-documented white paper was completed. The science team concluded that an OCO reflight or a functionally equivalent mission is necessary to advance carbon cycle science and to provide the basis for thoughtful policy decisions and societal benefits. Based on this scientific foundation (and working in parallel with the science analyses, anticipating the result), NASA tasked the engineering teams to examine several options for rapid mission implementation. The Team identified the top three candidate approaches as: (1) rebuilding an OCO mission with as few changes as possible and launching the so-called “Carbon Copy” into its planned orbit as an element of the “A-Train,” the constellation of five U.S. and international satellites flying in close formation to make a “virtual observatory” with highly synergistic, near-simultaneous measurements; (2) combining a near-copy of the OCO instrument with a Thermal Infrared (TIR) sensor on a single spacecraft, to be launched into close constellation with the Landsat Data Continuity Mission (LDCM), presently under construction for launch in December 2012; and (3) building a near-copy of the OCO instrument for launch to and flight on the International Space Station (ISS).

Each of these options has challenges, ranging from electronic parts obsolescence which preclude any complete identical rebuild of the OCO instrument and spacecraft, to significantly degraded coverage from the ISS orbit and the need to provide a dedicated pointing mechanism for the OCO instrument, and accommodation issues associated with the flight of both a TIR and an OCO-like instrument on the same spacecraft. There are also advantages to each of these approaches, which help offset the challenges described above, including early launch availability and relative simplicity for the “Carbon Copy,” possible lower launch costs and servicing potential for the ISS flight, and chances for an LDCM launch to allow more overlap than otherwise possible with the now-ancient Landsat 7 and Landsat 5 missions, while still providing synergistic multi-spectral and thermal infrared measurements within about six to twelve months after the LDCM launch.

At present, our understanding of the Carbon Copy option is most mature, while the OCO/TIR combined mission is being studied vigorously to refine its parameters. The scientific degradations associated with the flight of OCO on the ISS discourage near-term focus on this option. It is our objective to have solid technical and programmatic understandings of both the Carbon Copy and combined OCO/TIR missions by the end of May.

In parallel with NASA investigation of OCO reflight options, we have been collaborating substantively with our Japanese colleagues to expand and accelerate previously planned U.S. contributions to the validation of GOSAT/IBUKI CO_2 measurements and to utilize GOSAT/IBUKI data to help refine existing high-level OCO algorithms. While the accuracy and sampling characteristics of GOSAT/IBUKI are insufficient to allow key OCO science and policy questions to be addressed adequately, the use of the GOSAT/IBUKI measurements to help refine OCO algorithms now will accelerate the production of quality products from a future mission.

It should be noted that one of the mid-term missions that the Decadal Survey recommended for NASA to develop was a laser-based, carbon dioxide-measuring mission called "ASCENDS" (Active Sensing of CO_2 Emissions over Nights, Days, and Seasons). Using active lasers rather than reflected sunlight, ASCENDS is expected to provide CO_2 measurements in polar regions during the winter and at night. Technology development advances required for the lasers on ASCENDS preclude its early flight within the next three years. Furthermore, the use of reflected sunlight for OCO measurements (versus the active lasers for ASCENDS) makes the smaller and simpler OCO-like instrument attractive for long-term monitoring of near-surface CO_2 levels and offset processes.

We will keep the Committee informed as we develop the technical and programmatic understanding necessary for future decisions on OCO recovery options and their associated budget implications within the broader context of other Earth Science priorities.

Working With Our Interagency Partners

U.S. interagency programs provide the fora for coordination of the respective agency activities. These bodies include the CCSP Program Office, the Climate Change Technology Program, the U.S. Ocean Action Plan committees, and U.S. Group on Earth Observations (U.S. GEO). The majority of the collaborations and coordination are achieved through informal interagency interactions among the program managers and scientists that are responsible for the aforementioned research efforts. There are important inter-dependencies that both require and challenge interagency coordination. NASA relies on the Department of Energy, the United States Department of Agriculture, and the National Oceanographic and Atmospheric Administration for critical *in situ* and airborne observations of greenhouse gases and carbon storage in soils and plants—and, of course, they rely on NASA for calibrated, validated remote sensing data products. Together, we have developed vastly improved understanding of the atmosphere and carbon cycle to go with those measurements that can now be applied to the development of climate policy and carbon management.

Internationally, partnerships are made in many fora, examples include Global Earth Observation System of Systems (GEOSS), the Committee on Earth Observing Satellites (CEOS), the Global Carbon Project, the World Climate Research Program, and other IGBP and UNEP–WMO programs. International bilateral meetings are also helpful for the international coordination.

The academic research community and federal efforts are mainly coordinated by the program managers in the Earth Science Division, who take great strides at NASA among flight programs, research, and applied sciences to ensure the research community and management communities provide feedback to the overall efforts of the NASA Earth Sciences Division. The National Research Council of the National Academies of Sciences has provided valuable inputs from the community regarding future research directions for NASA (e.g., the recent Decadal Survey). NASA also listens closely to its advisory subcommittee and the Science Steering Groups associated with the U.S. Carbon Cycle Science Program, the North American Carbon Program, and the Ocean Carbon and Biogeochemistry Program.

Going Forward

Uncertainty of climate for the 21st century is driven as much by our inability to quantify the feedback between biogeochemical cycles and climate change, as it is by uncertainty in the physical modeling of the cloud and water vapor feedback or economic projections of fossil fuel emission. These uncertainties in the feedback processes result in large differences in the predictions of climate models. At present, even for fixed, prescribed fossil fuel emission scenarios, the predicted atmospheric CO_2 levels in 2100 from the best coupled carbon-climate models differ by more than 300 ppm, which is equivalent to about 40 years of present anthropogenic CO_2 emission levels (e.g., Freidlingstein et al., *J. Climate,* 19 (2006), 3337–3353).

Space-based observations sustained over a long period of time at the current level of quality or better are critical to improving the science of climate change and enabling better resource management and decision-making. Well-calibrated *in situ* and airborne observations for validation and for study and diagnosis of process controls, complementary research activities, as well as technology advancement, are necessary to improve observational capabilities. NASA, NOAA, NSF, and USGS must continue and enhance their collaborations to achieve these ends.

Thank you for the opportunity to discuss NASA activities in the measurement and monitoring of atmospheric greenhouse gases and the exchange processes between the atmosphere, the oceans, and the land. I would be pleased to respond to any questions that you or the other Members of the Committee may have.

BIOGRAPHY FOR MICHAEL H. FREILICH

Michael H. Freilich is the Director of the Earth Science Division, in the Science Mission Directorate at NASA Headquarters. Prior to coming to NASA, he was a Professor and Associate Dean in the College of Oceanic and Atmospheric Sciences at Oregon State University. He received BS degrees in Physics (Honors) and Chemistry from Haverford College in 1975 and a Ph.D. in Oceanography from Scripps Institution of Oceanography (Univ. of CA., San Diego) in 1982. From 1983–1991 he was a Member of the Technical Staff at the Jet Propulsion Laboratory.

Dr. Freilich's research focuses on the determination, validation, and geophysical analysis of ocean surface wind velocity measured by satellite-borne microwave radar and radiometer instruments. He has developed scatterometer and altimeter wind model functions, as well as innovative validation techniques for accurately quantifying the accuracy of space-borne environmental measurements.

Dr. Freilich served as the NSCAT Project Scientist from 1983–1991 and as the Mission Principal Investigator for NSCAT from 1992–1997. Until he relinquished his project posts to join NASA HQ, he was the Mission PI for QuikSCAT (launched in June, 1999) and SeaWinds/ADEOS–2 (launched in December, 2002). He was the team leader of the NASA Ocean Vector Winds Science Team and is a member of the QuikSCAT, SeaWinds, and Terra/AMSR Validation Teams, as well as the NASDA (Japanese Space Agency) ADEOS–2 Science Team.

Dr. Freilich has served on many NASA, National Research Council (NRC), and research community advisory and steering groups, including the WOCE Science Steering Committee, the NASA EOS Science Executive Committee, the NRC Ocean Studies Board, and several NASA data system review committees. He chaired the NRC Committee on Earth Studies, and served on the NRC Space Studies Board and the Committee on NASA/NOAA Transition from Research to Operations.

His honors include the JPL Director's Research Achievement Award (1988), the NASA Public Service Medal (1999), and the American Meteorological Society's Verner E. Suomi Award (2004), as well as several NASA Group Achievement awards. Freilich was named a Fellow of the American Meteorological Society in 2004.

Freilich's non-scientific passions include nature photography and soccer refereeing at the youth, high school, and adult levels.

Chair GORDON. Thank you, Dr. Freilich, and Ms. Kruger, you are recognized for five minutes.

STATEMENT OF MS. DINA KRUGER, DIRECTOR, CLIMATE CHANGE DIVISION, OFFICE OF ATMOSPHERIC PROGRAMS, ENVIRONMENTAL PROTECTION AGENCY

Ms. KRUGER. Good morning, Chair Gordon and Members of the Committee. Thank you for inviting me to testify this morning about monitoring, measurement, and verification of greenhouse gas emissions. My name is Dina Kruger, and I am the Director of EPA's Climate Change Division, and my testimony this morning is going to focus on the data that EPA already collects, our National Greenhouse Gas Inventory, the proposed Greenhouse Gas Reporting Rule, and our assessment of international reporting programs.

I would like to begin by offering background information about some EPA programs that are relevant to today's topic. We implement successful cap-and-trade programs such as the one for acid rain, which has served as a model for greenhouse gas trading. EPA also heads an annual interagency effort to develop and publish the official U.S. inventory of greenhouse gas emissions, and just last month we issued a proposed rule to establish an economy-wide, facility-level reporting system for greenhouse gas emissions.

What is common to all of the work that we do is the emphasis on accurate, comprehensive, transparent, and timely monitoring.

Simply put, you cannot manage what you do not measure. Moreover, one size does not fit all. The best methods and systems for obtaining high quality greenhouse gas data must be customized to suit the specific policies we are implementing and the emission sources we are addressing.

For example, the monitoring system required to establish baselines and assess progress under a facility-based regulatory program must provide timely and accurate emissions data from each affected facility.

Since 1995, under EPA's Acid Rain Trading Program, power plants have reported sulfur dioxide emissions measured by continuous monitors in their stacks. Importantly, over the same period each unit has also reported carbon dioxide data. With power plants representing over one-third of the Nation's CO_2 emissions, we already have a head start on the monitoring program for greenhouse gas emissions.

Other large stationary sources could also potentially monitor greenhouse gas emissions, and these additional sources are the primary focus of EPA's proposed Greenhouse Gas Reporting Rule, which was signed by Administrator Jackson on March 10. In this rule EPA proposed to collect emissions data from entities that emit more than 25,000 metric tons of CO_2 equivalent per year. Many emission sources, including many agricultural sources, as well as cars, trucks, homes, and small businesses would not be subject to monitoring and reporting requirements under our proposed thresholds because of their small size or the complexity or cost of accurately monitoring their emissions.

Instead, greenhouse gas emissions from these smaller sources are covered by upstream providers of fossil fuels and industrial gases. EPA estimates that the proposed reporting program would provide baseline data for facilities representing between 85 and 90 percent of the national greenhouse gas emissions.

I would also like to highlight the U.S. National Greenhouse Gas Inventory, which is an annual accounting of all human-caused sources and sinks and provides a means of measuring progress against our national goals. EPA has published this inventory since 1993, in cooperation with numerous federal agencies including the Departments of Energy, Agriculture, Defense, and State.

Given its scope, the National Inventory requires a variety of methodological approaches and technologies. Fossil fuel combustion is the source of approximately 80 percent of our national greenhouse gas emissions, and estimates for this source are accurate to within a few percentage points. In the forest and agriculture sectors we believe that the data are good but could be improved through continued coordination between the land agencies such as USDA and agencies with remote sensing capabilities such as NASA and NOAA.

Finally, I will address greenhouse gas monitoring in other countries. We expect the same level of effort and accuracy from other industrialized countries as we have achieved with our own National Inventory, and to a large extent, our expectations are met. However, there is room for improvement in developing countries, and we have identified three main obstacles to better data.

First, reporting requirements for developing countries are inadequate because the reporting is currently too infrequent. Second, government agencies and technical experts in these countries do not receive the sustained support necessary for strong, for a strong inventory, and investments in fundamental data such as national statistics in many developing countries are lacking.

Third, deforestation and agricultural practices are the primary emission sources in many developing countries, and these are also the most technically-difficult sources to monitor. Approaches like remote sensing techniques could be a cost-effective tool to improve land use data in these countries.

In conclusion, the greenhouse gas monitoring challenge is complex but solvable. While our primary focus at EPA is on the management of emissions from specific emission sources and projects, we also need to be sure that the reported and verified bottom-up emissions data are representative of what we see in the atmosphere. We may find that our monitoring approaches need to be modified, obtain insights that lead to better policies, or identify additional ways to reduce greenhouse gas emissions. Agencies such as NOAA, NASA, DOE, and USDA are important players in this realm and a coordinated effort with and among these agencies can achieve the necessary comprehensive top-down understanding.

Thank you for the opportunity to speak to the Committee today, and I look forward to answering your questions.

[The prepared statement of Ms. Kruger follows:]

PREPARED STATEMENT OF DINA KRUGER

Introduction

Chairman Gordon, Ranking Member Hall, and Members of the Committee, thank you for inviting me to testify about monitoring, measurement and verification of greenhouse gas emissions. I am Dina Kruger, Director of EPA's Climate Change Division. Today my testimony will focus on what data EPA already collects under existing regulatory programs; EPA's proposed Mandatory Greenhouse Gas Reporting Rule; as well as international reporting programs. Accurate data on greenhouse gas emissions are an essential component for climate change research and the foundation for implementing and assessing programs to reduce emissions. EPA looks forward to continued opportunities to work with the Committee in this area.

Existing Data

I would like to begin by offering some background about programs EPA implements that are relevant to today's topic. We implement two successful cap and trade programs: the Acid Rain Trading Program and the NO_X Budget Trading Program. These two programs have served as models for greenhouse gas cap and trade programs such as the Regional Greenhouse Gas Initiative (RGGI), the Western Climate Initiative (WCI), and the European Union Emissions Trading System (EUETS). In order to fulfill reporting obligations under the United Nations Framework Convention on Climate Change (UNFCCC), ratified by the United States in 1992, EPA leads an annual interagency effort to develop and publish a national inventory of human-caused greenhouse gas emissions, the most recent of which was submitted last week on April 13. We also implement a number of partnership programs targeting non-CO_2 greenhouse gases such as methane, hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride. And, just last month, EPA issued a proposed rule to establish an economy-wide mandatory reporting system for greenhouse gas emissions. This Reporting Rule was discussed during your first hearing on this topic in February, and will be the focus of part of my testimony today.

Mr. Chairman, what is common to all of the work we do across the entire suite of EPA air programs, is the emphasis on accurate, comprehensive, transparent and timely monitoring. Simply put, you cannot manage what you cannot measure. Moreover, we recognize that effective greenhouse gas monitoring is inextricably linked to the specific policies being considered, and the types of emission sources we are addressing. One size does not fit all. The best methods and systems for obtaining high quality greenhouse gas data must be customized to suit our specific policies and purposes.

The monitoring equipment and systems required to establish baselines and assess progress under a facility-based regulatory program, for example, need to provide timely and accurate data of emissions from each affected facility. We collect this type of data under EPA's Acid Rain Cap and Trade Program, which covers electricity generating units. These units are required to install and operate continuous sulfur dioxide emission monitors in their stacks, or for smaller or low emitting units a continuous fuel monitor of comparable accuracy. Each facility measures hourly and reports to EPA on a quarterly basis. All of these measurements are uploaded to EPA's database automatically through secure Internet connections, where the data are then checked and checked again by sophisticated software routines. The end result is emissions data that provide empirical support for the trading program and assurance that each facility is operating on a fair and level playing field. Importantly, since the program began in 1995, each electricity generating unit also has reported carbon dioxide emissions data through the same procedures, as required under Section 821 of the 1990 *Clean Air Act Amendments.* With the electricity sector representing over one-third of the Nation's CO_2 emissions, we already have a head start on the monitoring program for greenhouse gas emissions.

Proposed Greenhouse Gas Reporting Rule

Other large stationary sources could also potentially monitor greenhouse gas (GHG) emissions. These additional sources are the primary focus of EPA's proposed Greenhouse Gas Reporting Rule, signed by Administrator Lisa Jackson on March 10th and published in the *Federal Register* on April 10th. Pursuant to the direction of Congress, EPA's proposed GHG Reporting Rule focuses on emissions from sources above appropriate thresholds in all sectors of the economy. The proposed Reporting Rule has not been designed to track project-based offsets, such as carbon sequestration from agricultural or forest lands, or to create a comprehensive national inventory—both of which I will discuss later.

In this rule, EPA proposes to collect greenhouse gas emissions data from about 13,000 entities that emit more than 25,000 metric tons of CO_2 equivalent per year, or produce or import fuel or industrial gases. In total, the proposed rule is estimated to cover 85 to 90 percent of U.S. greenhouse gas emissions. The 25,000 ton threshold is roughly equivalent to the amount of CO_2 that would be produced by burning 131 rail cars of coal. The proposed rule attempts to mitigate any impacts on small businesses by including the 25,000 metric tons of CO_2 equivalent per year threshold. As a result, this rule would affect larger industrial facilities, such as refineries, iron and steel mills, cement and petrochemical plants.

Many emission sources would not be subject to monitoring and reporting requirements under the thresholds proposed in the proposed Reporting Rule because of their small size or the complexity or cost of accurately monitoring their emissions. This includes many agricultural sources as well as emissions from individual cars and trucks, homes, and small businesses. Instead, emissions from the use of fossil fuels in smaller sources is covered "upstream," by which we mean that coal mines, petroleum refineries, natural gas processing facilities, and natural gas distribution companies would report on the carbon contained in fuel they supply to the economy. While there are tens of millions of cars and houses, there are approximately 3,500 suppliers of fossil fuel in the economy, representing approximately 30–35 percent of U.S. greenhouse gas emissions, and the estimation of emissions from these sources is both manageable and accurate.

EPA estimates that with the 25,000 ton annual threshold and the inclusion of "upstream" providers of fossil fuels and industrial gases, the greenhouse gas reporting program could provide baseline emissions data for facilities representing between 85 percent and 90 percent of national greenhouse gas emissions. We are working hard to complete the Reporting Rule this fall, and are proposing that the first reports will be due in March of 2011 and cover year 2010 emissions.

At this point, let me say a few words about verification in the proposed reporting program, as this issue has been the subject of discussions in this committee and in other venues. EPA is proposing a centralized verification program modeled on our experience in the Acid Rain program, which I just summarized. EPA has successfully verified data across its *Clean Air Act* programs for decades. The northeast states through the Regional Greenhouse Gas Initiative chose to run their greenhouse gas cap and trade program using the CO_2 data that EPA collects and verifies through the Acid Rain Program rather than reinvent the wheel. We are confident that this system currently applied to the Acid Rain program can be extended to the verification of all emissions data reported under EPA's greenhouse gas reporting program (i.e., 85–90 percent of U.S. greenhouse gas emissions).

Effective monitoring tools and protocols for offset projects must also be customized to the specific emission sources and project categories under consideration. In our experience, methane capture projects, such as landfill gas or coal mine methane, can be monitored effectively using off-the-shelf technology. EPA has experience with these technologies by virtue of having implemented partnership programs with these industries for more than fifteen years. Other offset projects, particularly in the agriculture and forestry sectors, pose unique monitoring challenges. While data may meet national inventory needs, project-level estimates can be more challenging in these sectors due in part to the variability of the emission reductions or sequestration levels. In the case of sequestered carbon specifically, there is also the risk of reversals back to the atmosphere, through natural disturbances like forest fires or changes in management practices, like tilling soil.

U.S. National Greenhouse Gas Inventory

The second greenhouse gas monitoring program that I would like to highlight is the U.S. National Greenhouse Gas Inventory which is an annual accounting of human-caused emissions and sequestration across all sectors. This inventory provides the means of measuring progress against national goals, including President Obama's goal to reduce emissions by 14 percent from 2005 levels by the year 2020 and by 83 percent by the year 2050, and will be the metric by which success is judged. EPA has coordinated our nation's annual greenhouse gas inventory since 1993, in cooperation with numerous other federal agencies. The Department of Energy provides essential data on the national fossil energy accounts. The Department of Agriculture (USDA) provides data and methodological support for land-based emissions and sequestration. The Department of Defense has proactively taken the lead on improving our understanding of emissions from their aircraft and ship operations. And the State Department, as the lead agency for United Nations (UN) treaties, submits the inventory each year to the UN Framework Convention on Climate Change.

As I indicated, the national greenhouse gas inventory includes all sources and sinks, from the burning of fossil fuels for transportation, to methane generated from decomposing organic wastes, to sequestration of CO_2 in our forests and soils. Such a wide-ranging effort necessarily requires a variety of methodological approaches and technologies, and the quality of the data varies across source categories. Fossil fuel combustion is the source of approximately 80 percent of our national greenhouse gas emissions—and our colleagues at the Energy Information Administration take great effort to ensure that the national energy snapshot is accurate and up to date. Our own studies and independent reviews confirm that this largest component of our national inventory is accurate to within a few percentage points, and because EPA and the Department of Energy (DOE) have "piggy-backed" on existing government systems, the American taxpayer has not needed to fund redundant projects.

Other sources are considerably more challenging. For example, nitrous oxide, a very potent greenhouse gas, is emitted primarily from highly variable biological process in soils, lakes and streams. These biological processes can be accelerated by the application of fertilizer, or through deposition of industrial pollutants, but our scientific understanding and our ability to predict emissions are incomplete.

As I indicated earlier, sequestration of CO_2 in soils and forests is a special case. We cannot realistically measure the carbon in every acre of land, so we must use a sampling approach. The Forest Service has an extensive national system of measurement plots covering much but not all of the country's forests. The U.S. Department of Agriculture's (USDA's) National Resources Conservation Service also collects data on our agricultural soils. From EPA's perspective, the data are good but our national inventory would benefit from the development of additional monitoring and measurement approaches and continued integration of the data currently collected by land agencies such as USDA and agencies with remote sensing capabilities such as the National Aeronautics and Space Administration (NASA) and the National Oceanic and Atmospheric Administration (NOAA).

International Reporting Programs

The third topic I would like to address is greenhouse gas monitoring in other countries. We expect the same level of effort and accuracy from other industrialized countries as we have achieved with our national inventory, and to a large extent our expectations are met. Europe, Japan, Canada, and Australia have strong greenhouse gas monitoring systems due to investments by each government and a rigorous system of international annual expert peer review. In addition to monitoring and reporting greenhouse gas emissions at the national level under the United Nations Framework Convention on Climate Change, many of these countries have developed or are developing, facility-level reporting systems, similar in scope to EPA's recent proposal for our domestic mandatory GHG reporting system. Among these countries there is a strong foundation of mutual trust in each other's data.

There is more room for improvement in the major developing countries. EPA has worked with many of these countries to build greenhouse gas monitoring capacity, and we have found that there are three main obstacles standing in the way of better data. First, the reporting requirements are inadequate for developing country parties to the UN Framework Convention on Climate Change. Developing countries are required to submit only a summary level inventory approximately every five to six years. Modest and infrequent international reporting commitments give the wrong signal to government agencies and technical experts in these countries—they do not receive the political and financial support necessary for a strong inventory. Second, there are low-tech or "no-tech" opportunities that are being missed. In many developing countries there is a need to strengthen government and research institutions so that agencies communicate and greenhouse gas monitoring expertise is built up and retained over time. The collection and retention of basic national statistics for the energy, transportation, and waste sectors by these organizations and institutions would provide a solid first step in developing national estimates of greenhouse gas emissions, without the use of prohibitively expensive monitoring technologies or practices. Third, deforestation and the addition of new agricultural lands are the primary sources of GHG emissions in many developing countries and these are also the most technically challenging sources to monitor. Remote sensing techniques could be a cost-effective tool to improve agricultural and land-use data in these countries. Given the lack of resources and capacity in many developing countries and a range of assurances necessary with regard to competitiveness, the U.S. may benefit from a robust global atmospheric greenhouse monitoring program. Such a program could verify that efforts to reduce emissions leads to real reductions in the atmospheric concentration of greenhouse gases, and that offsets agreed to by the international community are having the intended effects. Such a system should complement ongoing programs in developed countries and a concerted effort by developing countries to improve reporting.

Conclusion

EPA also recognizes the scientific community's important role in verifying the effectiveness of our domestic and international policies. EPA's focus is primarily on the management of emissions from specific emission sources and projects, but we also need to be sure that reported and verified bottom-up emissions data are representative of atmospheric measurements and to know whether these policies are having the desired result on the climate. This is a challenging task for an issue as complex as climate change, but it is essential. Agencies including NOAA, NASA, DOE, and USDA are important players in this realm and a coordinated effort among those agencies can achieve the necessary comprehensive "top-down" understanding. In some cases, we may find that our monitoring approaches need to be modified, as we identify new information about greenhouse gas sources, sinks or processes. Moreover, as we gain better understanding of how the atmosphere is responding to our policies through these top-down measurements, we can use that information to modify our policy goals or identify additional verifiable measures that can reduce greenhouse gas emissions. To the extent that this hearing serves to advance this important discussion, it will be very useful to EPA and our partner federal agencies.

In conclusion, I would like to emphasize that the greenhouse gas monitoring challenge is complex but solvable. We have high quality GHG emissions data for the large facilities that could be included in a future regulatory program such as cap-and-trade. Our national inventory is solid but could be improved in certain areas, particularly outside the energy sector. Inventories in major developing countries need to be improved through a combination of institutional and technological steps. And it is clear that collecting top-down measurement data can also play an important role in informing whether the bottom-up data being collected are comprehensive, helping policy-makers further evaluate the effectiveness of any policies implemented.

Mr. Chairman, thank you for the opportunity to speak to the Committee today. I hope the information I have provided is useful, and I look forward to the answering the Members' questions.

BIOGRAPHY FOR DINA KRUGER

Dina Kruger is Director of the Climate Change Division at the U.S. Environmental Protection Agency. Ms. Kruger is responsible for a wide range of programs and analyses dealing with climate change policy, economics, mitigation technologies, science and impacts, and communication. She is currently managing the development of an EPA rule-making on the mandatory reporting of greenhouse gases, in response to the FY 2008 Consolidated Appropriations Amendment. She also manages preparation of the U.S. National Inventory of Greenhouse Gases and Sinks, which is submitted annually to the UN Framework Convention on Climate Change, and served as an elected member of the Intergovernmental Panel on Climate Change's Task Force Bureau on Greenhouse Gas Inventories from 1998–2008. Ms. Kruger directs a wide range of economic, technical and scientific analysis on a variety of climate policy issues.

Ms. Kruger joined EPA in 1989, and prior to that worked at ICF Consulting, the Investor Responsibility Research Center, and the Office of Technology Assessment. She holds a Bachelor of Arts degree from the University of Washington, and received a Master's degree from the Energy and Resources Group at the University of California, Berkeley.

Chair GORDON. Thank you, Ms. Kruger, and Dr. Gallagher.

STATEMENT OF DR. PATRICK D. GALLAGHER, DEPUTY DIRECTOR, NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY, U.S. DEPARTMENT OF COMMERCE

Dr. GALLAGHER. Good morning, Chairman Gordon and Members of the Committee. I want to thank you for the opportunity to appear before you today and discuss the National Institute of Standards and Technology's role and interactions with other federal agencies in measuring, monitoring, and verifying greenhouse gas emissions.

Today what I would like to do is highlight how NIST works with these other agencies to support climate monitoring programs and to measure and verify greenhouse gas emissions. 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 very long timescales. Rigorous traceability of measurements to the international system of units called the SI are essential for meeting these requirements and provide a firm scientific basis for policy decisions and to help ensure that our measurements are accepted internationally.

The NIST Laboratories support other federal agencies that have a primary mission for climate research and monitoring, many of them represented here today with me on the panel. The NIST Laboratories provide the measurement science, measurement traceability, the production and dissemination of fundamental data, standards development, and dissemination to support these agencies in their satellite air and surface space measurement programs.

By statute, NIST is the national measurement institute of the United States, and in this capacity is responsible for the national standards of measurement and for their compatibility within the SI framework with the standards of other nations. To achieve international compatibility of measurement, NIST works with its counterpart agencies in other countries, and NIST advancement, maintenance, and dissemination of base SI units underpins private sector investments and measurement technology and standards, and it provides the means for assessing the quality of measurements.

We also provide benchmark references for so-called second and third tier suppliers of measurement services, including private sector test and calibration laboratories, manufacturers of test equipment and control systems, and the businesses that rely on these services and tools.

Today I would like to illustrate how NIST carries out this role by using two examples. First, NIST has a major role in supporting satellite remote sensing programs by developing the appropriate standards, calibration, and characterization methods and by creating the tools to analyze measurement uncertainties. This is important not only to the government satellite programs but also to the commercial satellite industry and various other civilian and government programs.

The NIST Laboratories possess unique measurement science capabilities such as specialized laser facilities, radiometers, and optical radiation sources that are developed at NIST to tie the measurements performed by the satellites to fundamental standards traceable to the SI units. Current NIST research is lowering the uncertainties on fundamental standards to meet the increasingly stringent measurement requirements for climate research. The requirements for these measurements are directly defined through our collaborations with other agencies and their satellite programs.

A second major area of activity at NIST is in the accurate measurement of gas emissions, including greenhouse gases. For over 15 years NIST has worked closely with the EPA to provide the measurement technologies and measurement traceability to the SI for gas emissions controlled under the Clean Air Act. This includes the cap-and-trade program for industrial sulfur emissions. This program provides measurement traceability to the SI for cylinder gas standards used to calibrate emission stack monitors and works directly with specialty gas suppliers to provide calibrated gases through the NIST Traceable Reference Materials Program. This program has been credited with resulting in a 30 percent reduction in sulfur dioxide emissions relative to 1980 levels.

This experience serves as a useful model for developing greenhouse gas mitigation programs. The ability to accurately measure and verify greenhouse gas emissions is an important foundation for policy-makers and regulators charged with the development and implementation of policies. Understanding the measurement technologies required and how they are deployed into the market are key considerations in the establishment of realistic and effective limits.

In my written testimony I have included further details on current capability and on some of the emerging measurement challenges for greenhouse gases and verification programs. Accurate climate change measurements provide confidence in measured and predicted climate change trends and aid the development and assessment of mitigation strategies. The NIST Laboratory Program is committed to providing the measurement science, traceability data, and standards to support other federal agencies in their climate programs and to ensure that their measurements tie to international standards as needed. We also work with the private sector so that they can provide the needed accurate and traceable measurement services to support any mitigation program.

I want to thank you for inviting me to testify today, and I look forward to answering any questions you may have.

[The prepared statement of Dr. Gallagher follows:]

PREPARED STATEMENT OF PATRICK D. GALLAGHER

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 surface[1]-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, 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,

[1] Surface denotes both land and ocean.
[2] *http://www1.bipm.org/en/CGPM/db/23/11/*

- working arrangements between the International Committee for Weights and Measures (CIPM) and the United Nation's World Meterological Organization (WMO),
- the increasing importance of optical radiation measurements and physico-chemical measurements of air, ground-based as well as airborne, 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 surface[1]-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 Instrument Calibration for Climate Change (ASIC3),[3] 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 pre-launch 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 Principles[4] 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.

[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*

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 percent 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 SO_2 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., CO_2 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 CO_2, is emitted primarily from landfills, the transport and use of natural gas, livestock production, and coal mining.[8] 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 CO_2 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 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

[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*

[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*

[1] Surface denotes both land and ocean.

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 CO_2 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 CO_2 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 CO_2 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.

BIOGRAPHY FOR PATRICK D. GALLAGHER

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.

Chair GORDON. Thank you, Dr. Gallagher. Dr. Heber, when my family gets together on Sundays, oftentimes my daughter and her cousins have to sit at the children's table because it is not big enough for everybody else. We still love them, and we are glad you are here and sorry you had to be pushed off a little bit, but your testimony still is as important as everyone else's. So you are recognized for five minutes.

STATEMENT OF DR. ALBERT J. HEBER, PROFESSOR, AGRICULTURAL AND BIOLOGICAL ENGINEERING DEPARTMENT, PURDUE UNIVERSITY

Dr. HEBER. Chair Gordon, Ranking Member Hall, and other Members of this committee, thank you for the opportunity to speak to you about the measurement and mitigation of greenhouse gases from livestock operation.

All farms generate various air pollutants to some degree. The big question is how much, and that is not an easy question to answer because on-farm measurements are difficult and costly.

Methane comes from enteric fermentation and anaerobic decomposition of manure. Enteric fermentation is primarily derived from beef and dairy cattle in this country. Nitrous oxide is generated directly and indirectly from the nitrogen in livestock manure. Carbon dioxide is produced by anaerobic digestion of manure and animal respiration.

Animal agriculture emits only two and a half percent of the total of United States greenhouse gas emissions according to a recent EPA report. According to a recent article by Dr. Capper in the *Journal of Animal Science,* greenhouse gas reductions occur with increased production efficiency.

For example, the carbon footprint was reduced by one-third since 1944, as milk yield per cow quadrupled. Other reductions occur through methane utilization by anaerobic digesters, good compost management, applying manure to land agronomically, and diet modification.

We have much to learn about greenhouse gas emissions from livestock operations, and we do this through laboratory and field studies. The field studies can give us baseline source emission rates, and they allow us to test mitigation strategies. The use of scientific emission models to estimate emissions is the least expensive, but they need to be validated with the expensive field data. While regulatory models have inherent limitations, science—academic scientific studies have, can have a great influence on them.

The National Air Emission Monitoring Study was funded by the livestock commodity groups. The objectives are to quantify air emissions from livestock production, provide reliable data for developing and validating barn and lagoon emission models, and to promote a national consensus on methods of measuring, calculating, and reporting air emissions in general.

The approach of the NAEMS is to monitor 38 barns at 15 different sites, and they are monitoring the regulated pollutants and also at ten open sources. Overall 20 farms are involved in this study. Prior studies that we conducted at pork and egg layer facilities are very similar, but they are not as comprehensive as what we are doing in the NAEMS. Each barn site monitoring site uses state-of-the-art equipment and an instrumentation trailer at the farm.

The open source measurements utilize open path laser technology to measure ammonia and other gases. The open paths surround the source. The 20 farms in the National Air Emission Monitoring Study are located throughout the United States and were selected to be representative of other livestock species or representative of other farms in their respective livestock species.

A 2,000-page protocol document was written in 2006, and was approved by the EPA prior to setting up the project, and all sites were set up in 2007, and so the two-year monitoring effort will be completed by the end of this year.

The NAEMS infrastructure and the expertise developed by it are a tremendous resource for conducting a similar comprehensive study of emissions of greenhouse gases as recommended in a recent report by the General Accounting Office. Such a study as a follow on to the NAEMS should continue to: One, refine and improve measurement methods, two, provide data to develop and validate computer models, three, consider expanding measurements to other farm sources like the land application of manure, which wasn't addressed by the NAEMS, and four, to test mitigation strategies that can reduce greenhouse gas emissions.

Thank you.

[The prepared statement of Dr. Heber follows:]

PREPARED STATEMENT OF ALBERT J. HEBER

Introduction

Chairman Gordon, Ranking Member Hall, and other Members of the Committee, I am Dr. Albert Heber, Professor of Agricultural and Biological Engineering at Purdue University, and Director of the National Air Emissions Monitoring Study. Thank you for the invitation and opportunity to speak to you about measurements and mitigation of GHG on livestock operations.

My statement will cover the following topics:

1. Agricultural sources of greenhouse gases.
2. Description of National Air Emission Monitoring Study.
3. Estimated costs of on-farm GHG monitoring.
4. Potential for using NAEMS infrastructure for follow-on GHG studies.
5. Measuring GHG emissions.
6. Uncertainty of on-farm GHG monitoring.

Agricultural Sources of Greenhouse Gases

1. Methane (CH_4) from ruminant livestock (sheep and cattle) and from anaerobic digestion of organic wastes.
2. Carbon dioxide (CO_2) from anaerobic digestion of organic wastes and from animal exhalation.
3. Nitrous oxide (N_2O) from conversion of nitrogen compounds in nitrification (NH_4 to NO_3) and denitrification (NO_3 to N_2) processes (McGinn, 2006).
4. GHG emission from agricultural land.

Research on quantifying GHG from agricultural sources started in the 1970s (e.g., Bremner and Blackmer, 1978). The International Atomic Energy Agency published a manual on measurement of methane and nitrous oxide emissions from agriculture in 1992 (IAEA, 1992). The First International Greenhouse Gas Measurement Symposium was held in San Francisco, CA from March 23–25, 2009. Research on mitigation of agricultural GHG emissions from soil started in the 1990s (e.g., Mosier et al., 1996; Mosier et al., 1998). Recent investigations on GHG emission reductions were conducted in animal barns and manure treatment facilities (e.g., Tada et al., 2005; Weiske et al., 2006; VanderZaag et al., 2008; Cabaraux et al., 2009). The warming potential of greenhouse gases (N_2O + CH_4) were about 22g, 34g and 168g CO_2 equivalents per day and per pig on fully slatted floor, straw or sawdust deep litter respectively (Cabaraux et al., 2009).

The latest inventory of GHG emissions and sinks in U.S. was published by USEPA (2009).

National Air Emissions Monitoring Study

BACKGROUND

Animal feeding operations (AFOs) commonly emit certain amounts of particulate matter (PM), ammonia (NH_3), hydrogen sulfide (H_2S), volatile organic compounds (VOCs), greenhouse gases (GHG), and odorous compounds. Historically, concern about non-GHG pollutants arose first from potential worker and animal health issues, and with nuisance complaints. The U.S. Government assumed a greater role in regulating air emissions from agriculture during the last decade. The U.S. Environmental Protection Agency (EPA) began applying federal air quality regulations to AFOs around the year 2000 (Schutz, et al., 2005). Particulate matter and non-methane VOCs are criteria air pollutants under the U.S. *Clean Air Act* (CAA) of 1990 (U.S. EPA, 1990). The *Comprehensive Environmental Response, Compensation, and Liability Act* (CERCLA) and the *Emergency Planning and Community Right-to-Know Act* (EPCRA) required reporting of NH_3 and H_2S emissions exceeding 100 lb/day. However the U.S. EPA recognized a lack of reliable data for emissions of these pollutants from AFOs (Schutz et al., 2005).

As the EPA began enforcing air laws at AFOs, the agricultural community voiced their concern that the current air contaminant emission estimates for AFOs were either based on data from outdated studies or did not represent modern livestock farms (Schutz et al., 2005). The National Research Council (National Research Council, 2003) shared this concern, and recommended that EPA improve its methods of estimating AFO air emissions. In January, 2005, the Air Consent Agreement (ACA) was announced in the *Federal Register* (U.S. EPA, 2005). The ACA is an agreement between livestock (dairy, pork, egg, and broiler chicken) commodity groups and U.S. EPA. The ACA required an industry-funded nationwide AFO emission study that would provide a scientific basis for the determination of compliance with the air laws. Industry participation in the ACA included 2,568 livestock production operations representing a total of 6,267 farms.

The objectives of the NAEMS were to: 1) quantify rates of air emission from pork, dairy, egg, and broiler production facilities, 2) provide reliable data for developing and validating models for estimating emissions from livestock operations, and 3) promote standardized methodology for measuring livestock and poultry farm emissions.

Unique Characteristics of the NAEMS

The barn portion of the NAEMS has several unique characteristics compared to previous baseline studies.

1. It is measuring a comprehensive set of pollutants ($PM_{2.5}$, PM_{10}, TSP, NH_3, H_2S, and CO_2 at all 15 barn sites, CH_4 at five sites, and non-methane VOC at two sites).
2. The monitoring period is 24 months. The longest previous baseline study was 15 months long (Jacobson et al., 2004).
3. Largest number of farm buildings (38) measured among four livestock species using the same protocols. Jacobson et al. (2004) monitored 12 buildings among three livestock species in their study of PM_{10}, TSP, NH_3, H_2S, and odor.
4. Sites were selected to maximize representativeness under the constraints of the other site selection criteria.
5. Quality assurance and quality control was improved with a Category 1 Quality Assurance Project Plan (QAPP).
6. The EPA-approved QAPP (barn portion) included 57 standard operating procedures (SOPs) and 14 site monitoring plans (SMPs).
7. Novel methods include the use of ultrasonic technology to measure the ventilation airflow of naturally ventilated barns (Ndegwa et al., 2008).
8. The NAEMS is measuring gas and PM emissions from barns (Heber et al., 2008) and gas emissions from lagoons, basins and dairy corrals (Grant et al., 2008) and both measurements are being conducted at four of the twenty farms.

BARN MONITORING SITES (taken from Heber et al., 2008)

The barn monitoring sites (Table 1) were selected based on the following criteria:

1. Producer participation in the ACA.
2. Representativeness of the farm for its livestock type.
3. Proximity to academic expertise in air quality research.
4. Conduciveness and suitability of the site for collecting reliable data.
5. Producer collaboration (very important to successful long-term, on-farm studies).
6. Potential for measurement of outdoor manure storage systems at the same site.

The sow farms in North Carolina (NC4) and Oklahoma (OK4) have pull-plug pits with outdoor (lagoon) manure storages (Table 1). The Iowa sow farm (IA4) uses deep pits in the barns to store manure. The North Carolina and Indiana finisher operations are flush and deep pit barns, respectively. Emissions at sow farms are measured at two gestation barns and one farrowing room. Three separate barns (NC) or four rooms of a "quad" barn (IN) are being monitored at swine finishing sites.

Egg laying buildings are either high-rise houses, in which manure accumulates in the lower level, or manure belt houses with belts under the cages that transfer manure to an external storage. Two high-rise houses and two manure belt houses with the associated manure shed are being monitored in Indiana (IN2). The layer sites in California (CA2) and North Carolina (NC2) are each monitoring two high-rise houses. Two barns monitored at a broiler ranch in California (CA1) consist of broiler chickens raised on a concrete floor covered with litter.

Table 1. NAEMS barn sites. All barns mechanically-ventilated unless indicated NV.
Source: Heber et al. (2008).

Site	Barn type (date)	# of barns	# hd/barn	GSL	Fans
Broilers					
CA1	TV litter on floor ('02)	2	21,000	7	24
Layers					
CA2	High-rise, DB ('03)	2	38,000	7	24
IN2	High rise, CBC ('97)	2	250,000	15	220
	Manure belt ('04)	2	280,000	18	192
	Manure shed ('04)	1	-	1	0
NC2	High rise, CBC ('03)	2	103,000	7	68
Swine					
IN3	TV finishing, deep pit ('03)	4	1000	17	32
NC3	TV finishing, PPR ('95)	3	800	4	15
IA4	TV gestation, deep pit ('98)	2	1100	18	42
	Farrowing room, PPR ('98)	1	24		3
NC4	TV gestation, PPR ('94)		850	6	20
	Farrowing room, PPR ('95)	1	24		3
OK4	TV gestation, PPR ('94)	2	1200	12	26
	Farrowing room, PPR ('94)	1	24		2
Dairy					
CA5	NV freestall, flushing ('01)	2	600	45	0
IN5	TV freestall, scrape ('04)	2	1600	23	152
	Milking center, flushing ('04)	1	562		26
NY5	TV freestall, scrape ('98)	1	470	7	30
	Milking center, deep pit ('90)	1	187		8
WA5	NV freestall, flush ('02)	2	650	33	0
WI5	Freestall, scrape ('07)	2	325	11	125
	Milking center ('90)	1	80		0

PPR: pull-plug with recharge, DB: dropping board, CBC: curtain-backed cages. GSL: gas sampling locations, TV: tunnel-ventilated, NV: naturally-ventilated. All barns mechanically-ventilated with sidewall fans unless indicated NV.

Two western dairy sites have naturally-ventilated free-stall dairy barns with outdoor exercise lots. The free-stall barns in California (CA5) have open walls. The free-stall barns in Washington (WA5) have open end walls and adjustable curtains on most of the sidewalls (Heber et al., 2008). Two MV free-stall barns per site are being monitored in Wisconsin (WI5) and Indiana (IN5). The New York (NY5) site is monitoring one MV free-stall barn. MV milking centers are also monitored at IN5 and NY5. Sites NY5 and IN5 have tunnel-ventilated barns and Site WI5 uses cross-flow ventilation (Heber et al., 2008).

Methodology and Instrumentation

An on-farm instrument shelter (OFIS) houses instruments and equipment for measuring pollutant concentrations at representative air inlets and outlets, barn airflows, operational processes, and environmental variables.

A multi-point gas-sampling system (GSS) inside the OFIS draws air sequentially from various barn locations and ambient air, and sequentially delivers selected streams to a manifold from which gas monitors draw continuous sub-samples. The number of sampling points per site ranges from four to forty-five. The average sampling tube length is 77m. The sampling periods for exhaust air are typically 10 minutes long.

Gas sensors include a photo-acoustic multi-gas analyzer (Innova Model 1412, California Analytical Instruments, Orange, CA) for NH_3 and CO_2, a pulsed-fluorescence analyzer (Model 450I, Thermo Environmental Instruments, Franklin, MA) for H_2S, and a gas chromatograph—flame ionization detector (Model 55C, Thermo Environmental Instruments, Franklin, MA) for CH_4 and non-CH_4 hydrocarbons. The Model 55C is used only at sites IN3 and CA5.

The ambient PM concentrations are measured with a beta attenuation PM monitor (Model FH62 C–14, Thermo Scientific, Waltham, NY). Exhaust PM concentrations are measured continuously with a tapered element oscillating micro-balance (Model 1400a, Thermo Scientific, Waltham, NY) at a minimum winter ventilation fan in each MV barn and in the ridge exhaust of each NV barn. The sampling location inside MV barns is near the fan inlet. PM_{10} is measured seven of eight weeks and TSP is measured every 8th week. $PM_{2.5}$ is monitored during two-week periods during winter and summer.

Fan airflow rates are spot checked using the portable fan tester (Gates et al., 2004), or a traverse method using a portable anemometer. Airflow data from spot checks are correlated with continuous data from rpm sensors and/or impeller anemometers. At least one fan per fan model is continuously monitored using a bidirectional impeller anemometer. The impeller anemometer accounts for the significant effects of wind and building static pressure. Individual fans are monitored using rpm sensors, current switches, or vibration sensors. At most sites, the operation of fan stages is monitored via fan motor control relays. Airflow through NV barns is measured using three-dimensional sonic anemometers.

All measured variables are listed in Table 2. Meteorological measurements (solar radiation, wind direction and velocity, temperature, humidity) are needed to study the influence of weather on emissions. Measurements such as feed composition, manure characteristics, pit flushing, and animal activity help to determine methods of abating emissions. The effect of weather on air emissions is coupled with the effect of manure accumulation, animal age and growth cycles, moisture content in manure storages, and animal live weight and feed consumption.

Standard operating procedures were written for all measurements and instrumentation to assure that the same methods would be used at all sites, and to maximize data comparability. The total number of monitored variables varies from 85 at sow site NC4 to 466 at layer site IN2. The data acquisition system reads data at 1.0 Hz, and records 15-s and 60-s data averages.

Milk, feed, bedding, manure, water and VOC are collected for *ex-situ* analysis. VOC samples are also collected in passivated canisters and multi-sorbent tubes, and analyzed by gas chromatography and mass spectrometry. Manure is analyzed for pH, total solids and ash content, and concentrations of total nitrogen (N) and ammoniacal N. Total manure N will be used in conjunction with total feed, bedding, milk, eggs, and/or meat nitrogen contents to generate a nitrogen mass-balance for each barn as a whole. Ash contents will be used at some sites to estimate manure volume (Keener and Zhao, 2008) which cannot be measured directly at some sites. The validity of the ash-balance method will be validated at sites where manure volume can be measured.

Table 2. Measured variables (Heber et al., 2008).

Variable	Measurement Method/Instrument(s)	Units
NH_3*, CO_2*	Infrared photo-acoustic	ppm
H_2S*	Pulsed fluorescence	ppb
NMHC*, CH_4*	GC-FID	ppb
EtOH*, MeOH*, CH_4*	Infrared photo-acoustic	ppb
VOCs*	GC/MS (mass spectrometer)	ppb
VOCs (amines)*	Ion chromatography	ppb
$PM_{2.5}$*, PM_{10}*, TSP*	TEOM, C-14 Beta attenuation	$\mu g/m^3$
Fan air speed	Anemometer	m/s
Fan run time	Vibration or rpm sensor, stage relays	% time
Vent air velocity	Ultrasonic anemometer	m/s
Barn static pressure	Capacitive/diaphragm sensor	Pa
Exhaust temperature	Thermistor or RTD	°C
Temperature*	Thermocouple type T	°C
Exhaust RH	Thin-film capacitor (TFC)	%RH
Ambient temperature	Thermistor/RTD, Passive shielded	°C
Outdoor humidity	TFC, Passive shielded	%RH
Atmospheric pressure	Electronic barometer	atm
Solar radiation	Pyranometer	W/m^2
Wind speed	Cup anemometer	m/s
Wind direction	Vane	degrees
Barn inventory, animal mortality	Farm records	head
Animal weight	Truck balance	kg
Manure volume	Farm records	gal
Manure pH	Electrochemical pH meter	pH units
Manure solids	Gravimetric	wt%
Manure NH_3 & N	Kjeldahl/titrimetric	wt%
Feed, bedding, milk, egg N	Kjeldahl/titrimetric	wt%
Feed input to barn	Farm records	kg
Animal activity in barn	Passive infrared detector	VDC
GSS sample and lab pressures	Capacitive/diaphragm sensor	Pa
GSS sample flow rate	Mass flow meter	L/min
Lab and raceway temperatures	Thermocouple	°C
Instrument filter pressure	Capacitive/diaphragm sensor	%

*Barn inlet and exhaust

The final processing of NAEMS data is facilitated with CAPECAB, a custom-written data analysis program. Data is invalidated for various reasons including: calibration of a sensor or analyzer, low flow through the GSS, sensor malfunction, electronic noise, DAC hardware or software problem, condensation in sampling lines, or gas analyzer equilibration. CAPECAB allows users to adjust gas concentration data based on calibration, extract equilibrium data, calculate ventilation rates, and calculate emission rates. Hourly and daily averages of emission rates and other parameters will be provided to the EPA.

OPEN SOURCE MONITORING SITES (taken from Grant et al., 2008)

Emissions of NH_3, H_2S, and CH_4 are being measured throughout the year at dairy and swine farms, along with other parameters that affect emissions such as time of year, atmosphere stability, and farm operation (Grant et al., 2008).

Experimental Methods

Instruments used with open sources include ultrasonic (sonic) anemometers to characterize the wind, sensors to measure the atmosphere (temperature, relative humidity, solar radiation, barometric pressure, wetness), sensors to characterize the source (temperature, pH, and oxidation-reduction potential for lagoons), and state-of-the-art instruments for measuring concentrations of target gases along open paths near the source. Manure samples from corrals and basins are analyzed for pH, and concentrations of solids, and $NH_2 \pm N$.

Measurements at ten sites in seven states began in the summer of 2007, and will continue through the summer 2009. Two sites are each measured continuously for one year. Eight sites are sequentially measured for 10 to 20 days during each season for two years.

Scanning NH_3 TDLAS

At a typical open source, TDLAS units are set up at opposite corners and 16m towers at the other two corners. Six retro-reflectors are mounted on each tower, with three facing each TDLAS system at heights of about 1m, 7m, and 15m. Two additional retro-reflectors are placed at 1m heights on tripods at one-third and two-thirds of the distance down each side of the source. Thus, each side of the source has three near-surface paths and two elevated paths. A computer-controlled scanner sequentially aims a TDLAS at each retro-reflector among two adjacent sides of the source. The advantage of scanning open-path TDLAS for continuous long-term measurements of NH_3 is that wind direction becomes a minor factor in determining the emitted gases because the plume location is not needed to properly measure it (Grant et al., 2008). Quality control (QC) procedures of the TDLAS measurements include checks for path obstruction, internal calibration checks, spectral feature checks and single-point calibration verifications, and multi-point calibrations. The minimum detection limits of the TDLAS units are about 2ppm-m or less.

S–OPS/GSS

The synthetic open-path system (S–OPS) consists of a 50m section of Teflon tubing, outfitted with 10 equally-spaced, flow-balanced inlets, through which a blended air sample of a plume is drawn and sampled by gas analyzers in the trailer. Two S–OPS are placed on opposite sides of the source. Proper sample flow is verified by continuously monitoring sample pressure, flow rate and direction. Extensive QC checks are conducted to maintain system integrity.

A multi-gas analyzer using the photo-acoustic spectroscopy is used to measure NH_3 and CH_4 for which the stated detection limits for CH_4 and NH_3 are 100ppb and 200ppb, respectively. A pulsed fluorescence SO_2/H_2S analyzer is used to measure H_2S. The manufacturer stated MDL is 1ppb. Interferents include methyl mercaptan and water vapor. The difference between the upwind and downwind gas concentration in the S–OPS air samples is used to determine gas flux from the area source.

Weather Measurements

In a typical setup, three-dimensional sonic anemometers are mounted at heights of 2m, 4m, and 16m and measurements in the three orthogonal directions are made at 16 Hz. Field inter-comparisons are made at least every 21 days by mounting the three anemometers next to each other and measuring wind for one hour. Typically, differences between sensors are less than 0.1m/s.

Emissions of NH_3

Emissions of NH_3 are determined at one-half hour intervals from wind profiles based on the three anemometers, and concentration profiles obtained by multiple TDLAS-measured path-integrated concentrations (PIC) using the vertical radial plume mapping (RPM) method. This method is limited by the need to have valid data for all five PIC and all three wind sensors. Weather conditions such as fog, heavy rain, high winds, and low winds (<0.2m/s) limit the availability of both PIC and wind data, thus limiting the periods during which emissions can be calculated.

Emissions of H_2S and CH_4

The gaseous emissions of H_2S and CH_4 are determined from one-half hour averages of concentration measurements of the air sequentially sampled from upwind and downwind S–OPS systems and either: 1) the bLS emission model using wind turbulence measurements of the 2m sonic anemometer, or 2) the ratio of the S–OPS measurement of H_2S and CH_4 concentrations to TDLAS PIC measurement of NH_3 of the nearest path to the S–OPS inlets multiplied by the RPM-measured NH_3 emission. Fog, heavy rain, high winds, and low winds limit the availability of both PIC and wind measurements, thus limiting the periods during which emissions based on the RPM emissions can be calculated. Emissions based on the bLS model are limited by low winds, very unstable or stable conditions, and upwind fetch.

COSTS OF ON–FARM GHG MEASUREMENTS

Costs for on-farm measurements of GHGs vary with the complexity of the farm. Factors include the number, size and ventilation type of the barns, and the presence, number, and type of other external or outside sources.

The following conservative cost estimates for monitoring enclosed building sources assume a focus on GHG emissions only, and are based on the costs to conduct the NAEMS at various types of barn sites (two to four buildings per site), including a "simple" barn site (e.g., a small broiler operation) and a "complex" one (a large dairy or egg-layer facility). Naturally-ventilated facilities (most frequently dairies) present special challenges and additional costs, mostly due to the need to measure barn airflow with a large array of ultrasonic anemometers.

Barn site type	Equipment cost	Maintenance/mon
Simple	$150K	$14K
Complex	$200K	$18K
Naturally-ventilated	$250K	$18K

These estimates include a climate-controlled mobile laboratory, gas analyzer(s) for CO_2, CH_4 and N_2O, calibration equipment and supplies, site-customized systems for gas sampling and data acquisition, and sensors and equipment for monitoring building airflow. Setup time estimates above include both the time to design and customize these systems, and to deploy them in the field. Maintenance time estimates include equipment maintenance and calibration, and processing and interpretation of the data.

Monitoring of outside sources can be conducted in different ways. If CH_4 is the only gas of interest, the initial cost of open-path spectroscopy with methane-specific lasers is approximately $60,000 and monthly cost is approximately $14,000. This approach might be sufficient for sources such as anaerobic manure lagoons, which may (Monteny et al., 2001) or may not (Jones et al., 2000; Berg et al., 2006) have minimal emissions of N_2O. Expanding monitoring to CO_2 and N_2O in addition to CH_4 would most likely be done by open-path Fourier Transform Infrared (FTIR) spectroscopy, or by deploying synthetic open-path systems (Grant et al., 2008). The approximate cost of a fully-automated FTIR system to measure gas concentrations on all sides of a source such as a lagoon, feed storage pile, etc., could be as high as $300,000. A synthetic open-path system, with its associated gas analyzer(s), can be set up for approximately $75,000.

UTILIZING NAEMS INFRASTRUCTURE FOR GHG STUDIES

It required about one year (2006) to develop the 2000-page NAEMS Quality Assurance Project Plan and gain EPA's approval, and another year (2007) to set up the monitoring equipment at 20 farms across the U.S. The two years of monitoring (2008–09) will be completed in about eight months, at which time the monitoring sites will dismantled or used in follow-on studies.

The NAEMS was not designed to measure baseline greenhouse gas emissions. In the process of determining non-methane hydrocarbons, methane was measured at five of fifteen barn sites and in less than one-third of the open source measurements. Carbon dioxide was measured at the barn sites but not at the open source sites. Nitrous oxide was measured at only a sow operation and at a dairy site with local add-on studies.

To take advantage of the existing NAEMS infrastructure and expertise, the dairy industry funded a project to add all three major GHG to all the dairy sites for the last few months of the NAEMS and to extend three of the barn sites until January 31, 2010 to obtain some baseline GHG emissions data over a limited period of time.

Federal support of follow-on GHG studies using the NAEMS infrastructure and expertise could provide:

1. Long-term monitoring of baseline GHG emissions at existing or other sites.
2. Tests of GHG mitigation strategies at existing or other sites.
3. Expansion of monitoring to all sources at the farms, e.g., land application, feed storage, feedlots, lagoons, etc.
4. Refinement of on-farm GHG measurements.

The GAO (2008) recommended that, at a minimum, a comprehensive study of greenhouse gas emissions from AFOs would require a study, or combination of studies, of similar scope and size to the NAEMS.

MEASURING GHG EMISSIONS

Emissions cannot be directly measured. Emissions can only be estimated/calculated based on concentration measurements and airflow measurements. Accurate concentration and airflow measurements in barns are challenging in barns because of the number of emitting locations (i.e., fans) and/or the lack of well-defined emitting locations (i.e., a naturally-ventilated barn).

The comprehensive emission measurements for the NAEMS sites require between 80 to 300 measured variables at each site (includes concentration, temperature, weather information, fan operation, and site operation variables), with each variable monitored on a one-minute basis. The number of data points in the NAEMS is expected to exceed 2.4 billion (Ni et al., 2008). All data collected requires evaluation and further processing by trained individuals to generate the required emission data.

UNCERTAINTY OF ON–FARM GHG MONITORING

Multi-gas analyzers based on photo-acoustic infrared (PIR) detection are commercially available, and are designed for simultaneous detection/measurement of all the greenhouse gases relevant to agriculture (CO_2, CH_4, N_2O). Preliminary CO_2 concentration control chart data from three out of fourteen sites of the NAEMS indicate that the total relative uncertainties for the CO_2 concentration were between four and nine percent. The order of magnitude of these values are representative of the expected uncertainty in the concentration of the other GHG being monitored (CH_4, N_2O). This determination is based on calibration with a single gas standard in dry air.

However, besides the typical uncertainty of measurements of single gases, there is the added uncertainty caused by interferences of other gases including water vapor. The analyzer manufacturer has corrections in place for those interferences but improvements are needed in the compensations to reduce the uncertainty incurred when measuring at livestock facilities as compared with other applications of the multi-gas analyzer. For example, cross-compensation calibrations are generally performed with single concentrations of gases (or a single humidity level), but if the relationship between the interfering gas concentration and light absorbence is not linear over the relevant concentration/humidity range, errors will be introduced. As compared with other applications for the multi-gas analyzer, carbon dioxide and water vapor (major interferents) concentrations are high. The effects of these interfering gases need to be carefully accounted for in GHG measurements.

SUMMARY

The NAEMS consists of two components: measurement of gas and particulate emission from barns (Heber et al., 2008) and the measurement of gas emissions from open-air sources (Grant et al., 2008) including dairy corrals and manure storage lagoons and basins. In the open-source component, gaseous emissions of NH_3, H_2S, and CH_4 are being measured throughout the year at four dairy and six swine operations, along with a range of other parameters that affect emissions such as time of year, stability of the atmosphere, and facility operation.

In the barn component, the NAEMS is collecting continuous air emission data from 38 barns at five dairies, five pork production sites, three egg layer operations, one layer manure shed, and one broiler facility for a period of two years. Concentrations of NH_3, H_2S, VOC, and PM (PM_{10}, $PM_{2.5}$, and TSP), building ventilation rate, and supporting parameters are monitored. Motion sensors monitor animal, worker and vehicle activity. Barn ventilation rate is assessed by monitoring fans and barn static pressure in MV barns, and air velocities through ventilation openings in naturally-ventilated buildings. Custom software (CAPECAB) efficiently handles large amounts of data being generated by NAEMS, and is used to validate, and process the data.

The costs of conducting long-term continuous emission monitoring studies at commercial farms are significant. There is a significant cost savings if the existing setups at farms are used to conduct needed additional studies. While a limited number of GHG measurements were obtained at some of the farms, a comprehensive GHG study conducted at existing NAEMS sites or with the NAEMS equipment and expertise could potentially answer a lot of important questions in a timely manner.

REFERENCES

Berg, W.R., R. Brunsch, and I. Pazsiczki. 2006. Greenhouse gas emissions from covered slurry compared with uncovered during storage. *Agriculture, Ecosystems and Environment* 112:129–134.

Bremner, J.M. and A.M. Blackmer. 1978. Nitrous-Oxide—Emission from Soils During Nitrification of Fertilizer Nitrogen. *Science* 199(4326):295–296.

Cabaraux, J.F., F.X. Philippe, M. Laitat, B. Canart, M. Vandenheede, and B. Nicks. 2009. Gaseous emissions from weaned pigs raised on different floor systems. *Agriculture Ecosystems and Environment* 130(3-4):86–92.

Gates, R.S., K.D. Casey, H. Xin, E.F. Wheeler, J.D. Simmons. 2004. Fan Assessment Numeration System (FANS) design and calibration specifications. *Transaction of the ASAE* 47(5): 1709–1715.

GAO. 2008. *Concentrated animal feeding operations: EPA needs more information and a clearly defined strategy to protect air and water quality from pollutants of concern.* Report GAO–08–944. Report to Congressional Requesters, United States Government Accountability Office.

Grant, R.H.; M.T. Boehm; A.J. Lawrence; A.J. Heber; J.M. Wolf; S.D. Cortus; B.W. Bogan; J.C. Ramirez-Dorronsoro and C.A. Diehl. 2008. *Methodologies of the National Air Emissions Measurement Study Open Source Component. Proceedings, Symposium on Air Quality Measurement Methods and Technology,* Air Waste Management Assn., Durham, NC (CD).

Heber, A.J., J.-Q. Ni, T.-T. Lim, A.M. Schmidt, J.A. Koziel, P.C. Tao, D.B. Beasley, S.J. Hoff, R.E. Nicolai, L.D. Jacobson, and Y. Zhang. 2006. Quality assured measurements of animal building emissions: Gas concentrations. *AWMA Journal* 56:1472–1483.

IAEA. 1992. *Manual on Measurement of Methane and Nitrous Oxide Emissions from Agriculture.* IAEA, Vienna, Austria. IAEA–TECDOC–674. November. 91 p.

Jacobson, L.D., B.P. Hetchler, K.A., Janni, J. Linn, A.J. Heber, and E.L. Cortus. 2008. Animal and environmental performance of a mechanical cross ventilation system retrofitted to a naturally ventilated free-stall dairy barn in the Midwestern U.S. Paper presented at the Eighth International Livestock Environment Symposium, Iguassu Falls, Brazil, Sept. 1–5.

Jacobson, L.D., B.P. Hetchler, V.J. Johnson, R.E. Nicolai, D.R. Schmidt, P.R. Goodrich, A.J. Heber, J.-Q. Ni, T.-T. Lim, P.-C. Tao, S.J. Hoff, D.S. Bundy, M.A. Huebner, B.C. Zelle, Y. Zhang, J. McClure, M. Roberts, J.A. Koziel, B.H. Baek, A. Balota, J.P. Spinhirne, J.M. Sweeten, D.B. Beasley, G.R. Baughman, and R. Munilla. 2004. Preliminary NH_3, H_2S, and PM_{10} data from pig and poultry buildings from six-state project. ASAE Paper #044156. American Society of Agricultural and Biological Engineers, St. Joseph, MI.

Jones, M.L., S.K. Liehr, J.J. Classen, and W. Robarge. 2000. Mechanisms of dinitrogen gas formation in anaerobic lagoons. *Advances in Environmental Research* 4:133–139.

Keener, H.M. and L. Zhao. 2008. A modified mass balance method for predicting NH3 emissions from manure N for livestock and storage facilities. *Biosystems Engineering* 99:81–87.

McGinn, S.M. 2006. Measuring greenhouse gas emissions from point sources in agriculture. *Canadian Journal of Soil Science* 86(3):355–371.

Monteny, G.J., C.M. Groenestein, and M.A. Hilhorst. 2001. Interactions and coupling between emissions of methane and nitrous oxide from animal husbandry. *Nutrient Cycling in Agroecosystems* 60:123–132.

Mosier, A.R., J.M. Duxbury, J.R. Freney, O. Heinemeyer, and K. Minami. 1996. Nitrous oxide emissions from agricultural fields: Assessment, measurement and mitigation. *Plant and Soil* 181(1):95–108.

Mosier, A.R., J.M. Duxbury, J.R. Freney, O. Heinemeyer, K. Minami, and D.E. Johnson. 1998. Mitigating agricultural emissions of methane. *Climatic Change* 40(1):39–80.

National Research Council. 2003. *Air Emissions from Animal Feeding Operations: Current Knowledge, Future Needs.* National Academies Press, Washington, DC.

Ndegwa, P.M. Ndegwa, P.M., H.S. Joo, A.J. Heber, J.C. Ramirez-Dorronsoro, E.L. Cortus, J.-Q. Ni, W.W. Bogan. 2008. A method for determination of pollutant emissions from naturally ventilated free-stall dairy barns. Paper presented at the Eighth International Livestock Environment Symposium, Iguassu Falls, Brazil, Sept. 1–4.

Ni, J.Q., A.J. Heber, M.J. Darr, T.T. Lim, C.A. Diehl and W.W. Bogan. 2008. Air quality monitoring and data acquisition for livestock and poultry environment studies. Paper presented at the Eighth International Livestock Environment Symposium, Iguassu Falls, Brazil, Sept. 1–5.

Schutz, M.M., T.J. Applegate, B.T. Richert, A.L. Sutton, D.D. Jones. 2005. *Air Emissions Consent Agreement and National Air Emissions Monitoring Study—How Do They Affect Me?* ID–325W, Purdue University, West Lafayette, IN.

Tada, C., Y. Yang, T. Hanaoka, A. Sonoda, K. Ooi, and S. Sawayama. 2005. Effect of natural zeolite on methane production for anaerobic digestion of ammonium rich organic sludge. *Bioresource Technology* 96(4):459–464.

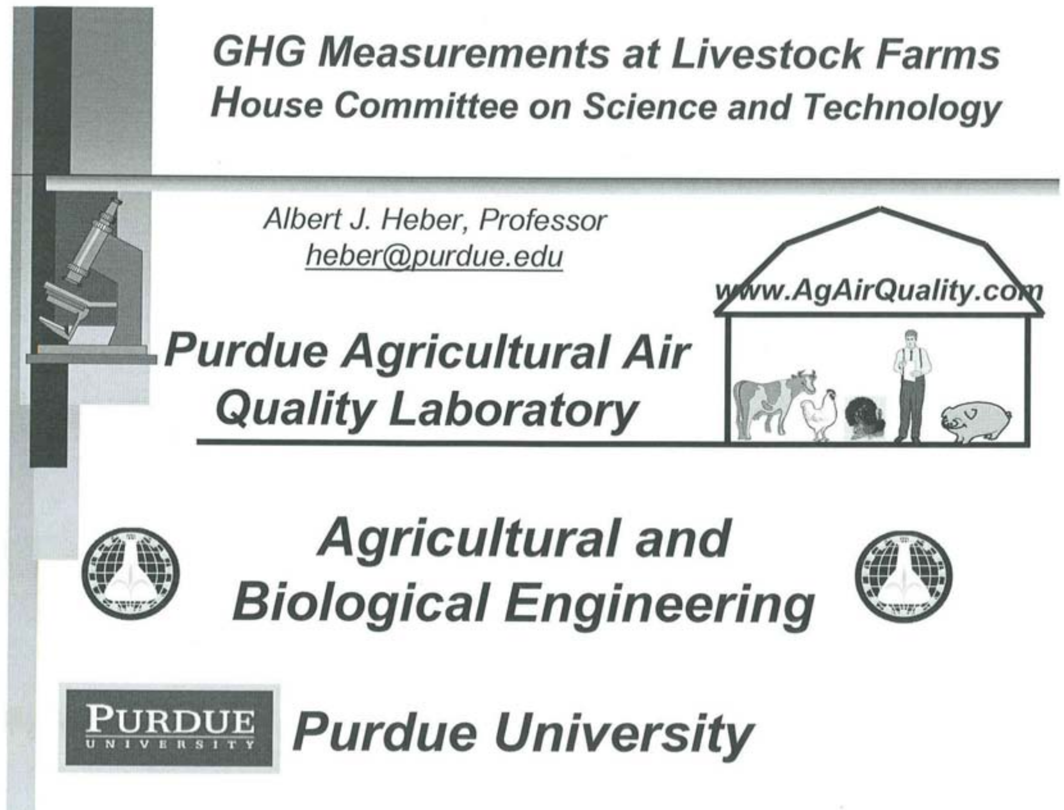
USEPA. 2009. *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2007*. U.S. Environmental Protection Agency, Washington, DC. EPA 430–R–09–004. April 15. 441 p.

U.S. EPA. 1990. *Clean Air Act.* U.S. Code Title 42, Chapter 85. [*www.epa.gov/air/caa/*].

U.S. EPA. 2005. Air Consent Agreement. *www.epa.gov/compliance/resources/agreements/caa/cafo-agr-050121.pdf*, January 31.

VanderZaag, A.C., R.J. Gordon, V.M. Glass, and R.C. Jamieson. 2008. Floating covers to reduce gas emissions from liquid manure storages: A review. *Applied Engineering in Agriculture* 24(5):657–671.

Weiske, A., A. Vabitsch, J.E. Olesen, K. Schelde, J. Michel, R. Friedrich, and M. Kaltschmitt. 2006. Mitigation of greenhouse gas emissions in European conventional and organic dairy farming. *Agriculture Ecosystems & Environment* 112(2–3):221–232.


GHG Measurements at Livestock Farms
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Air Emissions from Livestock

- ***Odor***
- ***Ammonia***
- ***Hydrogen sulfide***
- ***Particulate matter (TSP, PM_{10}, $PM_{2.5}$)***
- ***Greenhouse gases (CO_2, CH_4, N_2O)***
- ***Volatile organic compounds (VOC)***

GHG Emissions from Animal Agriculture

- U.S. agriculture emits 6.4% of total US GHG emissions (FAO, 2006)
- Animal agriculture emits 2.5% of total US GHG emissions (EPA, 2008)

EPA Report 430-R-09-004

GHG Sources from Animal Ag

- Methane
  - Enteric fermentation (beef 72% dairy 23% swine 2%)
  - Anaerobic decomposition of manure.
- Nitrous oxide
  - Direct:
    - Nitrification/denitrification of organic N in manure
  - Indirect:
    - Ammonia and NOx volatilization and
    - Runoff and leaching of nitrogen during treatment, storage and transportation.
- Carbon dioxide
  - Anaerobic digestion of manure
  - Animal respiration

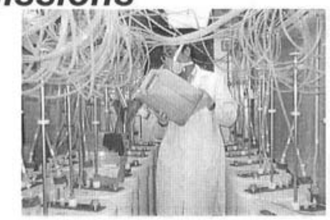
EPA Report 430-R-09-004

Potential GHG Mitigation by Animal Agriculture

- Improve production efficiency. For example, the average milk yield per cow increased from 2,074 kg/year in 1944 to 9,193 kg/yr in 2007 resulting in 1/3 lower carbon footprint
- Methane utilization
- Compost management
- Apply manure to land agronomically
- Diet modification

Capper et al., 2009, J. Animal Science.

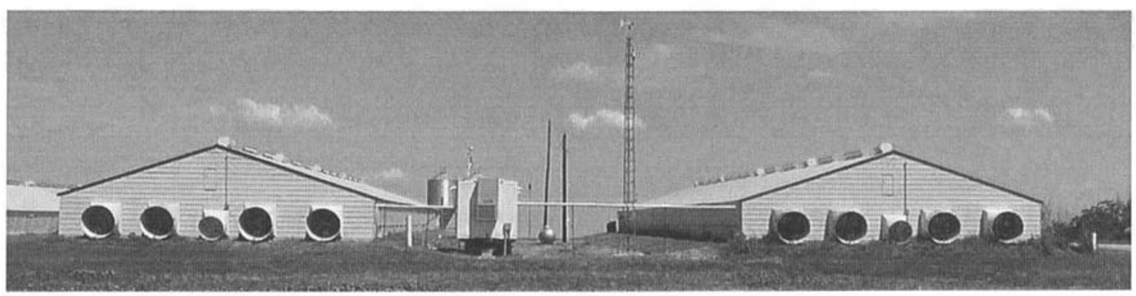
Increasing Knowledge about Emissions



- ***Laboratory studies***
  - *Kinetics and process dynamics*
  - *Controlled tests of abatement ideas*
- ***Field studies***
  - *Baseline source emission rates*
  - *Emission characteristics*
  - *Demonstrations of abatement methods*
  - *Ambient downwind concentrations*
- ***Scientific emission models***
  - *Process-based*
  - *Component emissions, e.g. barns, manure storage, etc.*
  - *System models (show tradeoffs and consequences)*
- ***Regulatory models***
  - *Often shaped by untimely political and societal pressures*
  - *Marked by simplicity, unfairness, arbitrariness, and inaccuracy!*
  - *Can be influenced by scientific knowledge in a positive way.*
- ***Multi-state and interdisciplinary research and education***

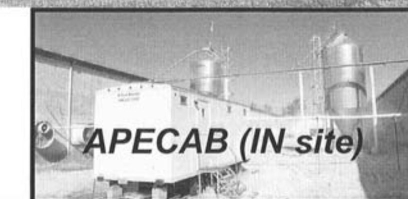
National Air Emission Monitoring Study

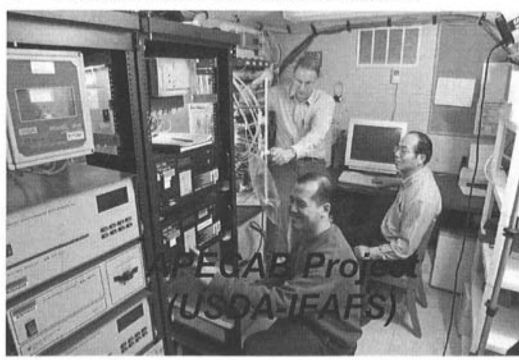
- Objectives
  - Quantify air emissions from livestock production.
  - Provide reliable data for developing and validating barn and lagoon emission models.
  - Promote national consensus on methods of measuring, calculating, & reporting emissions.



Barn emission projects '01-'04

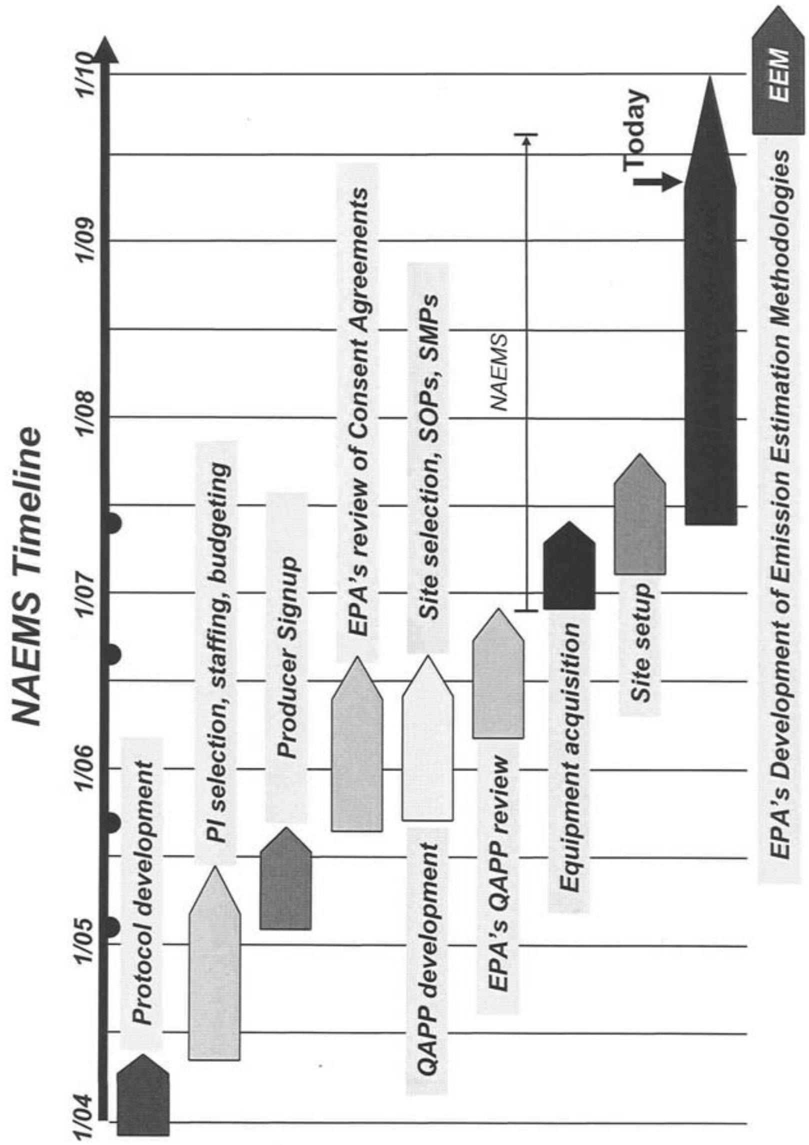
- ***Mechanically ventilated livestock buildings***
- ***Continuous emission monitoring (source)***
  - ***Multiple gas sampling points***
  - ***Gases (NMHC, CH_4, NH_3, H_2S, traces)***
  - ***PM_{10}, TSP, $PM_{2.5}$***
- ***Grab samples (bags, traps, filters)***
- ***Reliable emission measurements***

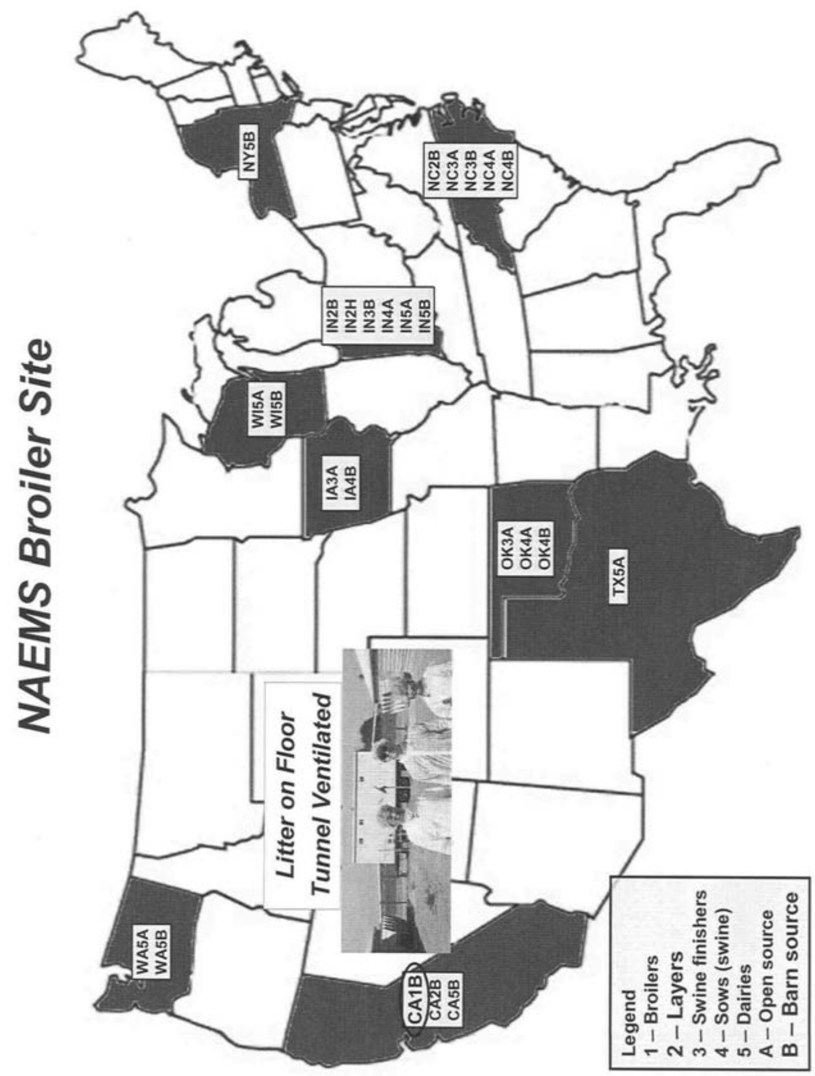


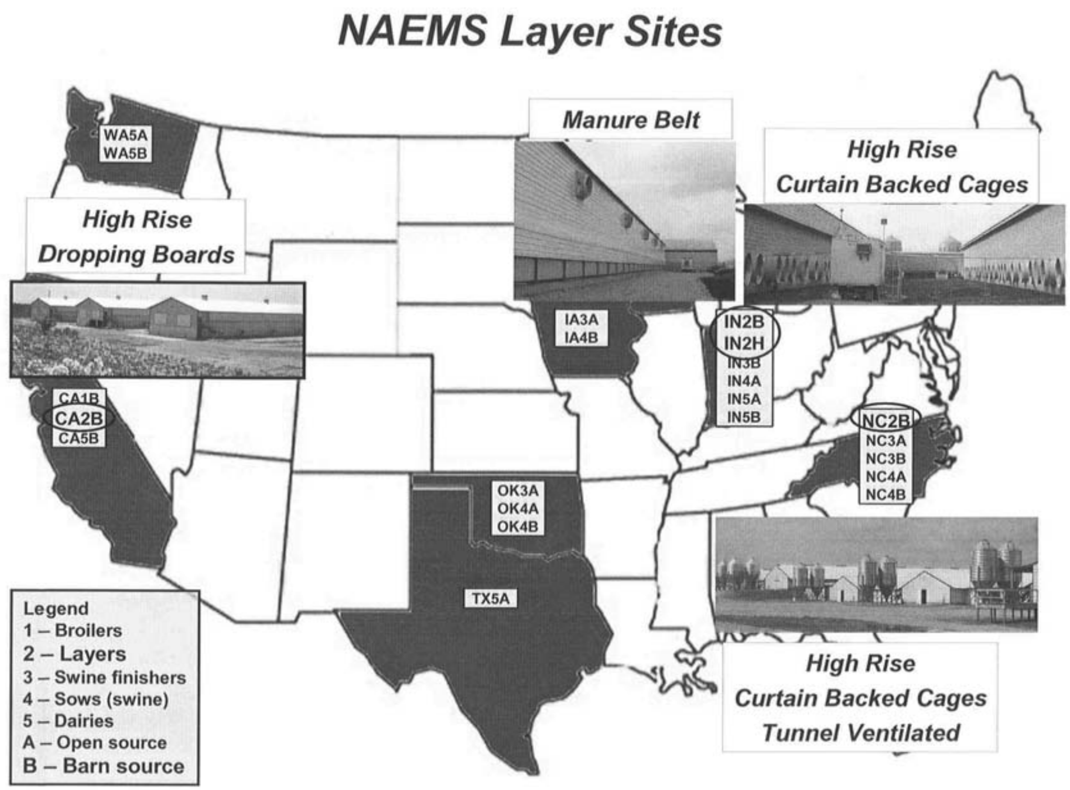


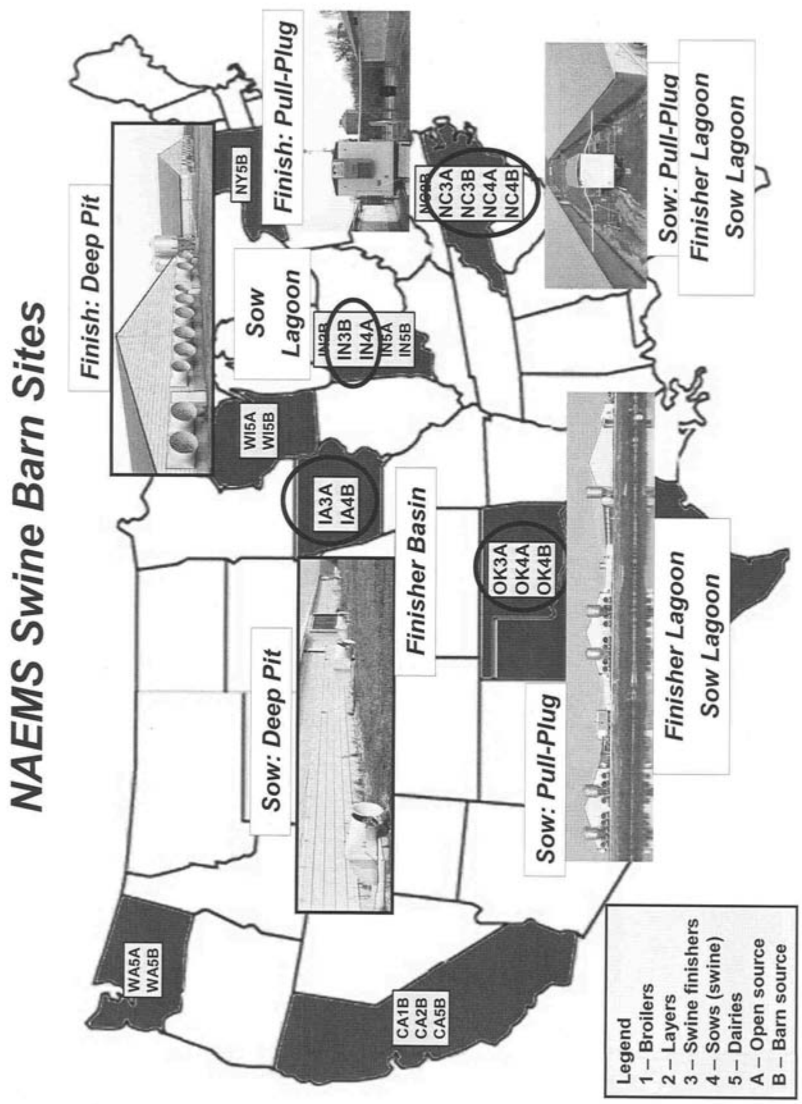
Approach

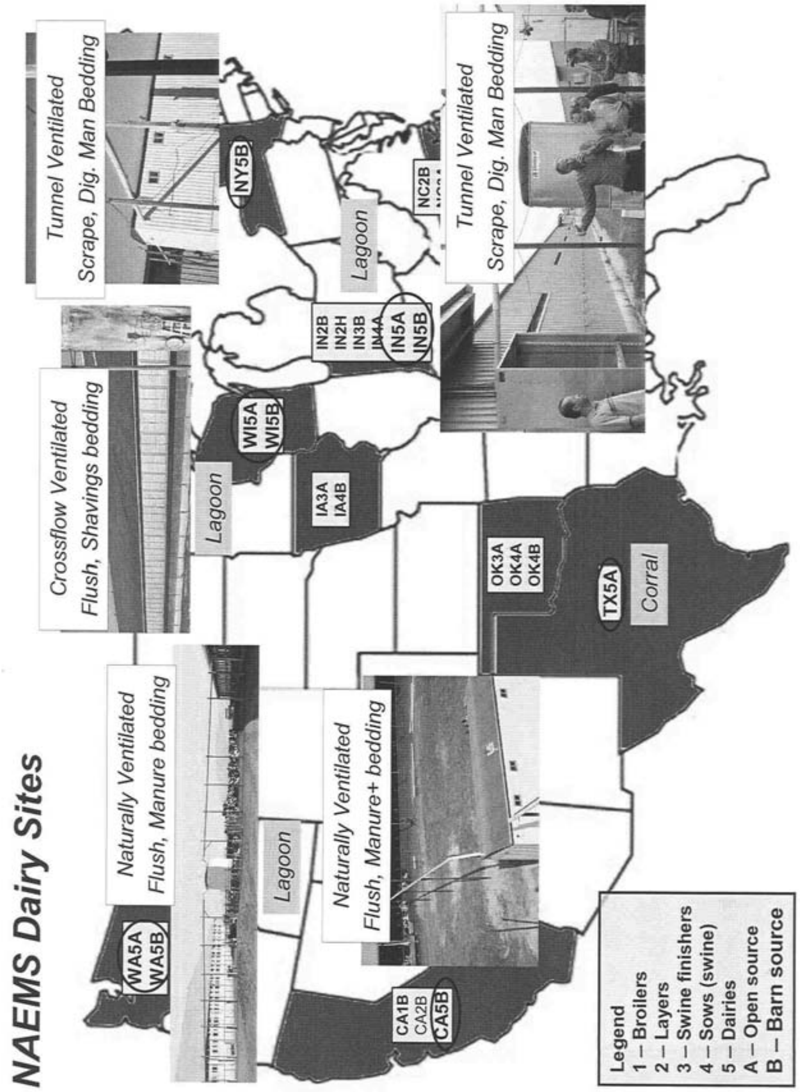
- Barns (38) monitored continuously at 15 sites
  - <u>Hydrogen sulfide</u> (pulsed flourescence)
  - <u>Ammonia</u> (photoacoustic spectroscopy)
  - Methane and <u>non-methane HC</u> (GC-FID) (2 sites)
  - Methane (photoacoustic spectroscopy) (5 sites)
  - Carbon dioxide (photoacoustic spectroscopy)
  - <u>TSP, $PM_{2.5}$, PM_{10}</u> (TEOM)
- Open sources (9 lagoons and 1 corral) tested quarterly
  - <u>Hydrogen sulfide</u> (pulsed fluorescence with S-OP).
  - <u>Ammonia</u> (TDLAS, photoacoustic spectroscopy)
  - Methane (photoacoustic spectroscopy) 1/3 of time


NAEMS Timeline
1/04
1/05
1/06
1/07
1/08
1/09
1/10
Protocol development
PI selection, staffing, budgeting
Producer Signup
EPA's review of Consent Agreements
Site selection, SOPs, SMPs
QAPP development
EPA's QAPP review
Equipment acquisition
Site setup
NAEMS
Today
EEM
EPA's Development of Emission Estimation Methodologies

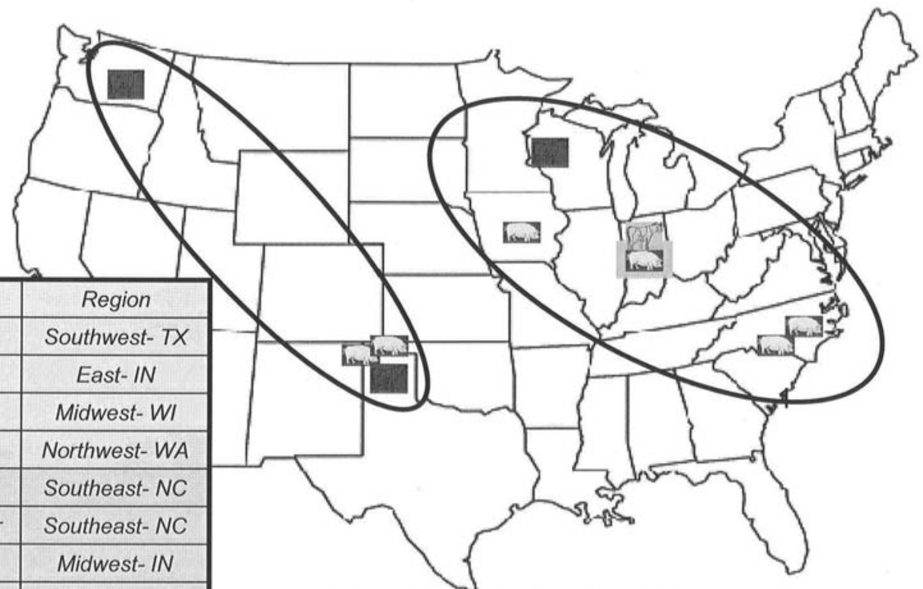

NAEMS Broiler Site
Litter on Floor
Tunnel Ventilated
WA5A
WA5B
CA1B
CA2B
CA5B
IA3A
IA4B
WI5A
WI5B
IN2B
IN2H
IN3B
IN4A
IN5A
IN5B
NY5B
NC2B
NC3A
NC3B
NC4A
NC4B
OK3A
OK4A
OK4B
TX5A
Legend
1 — Broilers
2 — Layers
3 — Swine finishers
4 — Sows (swine)
5 — Dairies
A — Open source
B — Barn source


NAEMS Layer Sites
WA5A
WA5B
High Rise
Dropping Boards
CA1B
CA2B
CA5B
Manure Belt
IA3A
IA4B
High Rise
Curtain Backed Cages
IN2B
IN2H
IN3B
IN4A
IN5A
IN5B
NC2B
NC3A
NC3B
NC4A
NC4B
OK3A
OK4A
OK4B
TX5A
High Rise
Curtain Backed Cages
Tunnel Ventilated
Legend
1 – Broilers
2 – Layers
3 – Swine finishers
4 – Sows (swine)
5 – Dairies
A – Open source
B – Barn source


NAEMS Swine Barn Sites
Finish: Deep Pit
Sow Lagoon
Finish: Pull-Plug
Sow: Pull-Plug
Finisher Lagoon
Sow Lagoon
Sow: Deep Pit
Finisher Basin
Sow: Pull-Plug
Finisher Lagoon
Sow Lagoon
NY5B
WI5A
WI5B
IN3B
IN4A
IN5A
IN5B
NC3A
NC3B
NC4A
NC4B
IA3A
IA4B
OK3A
OK4A
OK4B
WA5A
WA5B
CA1B
CA2B
CA5B
Legend
1 – Broilers
2 – Layers
3 – Swine finishers
4 – Sows (swine)
5 – Dairies
A – Open source
B – Barn source


NAEMS Dairy Sites
WA5A
WA5B
Naturally Ventilated
Flush, Manure bedding
Lagoon
Naturally Ventilated
Flush, Manure+ bedding
CA1B
CA2B
CA5B
Crossflow Ventilated
Flush, Shavings bedding
Lagoon
WI5A
WI5B
IA3A
IA4B
OK3A
OK4A
OK4B
TX5A
Corral
IN2B
IN2H
IN3B
IN4A
IN5A
IN5B
Lagoon
Tunnel Ventilated
Scrape, Dig. Man Bedding
NY5B
NC2B
Tunnel Ventilated
Scrape, Dig. Man Bedding
Legend
1 — Broilers
2 — Layers
3 — Swine finishers
4 — Sows (swine)
5 — Dairies
A — Open source
B — Barn source

Open Source Measurement Sites (Dr. Rich Grant)

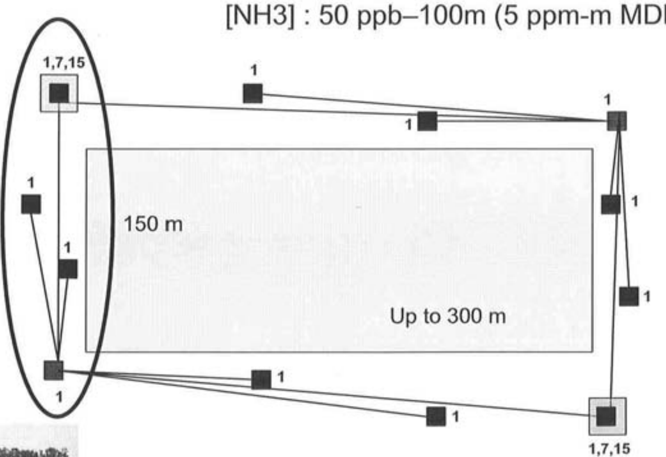


Type	Region
Dairy	Southwest- TX
Dairy	East- IN
Dairy	Midwest- WI
Dairy	Northwest- WA
Pork-sow	Southeast- NC
Pork-finisher	Southeast- NC
Pork-sow	Midwest- IN
Pork-finisher	Midwest- IA
Pork-sow	West- OK
Pork-finisher	West- OK

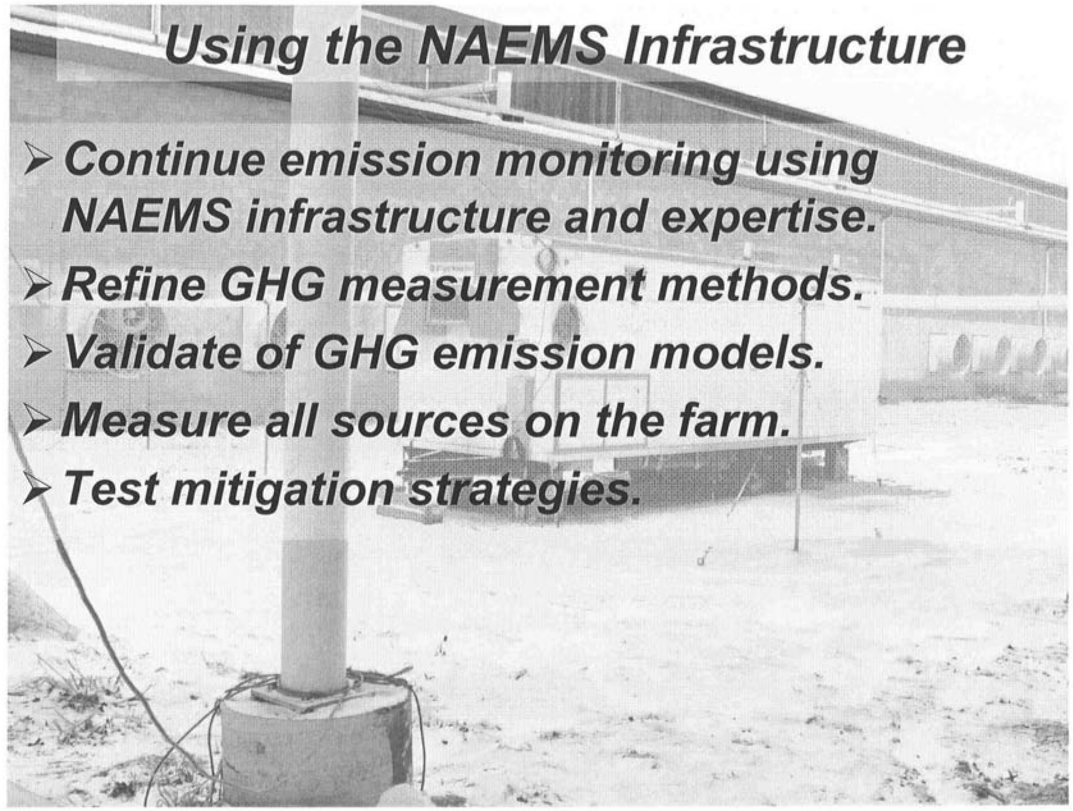
Roving teams visit each area source once each quarter

Source: Dr. Rich Grant, Purdue University, April, 2008

NH_3 Measurements: TDLAS



Source: Dr. Rich Grant, Purdue University, April, 2008


Using the NAEMS Infrastructure
➢ Continue emission monitoring using NAEMS infrastructure and expertise.
➢ Refine GHG measurement methods.
➢ Validate of GHG emission models.
➢ Measure all sources on the farm.
➢ Test mitigation strategies.

BIOGRAPHY FOR ALBERT J. HEBER

Dr. Albert Heber is a Professor of Agricultural and Biological Engineering at Purdue University with degrees from South Dakota State University and the University of Nebraska. Including his nine years at Kansas State University, he has a total of 24 years experience in livestock facility research, education, and consulting with emphasis on air quality. He directs Purdue's Agricultural Air Quality Laboratory and his primary research today is the assessment and mitigation of particulate matter, odor and gas emissions from livestock barns, and waste storage and treatment facilities. Since 2000, he has published 28 journal articles, given 56 invited papers and lectures, and provided scientific expertise and information on livestock emission factors, emission measurements, and emission controls at livestock facilities to State and federal agencies and the livestock industry. Prior to the National Air Emissions Monitoring Study, over 500 barn-months of air emission data were collected under his leadership. Other research has involved science-based separation distance guidelines for U.S. pork and dairy production, testing of odor measurement protocols, pathogen emission and dispersion from swine houses, and odor emission from industrial composting operations. Since 1984, he has published 53 journal articles, 126 conference papers, three patents, and four book chapters. In 2005, Dr. Heber received the Tony and Mary Hulman Health Achievement Award in Environmental Health from the Indiana Public Health Foundation and his Agricultural Air Quality Group at Purdue received the Dean's Team Award.

DISCUSSION

Chair GORDON. Thank you, Dr. Heber.

We will now start the questioning, and we will begin with the Chair recognizing himself for five minutes.

Let me—well, first of all, as Mr. Hall pointed out, we wear two hats, and we are also on the Energy and Commerce Committee and will be a part of developing some type of a carbon reduction program here for the United States. To be successful, obviously, we have to monitor it, and secondly, I think there needs to be an international component.

CLIMATE MODELING PROGRAMS

So let me ask a couple of questions in that regard, quick ones, and then I want to get to a more threshold-type question. Dr. Law, you had talked about this FluxNet Program in Europe and about how they use it in terms of modeling. Do they verify that modeling with any type of atmospheric sensors?

Dr. LAW. The ICOS, Integrated Carbon Observation System, I think is what you are talking about, and they have very similar components as we have in the North American Carbon Program. So they are both top-down greenhouse gas observations in modeling and bottom-up inventories and flux sites.

Chair GORDON. And what is the vehicle for coordination between those agencies and the U.S.?

Dr. LAW. It is primarily through, right now through the FAO Global Terrestrial Observing System and through the FluxNet Network of networks, flux sites particularly are covered by that. FluxNet, the primary goal of that is to standardize data and to be able to synthesize data.

Chair GORDON. Are you satisfied that it is doing an adequate job?

Dr. LAW. I think we need a lot more infrastructure on that. That has been an intermittent-type project. It has been on and off again.

Chair GORDON. Is that European infrastructure?

Dr. LAW. That is the U.S.

Chair GORDON. Oh.

Dr. LAW. That is U.S. Yeah.

Chair GORDON. Let me—I am just going to flip through some things.

Dr. LAW. Sure.

REMOTE SENSING DATA AND STANDARDS COORDINATION

Chair GORDON. Ms. Kruger, you had mentioned the developing countries and the obvious difficulties there. Is remote sensing—can we—will that be adequate for us to be able to monitor these other countries?

Ms. KRUGER. Remote sensing would certainly be very helpful for monitoring what is happening with the issue of deforestation, which is a very important one now in the international context. That would need to be coupled with ground truthing and with a capacity in the country to actually track what is happening on the ground as well.

Chair GORDON. We would have to have their cooperation to do that.

Ms. KRUGER. So we do need to have their cooperation and more broadly, remote sensing does not apply to all the different emission sources that we would be looking at.

Chair GORDON. And on this same theme, Dr. Gallagher, you talked about it with NIST, having to coordinate international standards. Is there a central coordinating body for that?

Dr. GALLAGHER. Well, I think that it is happening on several fronts, and so there is a lot of coordination happening with consensus bodies, for example, through the U.N. and the world meteorological organizations and so forth that are coordinating global climate measurements, but what is happening in addition is that the international measurement system, the—what is called the BIPM, the International Bureau of Weights of Measures, is also beginning to be brought into these questions, and that is the system that ties with national measurement institutes in all of the member countries. And so that is particularly important as measurements need to be pushed into the market.

Chair GORDON. Well, I guess here is where I am getting to. Clearly there is an international component, international in the sense of undeveloped or non-cooperating countries. Certainly there is an international component in terms of cooperating countries. Here at this table you have demonstrated the enormous amount of assets that we have in this, in the country.

And so I guess my question is two-fold, is do we have adequate assets here? Do we need a separate system? And just—I won't say more importantly, I am a little concerned about the coordinating aspect of all of this, bringing the information together and then being able to have it effectively analyzed.

Do, you know, do we have an adequate coordinating system now in the U.S. and internationally, and if not, what do we need to do for that coordinating system, and what additional assets do we need? And I will start with whoever wants to start.

Okay. Yes, sir. Dr. MacDonald.

Dr. MACDONALD. Congressman, we have a program where we inter-compare our carbon measurements, and we work together with the other countries, and you have heard sort of the——

Chair GORDON. You say a program. So what is the coordinating body? Or what is the vehicle for that?

Dr. MACDONALD. The vehicle is that the standards are all checked against the NOAA standard that we have developed.

Chair GORDON. But who says meeting come to order, everybody get started? What is the coordinating body?

Dr. MACDONALD. I will have to get back to you on the name of it.

Chair GORDON. Okay. So would you say that we have an adequate coordinating national or international agency?

Dr. MACDONALD. Yes. We are calibrating against each other and——

Chair GORDON. Okay. So what is that agency?

Dr. MACDONALD. Well, what we do is we bring the other samples and test them against our NOAA standard, so they have all agreed to do this, so that is how we have been doing it in the past.

Chair GORDON. But is someone saying, NIST, you are not cooperating. We need to get this over here or——

Dr. MACDONALD. No. It is a voluntary——

Chair GORDON. And is that going to be, you know, if we are going to bed billions of dollars on a system and raise people's rates and——

Dr. MACDONALD. I think we will——

Chair GORDON.—be concerned about our children's future, is that adequate?

Dr. MACDONALD. No. I think we will have to improve it, but it has been a cooperative effort so far.

Chair GORDON. Okay. Well, that is what I am—my question is—so is your answer then, no, it is not adequate?

Dr. MACDONALD. My question [sic] is that we have the right kinds of cooperation going on and that we will have to basically increase it significantly.

Chair GORDON. Okay, and so does anybody disagree with that statement, that we need to do—okay. So what—I am telling you, we are getting ready to write some legislation here pretty soon, and I would like a little, you know, some help in determining do we have enough assets, how we coordinate it, what needs to be the body to bring it together, and who needs to coordinate that.

Ms. Kruger, you mean EPA has played a role I think in trying to synthesize a lot of this information. What is your view?

Ms. KRUGER. Well, I would say the perspective that I bring to this is as someone who is really thinking about it from the standpoint of what are sources, specific sources emitting and how are we managing that and implementing those policies. And I would—I think that the—my impression is that the coordination that is going on at the scientific level is very robust among all of the agencies. It may need expansion in the policy dimension because I don't know if the coordination between the scientific research and the policy is as well developed or mature as the coordination on the science side.

Chair GORDON. Okay. I am getting a little scared here because we are getting ready to make a multi-billion-dollar bet, and again, in our children's future and in our industry and in our pocketbook, and so we got to sort of have a, you know, a little more than faith here.

Yes, sir.

Dr. BIRDSEY. Yeah. I would like to mention again the Interagency Working Group that has done quite well at coordinating the science side of things and——

Chair GORDON. Is this the North American Carbon——

Dr. BIRDSEY. Well, the North American Carbon Program was an activity that was fostered by the Interagency Working Group, and that program has brought together literally hundreds of scientists from all kinds of disciplines working on methods to bring our assets together. We do have a lot of inventories and remote sensing and sampling and so forth.

Chair GORDON. So who chairs that?

Dr. BIRDSEY. Well, the Chair is rotated among agencies. It is currently co-chaired by USDA and NOAA, I believe. Is that right?

VOICE. NASA.

Dr. BIRDSEY. USDA and NASA. Sorry.

Chair GORDON. Okay. Well, we are going to have to a little more delving. I don't want to get into my time.

MONITORING RESOURCES

The last quick question is do we have adequate resources now, assets in terms of monitoring, or do we need to authorize more? If you think we are okay, then you don't need to say anything. If we need more, please tell me what it needs to be.

Yes, sir.

Dr. FREILICH. Well, as you heard in the accumulation of testimony here, within the confines of North America and the Continental United States in particular, we have, I believe, an excellent mix of *in situ,* airborne, and remote sensing. To extend that understanding globally clearly requires additional resources for non-cooperating countries or difficult to get to places. And the unique vantage point of space with broad coverage but high resolution and frequent revisit needs to play a key role there. However, as was pointed out, those measurements are at the limits of our technological ability. We are succeeding at them, but they do require ground truthing verification and validation, but that is the basis for a global monitoring system.

Chair GORDON. So that is something that we need to keep in mind when we go to Copenhagen.

Dr. FREILICH. Definitely.

Chair GORDON. Okay. Unless—did you want to say something? I don't want to take other people's—okay. Then this is, again, I would hope that, I know that it is difficult for many of you because you are within an agency and you got to get clearance, and you can't get a free agent, but if your brother-in-law has, with your maybe consultation, some suggestions as to how we can set up some type of system, what we need, I would, we would like to have that, and we would like to have that, you know, pretty soon.

So Mr. Hall, you are recognized for five minutes.

REGULATING CARBON CREDIT SOURCES

Mr. HALL. I would have yielded you more time if you needed it.

Dr. Heber, a lot of people are looking to forestry and agriculture as potential sources of carbon credits, planting trees, switching to no-till farming practices, and some other projects, what they call low-hanging fruit for some of these folks.

If you are unable to take direct measurements, how are these reductions verified? And what would this mean in terms of generating offset credits in a mandatory regulatory regime?

Dr. HEBER. I have not studied the methodology for determining those offsets, but I understand that models are used, inventorying of practices, agricultural practices and so on. Some assumptions are made, but direct measurements can help to refine those methodologies and make them more accurate. That is about how I would answer that question.

Mr. HALL. Anybody else care to answer it?

Dr. BIRDSEY. Yeah. I would like to mention that in practice there are a number of greenhouse gas registries and markets emerging and many of them have implemented ways to directly measure what is going on on the land. They are usually combined with remote sensing and models to provide a more complete picture and a better annual tracking of what is going on. So there is some technology available.

There is some concern about the cost of the measurement relative to the value of the credits, and so that is an issue of folks trying to come up with efficient ways to bring these information systems together.

Mr. HALL. We have had—excuse me. Go ahead.

Dr. MACDONALD. Congressman Hall, I would like to mention that we have, we actually instrument tall towers like television towers. We actually measure the amount of CO_2 being sucked out of the air by things like soybean crops and so on, so you can actually tell how much is being taken up by some of the plant life.

Mr. HALL. Well, you know, we have gone through some litigation and then some areas, particularly in Texas and Oklahoma and maybe other areas of the country where cities in the proximity of ranches or oil fields or something that the cities felt like had invaded their lakes or their supply of water, you all are familiar with those—some of that litigation, I take it.

In the interest of litigation I guess I am asking this question because their suits are still pending, and a lot of the cities are trying to use against ranches and they track the Superfund legislation we passed several years ago, because the Superfund legislation has more serious consequences of violation and increases their opportunity to get better and a more lasting and a more punishing judgment or verdict against the ranches or the oil fields or whatever they say pollutes the cities.

Like Waco, Texas, for example, has litigation against the farm bureau group that the farm bureau-supported group of farmers and ranchers whose ranches are probably polluting some of the waterways.

How would the use of this technology that you all have offset or how would this affect the emissions or the profile of the animal feeding operation industry, and how would the cost of this technology compare with the cost of the monitoring technologies?

I will go back to you if I might on that, Dr. Heber.

Dr. HEBER. Would you repeat the question about which technology——

Mr. HALL. I am not sure I can, but I will try.

Dr. HEBER. Sorry.

Mr. HALL. There has been interest on both sides of the Capitol the concept of poop to power or the use of—I wish you hadn't written that, the use of anaerobic digestion to generate pipeline quality methane. How would the use of the technology affect the emissions profile of the animal feeding operation industry, and how would the cost of this technology compare with the cost of the monitoring technologies?

Dr. HEBER. The anaerobic digestion process affects other pollutants in addition to utilizing the methane and reducing greenhouse gases. It reduces odor and so improves the neighborhood, a nuisance issue. It reduces hydrogen sulfide, which is also a regulated pollutant, and so it is very—it also helps the manure handling for the farm, the solid waste management issue. So there is a lot of benefits there and generates electricity, so there is some revenue available because of the heat and the electricity that can be generated from anaerobic digestion.

There is an economy of scale. These anaerobic digesters are typically put on large farms, and now, the monitoring of the emissions from an anaerobic digester can be kind of, you know, rather expensive. I can't really address how, you know, whether that expense is really too much or not or whether, you know, measurements—measurements need to be taken at anaerobic digesters to determine, you know, what the emission reductions are and then those measurements can then be used in models that would then predict the reductions at other sites or for other farms.

So I think models, if they are validated by measurements, that may be sufficient rather than requiring monitoring at each one.

Mr. HALL. I thank you, and I think my time is up.

Chair GORDON. Thank you, Mr. Hall, and Mr. Wu is recognized.

Mr. WU. Thank you very much, Mr. Chair.

BASELINES AND INVENTORIES

I want to ask a couple of narrow technical questions, but first I would just like to express my concern that we have gone from one era where we have been in almost complete denial that there is a problem to a period when we are charging ahead with doing something about it and at least consensus amongst many groups that there is a problem out there. And it makes me think of other challenging situations such as colonial countries that have had their political systems repressed for a very long time, and all of a sudden they are independent, and they are supposed to be self-governing, democratic systems.

It is not that I question the scope of the environmental challenge in front of us. It is just that looking back on that colonial experience it is a checkered history about success in going from suppressing certain forms of things and then running them well afterwards. I am very concerned that we are able to technically manage the systems that we are proposing, and I would like to get some assurance from you all.

Now, none of you all addressed baseline issues, and if you could discuss the importance of baselines. My understanding is that the Europeans, in not getting baselines quite right, created some issues for themselves and what each of your groups can contribute to getting accurate baselines so that we can adequately manage what we need to.

Dr. Birdsey.

Dr. BIRDSEY. Yeah. Thank you. I will take a—I will start on it anyways. We do have a national forest inventory and a national resources inventory that have been monitoring historical trends for quite a number of years, and this certainly gives a baseline for where we have been.

I think a lot of the greenhouse gas management systems that are being proposed, however, try to look to the future as to what things—what would happen without taking actions. So here you have to merge the inventory information with very good prognostic models, models that can pull together different sources of information and make accurate projections. Then you can see how well we have done compared to what was expected.

Mr. WU. Are you confident about those forest baselines, and is anybody else confident about any of the other baselines that we would need for the Continental United States?

Dr. BIRDSEY. Well, I think the historical baseline record is quite good. I would have less confidence in the projections actually because there you are dealing with events that are hard to anticipate.

Mr. WU. Do any of the other panelists—Ms. Kruger.

Ms. KRUGER. I think one of the primary reasons why we were asked by Congress to undertake the development of the Greenhouse Gas Reporting Rule, which we recently proposed, was so that we could establish, have the data that we needed for policy development and the establishment of baselines across the economy. And in the proposal that we have got out for comment right now, we have laid out methods for how we would collect facility-specific information on greenhouse gas emissions across the economy, and that is the kind of information that we would draw on to inform future actions.

So you are right. When the Europeans tried to start—were creating their emissions trading system, they had a good national inventory, but they didn't have that data disaggregated down to the facility level, and that caused some problems for them.

With the data that we are collecting, and it is our goal to have that data, 2010 data reported to us early in 2011, we are looking forward to having the kinds of information that we will need to develop the bottom-up policies.

Mr. WU. Well, my clock is ticking down now, so perhaps I could rephrase the question. What work do we need going forward to more accurately hone baselines so that they are useful for a regulatory process?

Dr. Heber.

Dr. HEBER. On the animal agriculture side we think that the field studies are needed for having more accurate reporting, and as I indicated in my testimony, we have the technology, and we have been measuring baseline of other air pollutants and actually greenhouse gas emissions are being added to that network now by the dairy industry.

Mr. WU. Dr. Law, a FluxNet perspective, or Dr. Gallagher, a NIST perspective on this?

Dr. LAW. I think that we need more sites in the FluxNet Network that are in managed systems. So I went through a rundown of that, and we don't have enough sites in early stages of forest development, for example, or after you have thinned forests and watch them recover. We don't have enough measurements there.

Again, the sites are used to calibrate models, and once we get that and the remote sensing data like Landsat goes back to 1972, we can go back and retrospectively look at the trends backwards and then go forward with estimates.

In terms of the inventory data, AmeriFlux also measures more of the carbon budget components and ecosystems. So beyond what the Forest Service does, it would be great if the forest inventory grew—did add some of those measurements like soil carbon.

Dr. GALLAGHER. Quickly, I guess, you know, I think you said it very well that the, you know, in terms of policy generation the more accurate and the more specific information you have the better off you are, and I think some of this will be a problem of looking at, making sure that, you know, baseline measurements are more and more detailed and more and more accurate.

One of the issues we see in this is an overriding trend that we are paying attention to is that, you know, sort of global average baselines in terms of, you know, large length scales, in other words, averaging over large geographic areas. That—the status of that is actually quite good.

I think one of the issues is where you start pushing to baseline levels, local emission levels at more localized measurements and how do those get incorporated, and that becomes important if you are looking at points of regulation or other things where you need specific information about greenhouse gas emissions over a sink or over an emission source.

Mr. WU. Thank you very much, Mr. Chair.

Chair GORDON. Thank you, Mr. Wu, and Mr. Rohrabacher is recommended for five—or recognized for five minutes.

SKEPTICAL ARGUMENTS

Mr. ROHRABACHER. Recommended for five minutes. That would be hard to do.

First of all, let me ask how much money is being spent in monitoring these greenhouse gases maybe over the last 10 years? What have we spent? Are we talking about billions of dollars?

Dr. Heber.

Dr. HEBER. On the animal agriculture side and pertaining to this study that we have done I would say, well, a half a million dollars has been put forward by the dairy industry to add greenhouse gases to five of the sites.

Mr. ROHRABACHER. Uh-huh.

Dr. HEBER. And with the limited amount of greenhouse gas measurements that were done by the National Air Emission Monitoring Study itself, I would estimate at least another half a million dollars. So approximately $1 million.

Mr. ROHRABACHER. But, I mean, in terms of overall in our national commitment to studying these greenhouse gases in the atmosphere. I mean, this is really a major commitment of resources, is it not? The answer I guess is yes.

Let me then for the record just put into the record this quote from maybe ten various resources that I have talked to and for example, one quote here is from Dr. Yuri Izrael from the—who is the Director of Global Climate and Ecology Institute and a member of the Russian Academy of Sciences and was the Vice President of the UNIPCC in which he suggests, and these other quotes are suggesting that CO_2 and these greenhouse gases really do not create global warming and do not change the, basically change the climate, which is what we are talking about.

I would imagine that you folks disagree with these assessments of your fellow scientific colleagues. Yes. The answer is yes. All right.

Then maybe what we could—let me just suggest that I am putting these in the record, Mr. Chairman, for the record of the hearing. If I could submit this now for the record of the hearing where we have 10 prominent scientists who are in disagreement with the theory that greenhouse gases are——

Chair GORDON. With no objection.

[The information follows:]

Quotes and Names for the Record

"Believe it or not, Global Warming is not due to human contribution of Carbon Dioxide (CO2). This in fact is the greatest deception in the history of science. We are wasting time, energy and trillions of dollars while creating unnecessary fear and consternation over an issue with no scientific justification. For example, Environment Canada brags about spending $3.7 billion in the last five years dealing with climate change almost all on propaganda trying to defend an indefensible scientific position while at the same time closing weather stations and failing to meet legislated pollution targets."

-Dr. Timothy Ball
Quote from "Global Warming: The Cold, Hard Facts?"
The Canadian Free Press (online) Monday, February 5, 2007
http://www.canadafreepress.com/2007/global-warming020507.htm

"As measured recently by satellite, and published in Science magazine, Greenland is losing .0004% of its ice per year, or 0.4% per century. All modern computer models require nearly 1000 years of carbon concentrations three times what they are today to melt the majority of Greenland's ice. Does anyone seriously believe we will be a fossil-fuel powered society in, say, the year 2500?"
"A small but very vocal band of extremists have been hawking a doomsday scenario, in which Greenland suddenly melts, raising sea levels 12 feet or more by 2100." "...it is repeated everywhere, and its supporters are already claiming that the IPCC" ... "is now wrong because it has toned down its projections of doom and gloom".

-Dr. Patrick Michaels
Quote from an article "Global Warming: So What Else Is New?"
in the San Francisco Chronicle on February 2nd, 2007.

"... in the theory the claim is that if CO2 goes up, temperature will go up. The ice core record of the last 420,000 years shows exactly the opposite. It shows that the temperature changes before the CO2. So the fundamental assumption of the theory is wrong. That means the theory is wrong."

- Dr. Timothy Ball
Quote from the Politics of Global Warming interview in the Pittsburgh Tribune-Review
http://iceagenow.com/Climatologist_Dr_Timothy_Ball.htm

"I DEVOTED six years to carbon accounting, building models for the Australian Greenhouse Office. I am the rocket scientist who wrote the carbon accounting model (FullCAM) that measures Australia's compliance with the Kyoto Protocol, in the land use change and forestry sector. . . . There is no evidence to support the idea that carbon emissions cause significant global warming. None. There is plenty of evidence that global warming has occurred, and theory suggests that carbon emissions should raise temperatures (though by how much is hotly disputed) but there are no observations by anyone that implicate carbon emissions as a significant cause of the recent global warming. . . . The new ice cores show that in the past six global warmings over the past half a million years, the temperature rises occurred on average 800 years before the accompanying rise in atmospheric carbon. Which says something important about which was cause and which was effect."

-Dr David Evans
consultant to the Australian Greenhouse Office from 1999 to 2005.
"No Smoking Hotspot" in *The Australian*
July 18, 2008
http://www.theaustralian.news.com.au/story/0,25197,24036736-7583,00.html

"I have grave difficulties in finding any but the most circumstantial evidence for any human impact on the climate. The quantity of CO2 we produce is insignificant in terms of the natural circulation between air, water and soil. I have tried numerous tests for radiative effects, and all have failed. I have studied the ice core record, in detail, and am concerned that those who claim to have a model of our climate future haven't a clue about the forces driving our climate past.

I am particularly concerned that the rigor of science seems to have been sacrificed on an altar of fundraising. I am doing a detailed assessment of the IPCC reports and the Summaries for Policy Makers, identifying the way in which the Summaries have distorted the science. I have found examples of a Summary saying precisely the opposite of what the scientists said."

Dr. Philip Lloyd
UN IPCC co-coordinating lead author
on the Technical Report on Carbon Capture & Storage
January 18, 2008.

Additional Scientists:

1. Dr. Yury Izrael, the director of Global Climate and Ecology Institute, a member of the Russian Academy of Sciences and UN IPCC Vice President, "Present day global warming resembles the 1940s, when ships could easily navigate Arctic passages... A Russian expedition that recently returned from the central Antarctic says that temperatures are now starting to decrease."
2. Dr. Mark Campbell, United States Naval Academy
3. Dr. Roy Spencer, University of Alabama – Huntsville
4. Dr. Brian Valentine, United States Department of Energy
5. Dr. James DeMeo, University of Kansas (Retired)
6. Dr. David Douglas, University of Rochester
7. Dr. Sherwood Isdo, United States Department of Agriculture (Retired)
8. Dr. Roger Cohen, Fellow, American Physical Society
9. Dr. Richard Keen, University of Colorado
10. Dr. Joel Kaufman, University of the Sciences, Philadelphia (Emeritus)

Chair GORDON. And I want to get one thing clarified is that, Mr. Rohrabacher, you are quoting a Russian scientist.

Mr. ROHRABACHER. I certainly am.

Chair GORDON. And you are betting on this Russian scientist?

Mr. ROHRABACHER. I certainly am. Along with the other nine who are American.

Chair GORDON. I wanted to get a clarification, because that hasn't been consistent with some of your past actions.

Mr. ROHRABACHER. In the past I have called into question the Russians, that is correct, although——

Chair GORDON. Thank you, Mr. Rohrabacher.

Mr. ROHRABACHER.—let me just note that I do recognize that they have a great deal of knowledge about the Arctic and about Greenland and all the rest.

So with that said, would you concede, would this panel concede that there are prominent members of the scientific community that have offered alternative viewpoints to this idea that greenhouse gases are causing a change in the climate that deserve to be—and their arguments deserve to be addressed? Or is it case closed, debate is over, let us spend the money? Come on. Here is your chance. The skeptics are just totally irrational, or yeah, maybe they have got some points that need to be addressed.

We will start with Dr. Heber down here.

Dr. HEBER. I am not an expert in this area of, you know, in this research area but——

Mr. ROHRABACHER. Uh-huh.

Dr. HEBER.—I think the skeptics ought to be heard and that their points ought to be addressed.

Mr. ROHRABACHER. Yeah. I would like to see a debate on the issue actually before this committee, Mr. Chairman. I would like to see several people just get up and have, with our participation, a—just a back and forth, rather than simply, which we have done, is base hearings on the premise that this is already an accepted truism and thus what do we need to do now to implement policy. I would suggest that this country is about to spend hundreds of billions of dollars on policies that are based on premises that have not been proven scientifically, and please feel free to disagree with me and if not, I would yield back the balance of my time.

Chair GORDON. Thank you, Mr. Rohrabacher. We had a skeptic today that had an opportunity. You know, we have had those discussions here, and again, I think it is valid that we continue to look for skeptics to keep us honest, but the fact of the matter is over 170 nations, including the United States, certified by President Bush, confirmed that we do have global warming with 100 percent certainty and within 90 or 95 percent certainty that it is a direct result of human activity.

Clearly, we need to continue to ask the questions, but I think that we have enough consensus that we need to move forward. But you serve a constructive part by making us continue to rethink.

And, let us see, Ms. Dahlkemper, I believe you are next.

Ms. DAHLKEMPER. Mine is not working. I will use yours. Thank you. Thank you, Mr. Chair.

THE EFFECTS OF FOREST DEGRADATION

According to an article in the October '08 issue of *EOS,* deforestation and forest degradation account for about seven to thirty percent of total anthropogenic carbon emissions. How well do we really understand the emissions from deforestation and degradation, and how much research is being done on the ways that we estimate these emissions from deforestation?

I open this up to the panel. Whoever would like to answer this. Dr. Birdsey.

Dr. BIRDSEY. I will take a start at it. You are interested globally in these estimates. Right?

Ms. DAHLKEMPER. Yes.

Dr. BIRDSEY. Yeah. I think over the years the—with the continuation of the remote sensing programs we have learned a lot about the rate of deforestation in countries of the globe where we didn't know much about that before. But there is quite a bit more difficulty in monitoring and estimating the impact of forest degradation because this is a lot more subtle process. We are not—land is not being cleared and put into some other use but rather some part of the growing stock or the biomass is being removed, and when you are taking a smaller portion of that out, it is not quite as detectable from space.

So we know part of the answer, but the degradation part I think really needs quite a bit more work.

Ms. DAHLKEMPER. Does any agency have the lead in this type of work?

Dr. BIRDSEY. I think, I don't think it is a U.S. agency. Really, the Food and Agriculture Organization of the United Nations has really worked on this over the decades more than anyone, and so they have tried to organize reporting by the individual countries and tried to build up the capacity of individual countries to make their own estimates. They have done some independent work looking at remote sensing globally, but I don't believe that has evolved into a robust system yet.

Ms. DAHLKEMPER. Anyone else like to address it?

Dr. Freilich.

Dr. FREILICH. Yes. To put some numbers on your assertion, if I can remember correctly from the last papers that I read, based on satellite measurements as well as modeling and *in situ* analyses over several decades, I think the estimate is that we as a species have put about 300 billion tons of carbon into the atmosphere from burning fossil fuels and that there have been about another 160 billion tons of carbon excess put into the atmosphere through land use and land use changes in the industrial era.

So those are relatively precise numbers that come from pretty sophisticated analyses of a whole wide range of global data, including the remote sensing data.

GAPS IN THE NATIONAL OBSERVATION NETWORK

Ms. DAHLKEMPER. Thank you. My other question really—Dr. Birdsey, you indicated that key elements of a National Observation Network are lacking, and I would ask you to maybe expand on this and of the major gaps in our National Observation Network, what two or three are particularly important to fill.

Dr. BIRDSEY. Yeah. Thank you. Well, on the land side our inventories are fairly comprehensive but as Dr. Law mentioned, we are not capturing changes in forest soils as well as we should, and there are some parts of the country like Alaska where our inventory systems are not as intense as they should be. That is the sampling intensity is not as good as it should be. So those are a couple of areas on the land side.

Our—we are concerned about the continuity of some of our observation systems. AmeriFlux, for example, is funded on an individual site basis, and sometimes they come and go is one example. Our atmospheric monitoring system, I am looking at direct measurements of the concentration of carbon dioxide in the atmosphere, shows great promise, but it is a very sparse system, so they are unable to resolve fluxes at a very small scale.

Those are the few that come to mind.

Ms. DAHLKEMPER. So if you were going to prioritize the gaps that need to be filled, number one, number two would be?

Dr. BIRDSEY. Well, coming from the Forest Service I would like to see the land inventories beefed up a little bit, but I would also associate that with FluxNet. I think that would give us a really robust picture of what is going on on the land.

My second area would probably be in measuring atmospheric CO_2 concentrations.

Ms. DALHKEMPER. Okay. Thank you. I yield back.

Chair GORDON. And Dr. Broun is recognized for five minutes.

Mr. BROUN. Thank you, Mr. Chairman.

MORE ON SKEPTICAL ARGUMENTS

Panel, I am a scientist. I am an applied scientist. I am a physician, and I believe in science. I believe in scientific integrity, and I believe when Mr. Rohrabacher asked you all a question the answer of silence was deafening except for from one individual, and that is Dr. Heber.

And I must say that I am extremely disappointed. I think you all have absolutely zero scientific integrity, because you all have drank the Kool-Aid and have decided absolutely this belief process of human-induced global warming is absolutely a fact. And I disagree with the Chair, respectfully so, that—and our former President, he was misled, he was wrong, you are wrong, there is a tremendous panel, a thousand or more scientists around the world that disagree with human-induced global warming.

My question to each of you all, are you all absolutely bound and determined to shut down the economy, create massive job losses, create a huge increase in the cost of food, medicine, all goods and services in this country to pursue an agenda, a political agenda that has absolutely no scientific consensus that there is human-induced global warming? And I would like each of you to answer just yes or no. Are you bound and determined to pursue this human-induced global warming idea that has no scientific consensus. Yes or no?

We will start with Dr. Heber.

Dr. HEBER. I would say no, and I applaud EPA for negotiating with the livestock industries to get the science before regulation on the *Clean Air Act* pollutants and also the CERCLA (Comprehensive Environmental Response, Compensation, and Liability Act) and (Emergency Planning & Community Right-to-Know Act) of pollutants. Get—make sure the science is there first before proceeding with regulations. Regulations can get ahead of the science, and I think it is important to get the science and even if we have to wait.

Mr. BROUN. Dr. Gallagher, just vote yes or no.

Dr. GALLAGHER. I, you know, our position in this is we are ready to carry out the policies that are needed and to support them with good measurements. We are really not a climate change agency, and as a scientist I have to say that there is a strong preponderance of evidence that there are climatic affects associated with the gases, and that seems to be what we see in the policy.

Mr. BROUN. Well, there are a lot of other theories about that. In fact, that have just as much data as human-induced global warming. In fact, we have had global cooling over the last almost decade now, and we—a volcano creates as much CO_2 emissions as every human being in the world. Yes or no?

Ms. KRUGER. Yes. I believe that we do need to act to deal with the threat of climate change, but I don't believe that we, that doing that needs to jeopardize our economic growth.

Mr. BROUN. It is going to. Yes or no?

Dr. FREILICH. I agree that we do need to act. The data are clear, the preponderance of evidence is in favor of human-induced global warming. I agree with Ms. Kruger that getting ahead of this issue will, in fact, be good for this country as opposed to shutting down the economy.

Mr. BROUN. Well, I am out of my time, but I want to reiterate. You all have shown me you have no scientific integrity, because you do not consider the skeptics and the other folks. You have just—you have drank the Kool-Aid, and I just ask you, in fact, the Secretary of Energy was here, and I asked him the same question about shutting down the economy. This Administration seems bent on shutting down our economy to pursue something that has no scientific consensus and no scientific, really no scientific basis. It is a theory, it is a belief system, it is a religion with you guys, and you are totally wrong.

And with that, Mr. Chairman, I will yield back.

Mr. BAIRD. [Presiding] I thank the gentleman. I would just encourage the panelists to be respectful of our panel and to avoid concluding that because someone disagrees with you that they have no integrity and you do. This is a committee that respects diversity of opinion, and in this case it is not just opinion, it is also scientific evidence. And questions of integrity we try to refrain from impugning the integrity of our colleagues here. I would just urge the panel members to show the similar respect for our witnesses.

With that I will recognize Ms. Dahlkemper. Sorry. Mr. Lipinski.

GREENHOUSE GAS MEASUREMENT

Mr. LIPINSKI. Thank you, Mr. Chair. I want to get back to the issue at hand in terms of measurement. There are a lot of debates going on right now about what to do about global climate change, and the two general categories of ways of addressing it right now that are being discussed here in Congress are going with a cap and—some type of cap-and-trade system or some type of tax or user fee, whatever you would like to call it.

Is there—does either one of these require a greater degree of certainty on—in terms of measurement than the other one does? That is, what we know, what we can measure right now, what we have available. Does either of those two systems in general require more or less? Can we get away with less measurement accuracy with one rather than another? I just wanted to throw that general question out there.

Ms. Kruger.

Ms. KRUGER. I think you are asking a very good question, and I think that the—that actually whether one were to do a cap-and-trade program or a tax, you would still need to measure the emissions accurately from the facilities or the entities that you are placing that tax on. So from the standpoint of the facility level of those bottom-up measurements, you are going to need, you would need a very similar type of measurement approach, whether that is continuous emission monitors or other means of measuring the emissions.

In a cap-and-trade system you may have other types of policies that come along with it like offset policies that might not be part of a tax, and so there might be some things that wouldn't be done under a tax. But the fundamental measurement to determine what the amount of the tax is going to be is very similar to what you would need to do to determine compliance with a cap.

Mr. LIPINSKI. Anyone else have—would agree with that then?

Dr. MacDonald.

Dr. MACDONALD. Yes. I agree. Fundamentally from the top-down viewpoint both of these would require a very similar monitoring system.

Mr. LIPINSKI. Dr. Birdsey.

Dr. BIRDSEY. Yeah. I would like to mention just that the details of the program are not independent of the monitoring system, or maybe I should say vice versa. I completely agree that considering the cost of monitoring needs to be part of the consideration of the program and, some of those details may or may not increase the cost.

For example, if you are looking at estimating a change in emissions or sequestration in forests and you want to separate out the effect of a human action from some natural variability in climate or a wildfire and so forth, it may cost more to do that separation than simply to look at the total change.

So there are ways the rules—the way the rules are written may affect the cost of the monitoring. So it is important to keep that in mind.

Mr. LIPINSKI. I want to ask, following up, Ms. Kruger, the Reporting Rule as you say in your testimony does not establish protocols for offset projects. What would have to be—what kind of research projects would be needed to address that, the monitoring challenges of the offsets?

Ms. KRUGER. Well, I think if we were developing an approach like this for offsets, we would approach it the way that we did when we did, when we looked at, when we started working on the reporting rule. That is there are a number of monitoring protocols that have been developed in voluntary markets dealing with a wide range of possible offset sources. We have done that at EPA under our Climate Leaders Program, but there are many others, and you would basically want to look at what has been done out there, take the lessons from that, and use that to establish the types of monitoring protocols that would be needed.

This would need to be supplemented, I think particularly in the agriculture and forestry area, with some additional policy considerations around whether the actions are additional and what happens if there is leakage or reversals. But broadly we could, we would draw on the—on a lot of good information that has been developed already.

Mr. LIPINSKI. Thank you, and I want to thank all of you for your testimony. It is a difficult position because we are here today—you are here today to talk about measurement in the bigger question of what we are going to do about global climate change. It is sort of a separate issue, those policies, but it all comes down to the ability to measure as accurately as possible emissions, offsets, and so it is critical that we get that right in order to be able to have a policy that can work.

So I yield back. Thank you, Mr. Chair.

Mr. BAIRD. Thank you. I recognize Mr. Bilbray for five minutes.

Mr. BILBRAY. Thank you, Mr. Chairman.

MEASURING IN SECOND AND THIRD WORLD NATIONS

My question is, traditionally we have used air indexing as an indication of traditional emissions, basically a paper chase in the United States, in North America, and Europe. What is the credibility of our emissions measurement at this time in the Third World? Anybody want to talk about how you go down into Nicaragua right now and determine what is the emissions coming off of Nicaragua right now?

Go ahead.

Dr. MACDONALD. Congressman, one thing we can do is with both our satellite assets and our aircraft assets, you can actually get estimates of the total amount of greenhouse gases coming off of a country by measurements that you take offshore and around it and that are observatory. So you get some estimate of what the source is.

Mr. BILBRAY. Because in the Third World right now this is the season where they are burning off half the forest right now. Anybody flies over Latin America right now will see the fires going off.

My biggest concern is that traditionally we have always based it on the paper chase, because it is like if it isn't filed, it isn't there. China, you know, when we are facing areas like China and India, in fact, I—last report I saw China's increase last year was more than the total emissions of India.

How do we monitor that kind where you end up having not only the massive industrial but also the urban practices that may have a massive increase in emissions, everything from the way they raise their poultry to the fact of the way they handle their lifestyle totally to their ag uses? How do we monitor it in places like China and India?

Dr. MACDONALD. Congressman, there is a similar answer. You know, we had this problem in the '50s where we tried to monitor if there were nuclear bombs, and we would actually measure the flow of various carbon isotopes. When we make measurements, both with our satellite assets and out over the ocean, we can actually determine how much the gases are in these quantities and at our observatories, and I think you are right that it is not a very precise measurement, but it does give us an estimate of what they are doing.

Mr. BILBRAY. Yeah. Anybody comment about that challenge? Because let me tell you something. I worked with cap-and-trade in California, and I know the Committee gets sick and tired of hearing about my air resources background, but I was a big supporter of cap-and-trade when it was, when it could be actually monitored. What scares me to death, and I see a huge potential for corruption, when we start going overseas with the cap-and-trade to where the monitoring and accountability, that there will be a teak forest that was grown anyways, it was going to be cut down, all at once becomes part of a sink program, and the ability to account for this scares me to death. I just think there are people out there looking to make a fortune off of this, and I will say this to the Chairman. Mark my words. We go into an international cap-and-trade, the scandal of what the diversion of funds and the way this is being hit is going to be a big one.

So I will raise that. And let me just say to my colleagues that are frustrated at some of our colleagues attacking you guys about the whole concept of the climate change issue, my real concern is based on ice core samples. I am just looking at historical levels from ice core samples. I work with my scripps guys on that, but the problem is the credibility of the whole climate change issue was really hurt when the same people that are screaming that the world is coming to an end and that we must do extraordinary things to save the planet will not even stand up and say that the Federal Government's subsidy of corn ethanol is not only not solving the problem, in fact, the latest report from Duke University is it would be better to burn regular gasoline than to do what we are doing with corn ethanol. You know, that is the kind of thing that comes down.

When the State Air Resources Board—Duke said it is better never to plant the crop. The California Air Resources scientists, the best in the world, said that it is better to burn regular gasoline than ethanol, but this town continues to subsidize it, under what justification? That we care about the planet? Our whole credibility is being destroyed. So when you see someone like Dana Rohrabacher throwing a fit, his argument is if you really cared about the planet, you would be taking on the corn industry, you would be willing to stand up for next generation nuclear, but you are not willing to take the heat to do what needs to address the problem that you are claiming around.

And so actions do not reflect the concerns, and that is the credibility problem we have here.

I apologize, Mr. Chairman, but every chance to be able to rattle a cage, you know, I will do it. Thank you.

Mr. BAIRD. We do know that, and I would only point out that articles in Science Magazine and Nature and others have addressed precisely the gentleman's point. So it is not at all that the science community has been silent on this. They actually have spoken about it.

Mr. BROUN. I am talking about this——

Mr. BAIRD. Oh, well, then don't take it out on these folks. Take it out on our folks.

I will recognize myself for five minutes.

FORESTRY AND OCEAN ACIDIFICATION ISSUES

I thank the panel. Two major issues for me are forests and oceans. Dr. Birdsey, when you were asked earlier by Ms. Dalhkemper about the lack of monitoring, I would added to that the CO_2 in the oceans. While the skeptics can talk about climate change, to be skeptical about ocean acidification is to skeptical about chemistry. This is an abstract computer modeling. This is CO_2, goes in water, makes carbonic acid, carbonic acid makes the minerals less available, less available minerals means coral die. You can do that. It has been done. It has been replicated. It has been tested in a number of ways, and I hope you can talk a little bit about monitoring the oceans. I have the belief that that satellite that went into the oceans instead of the atmosphere was trying to tell us something.

The second issue is forestry. So I am going to put that out there and ask the panel in a second to talk about the second issue, forestry. The renewable fuel standard and the new legislation being debated elsewhere in this building at this moment proscribes, prohibits the use of fuels from federal forests as part of biomass that would be subsidized. I think that is a terrible mistake. The dead trees and dying trees, we have a million acres of forests that need treatment in the pacific northwest. If you don't take those trees out, they are going to become carbon because they are going to burn or going to be eaten by insects, and yet we have in the name of the environment prescribed using this wood for a fuel source. I don't get it. If somebody can tell me scientifically why that is the case, I would sure welcome that.

So let me put those two things on the table and open it up.

Dr. BIRDSEY. Yeah. First I will respond a little bit about the question about monitoring oceans. I am not an expert on the oceans. I work with trees, so I am a little bit outside my area here, but as Chair of the Carbon Cycle Science Steering Group I do hear about oceans, and I can report a little bit about what that community has said.

Everything we have said about continuity of satellites and the need to continue to improve the spectral resolution of those sensors applies to the oceans as well as the land, and so I hear a lot about the need to do a better job of sensing ocean color, for example, which indicates a lot about the biological activity there.

I think the other part on the ocean side is there is not a very coordinated or sustained I should say system of direct observations. It is just a little harder to get out there. You know, there is no roads and so forth, and so to actually confirm the satellite observations with direct measurements is much more difficult in the oceans. And so I believe that is an important component that needs to be added.

Mr. BAIRD. Given that they take up 25 percent of the carbon and the——

Dr. BIRDSEY. Yeah.

Mr. BAIRD.—a great portion of our oxygen is produced by the oceans, we got problems here with that lack of data.

Dr. BIRDSEY. Yeah. I agree.

Mr. BAIRD. Dr. MacDonald.

Dr. MACDONALD. I would like to agree with your comment. The CO_2 going in the ocean is a simple process. It does create acid, and we do go out on the ocean in NOAA with our ships and have made literally thousands of measurements, and it is very clear. The ocean is becoming more acidic, and it really is almost a completely independent problem associated with the release of CO_2.

Mr. BAIRD. Thank you. Would someone like to address the forest issue, because this is a critical—Dr. Freilich, if you wanted to talk about the ocean some more, that is fine, too, but I would sure like the forest issue addressed as well.

Dr. FREILICH. I will just say one word as an oceanographer by training, I don't know much about forests, and I do a little bit about the ocean, you mentioned some of the direct measurements and the validation. And in fact, there was a joint NASA, NOAA field campaign to the Southern Ocean, which is a huge expanse, which is very difficult to get to, has very high winds, and large gas transfer rates, and it was a very successful experiment about a year, about—just about a year ago, which actually pinned down some of the key transfer rates. And this coupled with satellite measurements such as we hope to get will actually open up those huge areas to calculation.

Mr. BAIRD. Okay. Someone address the forest issue, please.

Dr. BIRDSEY. I will get started on that. Obviously there are a lot of natural disturbances taking place in the forest; wildfire, insects, and so forth. If you go into the Rocky Mountains, vast areas of dead trees are visible.

Mr. BAIRD. Go in the Cascades it is the same.

Dr. BIRDSEY. Yeah. And so we—it would essential, I think, I didn't mention this in my previous response about some of the things that are needed, but some more direct measurement of impacts of these disturbances as they occur or right after they occur would be very useful to providing a much more accurate annual estimate of emissions from forests from these disturbances.

But perhaps more important would be to understand a little bit more what is going to happen to these lands in the future. How fast are those dead, standing dead trees, for example, how fast are they going to decompose, what happens when they hit the ground, what is going to regenerate on those lands, how fast will it regrow?

Mr. BAIRD. Let me ask you a simple question, because I am out of time. Would it be better to let them burn in a forest fire or to use them as—succinct them in a form of a house or to use them at least, if you are going to burn them, to create energy as an alternative to coal?

Dr. BIRDSEY. It is clearly better to make some use of that dead material rather than let it simply decompose and add CO_2 to the atmosphere.

Mr. BAIRD. Thank you.

Mr. Tonko.

Mr. TONKO. Yes. Just briefly.

Mr. BAIRD. Actually, you are recognized for five minutes.

Mr. TONKO. Okay. I—thank you. I wasn't here for the start of the interaction with the panel and the Committee, so forgive me if it has been asked, but I think for clarification sake it is important. First, let me thank you for your professionalism and for your willingness to contribute to what is a very important dialogue.

COORDINATING DATA COLLECTION

There are a number of groups independently from the scientific community and federal agencies that get into data collection, and the ground-based and space-based information feed, the data that are collected are important, I think, to developing policy.

Is there this structural concept that consolidates and coordinates all of the work done, the data collection, in a way that can drive the most meaningful policy response? I think that is critical to a sound outcome.

Dr. BIRDSEY. We talked earlier that there is an interagency working group that tries to coordinate the activities of ten or so different federal agencies, all of which collect data in some fashion or manage the data and so forth.

But in the end a lot of that goes back to the individual agencies and departments to manage those programs. In fact, many of those programs like the forest inventory that I am most familiar with is there anyways. It is not—it wasn't set up for a climate change type of program. It was set up for a lot of other purposes to assess the status of the forests in our country, to keep track of the changes, and so forth.

But that data has become essential as a baseline for understanding what has happened for—beginning to take a look into the future as to where these forests are going, and you need that information to design the policies.

Mr. TONKO. And is it, is there a connection to the scientific community, or is it just work done within an agency or a group of agencies that is feeding that system?

Dr. BIRDSEY. I think it is really very well integrated among the scientific community. Many of the users, if not the majority of the users, are from universities or private institutions.

Mr. TONKO. Uh-huh.

Dr. BIRDSEY. Companies, and so forth. So these data systems are very widely used.

Mr. TONKO. Are there improvements any of you could cite in terms of data collection and consolidation?

Yes, sir. Dr. MacDonald.

Dr. MACDONALD. I think that our existing systems, a lot were designed for scientific reasons to, you know, understand what was happening. I think a mitigation regulatory regime will require probably a denser resolution. It will require more surface ops and actual measurements.

So we are using them for a more extensive purpose, and it will probably require additional capabilities.

Mr. TONKO. Uh-huh. Dr. Law, were you going to comment on it?

Dr. LAW. Yeah. I was going to say the same thing, is there will need to be more of a density of measurements and more comprehensive data system. Right now we have several databases, and we need a good connection between data streams and final product.

Mr. TONKO. Is there like an example, a dynamic that you could cite for us that would reinforce that thinking?

Dr. LAW. I guess I would say with the North American Carbon Program a lot of the activity that is going on there right now is bringing all of this information together to feed into the models.

Mr. TONKO. Yes. Ms. Kruger.

Ms. KRUGER. I think from the perspective of implementing a policy, we do have the measuring and monitoring technologies that we need to be confident in what we see happening, say, at a power plant or at an industrial facility. The new dimension to this discussion is to connect this now up to the scientific verification that is being done through the atmospheric measurements. I guess the scientists talk about ground truthing, and I sort of think about it as sky truthing. So is our, you know, is our policy, our policies in an aggregate way having the intended result, and if we see things that surprise us or we don't see the results that we were expecting, then we need to dig in and figure out why. Is it something that needs to happen in terms of the monitoring technologies we are using? Is there some interaction that we are missing that needs to be dealt with?

And so I agree with the comments of the others on the panel that more monitoring stations, more spatial dis-aggregation, more frequent monitoring so that we can get a better picture from the atmospheric side to be able to reconcile with what we are seeing at the very bottom-up, but the facility side will be helpful to this process that we need to engage in going forward.

Mr. BAIRD. We have been asked for a second round of questions, and I will now thank the gentleman from New York.

We will recognize the gentleman from Texas, Mr. Hall.

Mr. HALL. Yeah. I will be very brief because I am supposed to be somewhere right now. All of us have about four committees that we are trying to attend.

Mr. Chairman——

Mr. BAIRD. You are somewhere right now.

ECONOMIC CONSIDERATIONS

Mr. HALL. I am somewhere right now. I want to just, I want to ask you a question and ask you for a yes or no answer, because that is very difficult, and I know that you are here and were asked to beef your memories up on that that you are knowledgeable about, and that is monitoring and measuring and verifying greenhouse gases, and that is what we asked you to come here and testify to, and that is what you have testified to, and I appreciate that.

But what I—and I am going to make a presumption here that all of you have either been in a store, a Sears, a Wal-Mart, a Kmart, Walgreens, any of you that haven't been in some of those stores? Almost all of you have, haven't you? And I don't know much about forests or oceans, and Mr. Chairman, I know a story about an old man about my age that had applied for a job cutting timber with a company, and they asked him for a background, and he said, well, he worked for the Sahara Forest Company. And they said, well, Sahara is a desert. He said, yeah. It is now. That's not——

Mr. BAIRD. We don't get our fire policy right——

Mr. HALL. So I know nothing about forest or oceans, but I do know about——

Mr. BAIRD. Texas has neither I noticed.

Mr. HALL.—cash registers, and I want to ask you about a cash register, because that is very important. Each of you are probably pretty huge taxpayers, and as such you know that the government has a tax, has a cash register, and you send in the 15th of April every year, and we are all affected by that.

I just wanted to ask you if you will do this. As you go down through your testimony, as you go down making a decision on the future direction that we ought to go in the global warming thrust, is that you remember that there is a cash register and that somebody has got to pay, and remember that there are costs involved in it, and remember that there are taxes involved in it. That is the way the government extracts its money to pursue something like this. That you will certainly know that if we don't have help from China, Russia, Mexico, India, and I could go on and on, that we can't clean the world.

And I just ask you to take all that into consideration and remember that there is a giant thing there as you can't get out of any of those stores without going by that cash register. And that is what this Nation has got to do, not to endanger the economy or have generational theft from youngsters not even born yet by putting taxes upon them. That you consider that.

And that is all I ask. You are good Americans, and you care about this country, and you cared enough to come give your time today. I just want to ask you to remember that.

Mr. Chairman, I yield back my time.

Mr. BAIRD. I thank the gentleman.

I will recognize myself for five minutes.

Could you talk briefly about the percentage—very briefly. What is the percentage of CO_2 put out, global CO_2 put out by the United States of America at present?

Ms. KRUGER. I don't have the exact percentage for you, but it is on the order of 20 percent.

Mr. BAIRD. And we are about what percentage of the world's population? Three.

Ms. KRUGER. Three.

Mr. BAIRD. I think. Three to five. I mean, you can quibble a little but—so we are a small percentage of the population, we produce a large percentage of the greenhouse gases. So follow up on Mr. Hall's observations. If there is accuracy that ocean acidification, overheating of the climate are occurring, what are the economic costs to the next generation of that if we don't keep that in check?

Any thoughts about that? We got to get some economists. My wife is an economist. She will whack me over the head and say, get an economist there. They will talk about that.

Ms. Kruger.

Ms. KRUGER. I am not an economist. I am not a scientist either, so I am not going to——

Mr. BAIRD. You are perfect. I am not getting much from the scientists here so——

Ms. KRUGER. Yeah. Yeah. What I would say is there is an enormous amount of work under way in the economic community coordinating with the scientific community to try to understand the costs of various climate change impacts, including the impacts of ocean acidification on coral reefs and in terms of both the ecosystems and the—and tourism and the like and—but looking across the broad range.

And I think it is a very complicated and challenging topic because some of these costs can be readily monetized and other things are much more difficult to put a value on. But there is a major effort underway in the economic community to tackle that.

Mr. BAIRD. Given the topic of the hearing about monitoring anthropogenic CO_2 or not just anthropogenic really, but in your scientific judgment do we have sufficient evidence of a linkage between anthropogenic CO_2 and increase in CO_2 in the atmosphere? Let us take that first. Let us set the temperature change aside and the acidification change aside. Is there a link between anthropogenic CO_2 and global atmosphere? Just quick yes or no around, down the line.

Dr. MACDONALD. Yes.

Dr. LAW. Yes.

Dr. BIRDSEY. Yes.

Dr. FREILICH. Yes.

Ms. KRUGER. Yes.

Dr. HEBER. I am—this is not my area, but I am skeptical as I indicated earlier.

Mr. BAIRD. Meaning you don't think that the historical measurements of CO_2, atmospheric CO_2 concentration suggests that there is any relationship to all this fossil fuel we have been burning and the concentration of CO_2 in the atmosphere change? Let us set aside the temperature change. Just CO_2.

Dr. HEBER. Right. I am skeptical that there is sufficient evidence to absolutely conclude that CO_2 production from human activities has created that significant amount of increase in CO_2. There are other effects such as volcanoes, et cetera, and natural cycles.

Mr. BAIRD. Okay. Do you believe that there has been an increase in CO_2 based on historical monitoring?

Dr. HEBER. I am not an expert in studying ice cores and that sort of thing, but I understand that there has been an increase in CO_2 in recent years, since it has been measured.

Mr. BAIRD. Yes. Do you believe that the burning of fossil fuels creates CO_2?

Dr. HEBER. Yes.

Mr. BAIRD. Do you believe we burn a lot of fossil fuels?

Dr. HEBER. Yes.

Mr. BAIRD. Do you believe that produces a lot of CO_2?

Dr. HEBER. Yes.

Mr. BAIRD. And do you—where do you think it goes?

Dr. HEBER. It goes into the atmosphere.

Mr. BAIRD. Okay. And the ocean. Apparently 25 percent roughly.

Dr. HEBER. And some of it is used by plants, too.

Mr. BAIRD. Yes. No question about that. If we look at the monitoring process, we actually had a hearing a few weeks back that suggested there was enough ambiguity that might make a cap-and-trade system somewhat difficult to monitor, even domestically. Certainly the non-point source. If you look at, you know, we have got some mechanisms to monitor coal plants, for example, but it is much more difficult to track at the pump or the tailpipe, those.

Is there any reason—well, I am going to—I will defer. The question would run us into far more than—the question I was going to ask is there is a lot of folks in this town wedded to cap-and-trade. I think there is a legitimate argument that the complexities of a cap-and-trade system along the lines of what Mr. Bilbray presented might cause us to suggest that a carbon tax is more elegant, more efficient, more defensible in many ways economically, but I will leave that.

Mr. Rohrabacher is recognized for five minutes.

Mr. ROHRABACHER. Thank you, Mr. Chairman.

THE HUMAN CONTRIBUTION OF GREENHOUSE GASES

What percentage of the atmosphere, of the air, what percentage of that is CO_2? Come on. We got the experts here. What percentage of the air is CO_2?

Dr. GALLAGHER. Approximately 21 percent.

Mr. ROHRABACHER. Twenty-one percent of the air is CO_2?

Dr. GALLAGHER. No, no. That is——

Dr. HEBER. CO_2 is approximately, around 400 PPM, which is around——

Dr. GALLAGHER. Point 03 percent.

Dr. HEBER. Point 03?

Mr. ROHRABACHER. So it is not 21 percent. It is .0—what was that? Three? Point 03 percent of the—what we are studying is CO_2.

Dr. HEBER. Dr. Gallagher, you were talking about oxygen, weren't you? Okay.

Mr. ROHRABACHER. All right. Now——

Dr. GALLAGHER. O_2.

Mr. ROHRABACHER. Yeah. CO_2. Of that CO_2 how much of that—now, we have—we keep hearing this other 20 percent figure that the United States is responsible for 20 percent of the CO_2. Well, that really isn't the case, is it? Of the CO_2 that is 20 percent of the man-made CO_2. Correct? And how much of that .03 percent of that, how much of that is man made?

Dr. MACDONALD. The—about a third of it, Congressman.

Mr. ROHRABACHER. Okay.

Dr. MACDONALD. So we started——

Mr. ROHRABACHER. Do we agree? Is that agreed with the panel? That is a lot higher than anything—I have been through many hearings like this. The biggest thing I have ever heard is five to 10 percent. Now you are saying it has gone up to 30 percent. Is that right?

Dr. MACDONALD. Congressman, we started at 280 when we started putting industrial gases in, and we are now at 385, so it is approximately a third.

Mr. ROHRABACHER. So the panel agrees with that? A third of all the CO_2 that is being put into the atmosphere comes from human sources. Is that agreed? Agree with that? Okay. I don't hear any—what about you? Do you agree with that? Okay.

That is contrary, let me just note that that is contrary to what has been testified before this committee on several occasions by other scientists. But—so it is one-third of the .03, so you say .01 is what human beings are contributing to this. Is that what you are saying? Is that right?

Dr. MACDONALD. Yes, sir.

Mr. ROHRABACHER. Okay, and .01 and of that 20 percent of that is America's contribution of that. That would be—I am not—it is miniscule, ultra miniscule, and the changes the you would expect that we can actually change the amount of CO_2 through severe regulation or whatever cap-and-trade or whatever, what percentage of that human contribution to CO_2 could we expect to see without destroying the economy, et cetera, which we have heard about? What is the percentage would you expect that we would be able to eliminate? Are we talking about just setting the cap on where it is now? Are we talking about actually decreasing it? How much could we decrease it without hurting our economy? Maybe 10 percent or 20 percent of what we are currently contributing? Would that be fair?

In other words, are we expecting a 10 to 20 percent decrease of what we are currently contributing? Would that be something that would not be so catastrophic to our economy that it would damage the standard of living of our people? And then what percentage of that, what percentage of that is the percentage that we are talking about in the air? What kind of contribution would that make?

I think what we are talking about, Mr. Chairman, is a massive effect on the lives of our people and a miniscule, if not even recordable, impact on the amount of CO_2 going into the air. It is very easy to say, oh, the United States put 20 percent of the CO_2 into the air, as if that is a huge impact on the air, but what we are now seeing that just represents a very tiny, insignificant part of what is going on on this planet in terms of air.

Were there other times before humankind even existed when the CO_2 was a lot higher than that? How much higher was it in the past even before human beings existed?

Dr. MACDONALD. Congressman, in the last several hundred thousand years we are well above what we were in——

Mr. ROHRABACHER. Yeah.

Dr. MACDONALD.—very ancient times——

Mr. ROHRABACHER. Uh-huh.

Dr. MACDONALD.—say 100 million years ago. There were higher amount than there are now.

Mr. ROHRABACHER. Okay. Right. And in terms of the history of the planet, you know, we are talking about the last 5,000 years as being, you know, a very miniscule part of the history of the planet. In the history of the planet there have been times when say 100 million years ago what level of CO_2 was in the air at that time?

Dr. MACDONALD. Congressman, in ancient history like 100 million years ago there was significantly higher than there is now.

Mr. ROHRABACHER. Right. I have heard, you know, perhaps four or five times the amount, maybe even ten times the amount. During that time period did plants—oh, I am sorry.

Mr. BAIRD. That is all right.

Mr. ROHRABACHER. Could I ask one last-minute—did plants and animal life thrive during that time period, or was there some huge problem that plagued humankind so the plants were less abundant and the animals were less healthy?

By the way, I am sorry I have used my time. Obviously the answer is——

Mr. BAIRD. It is a dangerous thing——

Mr. ROHRABACHER.—there were abundance of dinosaurs and other animals and an abundance of plant life, and that is why this issue is a threat.

Mr. BAIRD. It is a dangerous thing when someone has already exceeded their time limit by a minute and a half and they begin to ask you about the Mesozoic Era.

Mr. ROHRABACHER. Thank you, Mr. Chairman.

Mr. BAIRD. Mr. Bilbray for five minutes and beyond.

Mr. BILBRAY. For the record it was extra-terrestrial intervention that eliminated that dinosaur, not the CO_2 level. Okay. So, we can agree on that.

My question, Dr. MacDonald, is your baseline. You assume that everything above our baseline when we start testing is man induced. Right?

Dr. MACDONALD. The predominance of the CO_2 added is man induced.

Mr. BILBRAY. Okay. So that assumption sort of really moves towards the one extreme of an assumption rather than mostly because it is hard to quantify how much of the natural fluctuation is going on because we haven't had measurements. Right? We don't have a history of measurements prior to the baseline.

Dr. MACDONALD. We really have quite a good history in the ice cores, Congressman.

Mr. BILBRAY. Okay. The—and it is the ice cores that we are looking at. I am just looking at two issues that really kind of frustrate me with our policy is that we keep talking about the 28 percent of mobile sources and developing technology to address those as the Chairman pointed out, at the same time that we have the technology to eliminate 38 percent of just the stationary sources at the same time, you know, I guess what is it, black fuel they were talking about, Mr. Chairman? Trying to eliminate the credit for it?

Mr. BAIRD. They have already kept it out of the bill. The current bill would say that forest biomass from federal forests——

Mr. BILBRAY. Yeah.

Mr. BAIRD.—does not count towards renewable fuel.

Mr. BILBRAY. And the term black fuel or whatever they call it.

Mr. BAIRD. Well, it is a—it could be that. It depends on how you process it.

Mr. BILBRAY. That is one of the things.

Mr. BAIRD. Yes.

Mr. BILBRAY. But it is that kind of winners and losers we get into rather than looking at outcome.

CLOSING

One of the things that I really encourage with your science and let me just tell you this from practical knowledge, a huge mistake we made in California was assuming that our modeling, that our original assumptions were right. We were operating off of tailpipe emissions when we were working on automobile industry, and I think you will agree we are light years ahead of a lot of other people. I think there is over a third of the states are following our new emission standards.

But one of the things that really helped us get back on track that we were totally off, the so-called experts were dead wrong about was we grossly underestimated evaporation of emissions with automobiles, and the only reason why we were able to detect that failure is that we had remote sensing that detected that our emission reductions did not reflect our modeling standards. That is something that the experts were wrong, and the ability to go back and be able to do a reality check is why your industry or your science is so important. Because so often we love to make these assumptions and then—and not go back to make sure that, as good scientists would, that our assumptions can be proven not just in the laboratory but in real-world applications.

And there was a great example where the evaporative emission issue was so grossly underestimated, it was like 85 percent, that the air quality was not improving in the LA area basin, even though we had done extraordinary improvements with the tailpipe emissions.

And I would just like to point that out, Mr. Chairman, because I think a lot of people—I do not want to see us spending millions, if not billions of dollars about arguing the climate change issue. I want us to get—use that money to research what is and isn't working, where it is working, and continue to talk about the issue of what can be done to reduce it.

And I will say it again and again and again. I really resent the fact that this town is into winners, picking winners and losers on this issue rather than going with the good science. And the Chairman has been very cooperative with me, being brave enough for us to talk about the outcome is what matters, not who contributes to it and who is supposedly a good guy and who is a bad guy. And that is the frustration I have working again and again on this issue is everybody is looking—the bill that is being proposed on this Floor as pointed out by the Chairman is picking winners and losers based on some assumption that to me does not reflect the science that you are—you have presented to us on a lot of things and other scientists have presented to us.

And what I hate is it is being done under the guise of science, under the guise of saving the planet, and frankly—I will use the term I am sick of a town full of environmental Jimmy Swaggerts who wrap themselves in green blankets and claim that God demands that we give their money to them because they will save the earth, when, in fact, the science doesn't reflect that. And I think a lot of us got to be brave enough—and the challenge to you as scientists being willing to stand up and say what is not politically correct at the moment or acceptable among certain groups, being able to say here is the science, and that science leads me to an assumption that the system or those who are trying to say they are addressing the problem are not working with that.

And I appreciate the chance to jump into this again, Mr. Chairman, but I just think we got to stand up and say the emperor has no clothes on this issue. This is a crisis we need to address. We need to address it with real answers, not manufactured ones that reflect some agenda that has been sitting around for 30 years.

Thank you, Mr. Chairman.

Mr. BAIRD. Thank you, Mr. Bilbray.

I think at this point we will thank our witnesses and thank those others in attendance, thank the colleagues on the panel, and I appreciate very much your insightful and informative testimony. The hearing will stand adjourned. Thank you very much.

[Whereupon, at 12:13 p.m., the Committee was adjourned.]

Appendix:

ANSWERS TO POST-HEARING QUESTIONS

ANSWERS TO POST-HEARING QUESTIONS

Responses by Dr. Alexander E. "Sandy" MacDonald, Deputy Assistant Administrator for Laboratories and Cooperative Institutes, Office of Oceanic and Atmospheric Research, National Oceanic and Atmospheric Administration, U.S. Department of Commerce

Questions submitted by Representative Ralph M. Hall

Q1. Dr. MacDonald, in your testimony, you state that the only way to prove that any greenhouse gas reduction policies are actually working is through reporting and measurement of human-caused emissions.

Q1a. Do you consider emissions as a result of land-use change as human-caused? How are the indirect emissions associated with land-use change measured?

A1a. Land-use change as referred to in my testimony and in discussions of climate change is human-caused. Emissions from land-use change usually result from conversion of forests or other natural systems into agricultural land, or conversion of agricultural land into cities and suburbs. Other phenomena, such as desertification (i.e., the extreme deterioration of land in arid and dry sub-humid areas due to loss of vegetation and soil moisture), include a significant human-caused component. Human-caused land-use change can also reduce emissions. For example, carbon sequestration through reforestation is one strategy for reducing the accumulation of carbon dioxide in the atmosphere.

There are a number of ways emissions associated with land-use are measured and understood. The most recent Intergovernmental Panel on Climate Change Assessment Report (IPCC–AR4) evaluated a multitude of published, peer-reviewed, scientific reports and determined that about 20% of the increase in carbon dioxide (CO_2) emissions in the 1990s could be traced to land-use change; the remainder could be attributed to fossil-fuel emissions and cement production. Making such a determination requires information from individual ecosystems (e.g., forest and soil carbon inventories), chemical/isotopic information on emissions, and comprehensive measurements of atmospheric components. *It is the combination of these approaches that allows such assessments to be made with a high degree of confidence.* Without such a comprehensive approach, it is difficult to assess with certainty the influence of the locations, types, and distributions of emissions on the global atmosphere.

Measurements are typically classified by the scientific community as "top-down" or "bottom-up." Common "bottom-up" measurements include source-specific emissions measurements, inventory-based reporting and accounting processes, which measure the amount and estimate relative contributions of different emissions on local-to regional-scales. "Top down" measurements calculate emissions from measured global burdens, atmospheric gradients, and atmospheric lifetimes. Bottom-up approaches generally provide more accurate measurements of individual and aggregate emissions sources. Top-down approaches typically provide a more robust estimate of total, global emissions or uptake because they look at the overall picture, whereas bottom-up approaches typically provide more robust estimates of the contribution of specific sources and sinks within countries and other political jurisdictions. To fully understand the impact of emissions and the effectiveness of greenhouse gas mitigation strategies, a combination of top-down and bottom-up measurements should be utilized. For example, recent advances in measurement technology and modeling techniques have allowed regional estimates of emissions from top-down analyses to verify regional or national bottom-up inventories.

Q1b. What about from agricultural by-products such as livestock manure?

A1b. Besides CO_2, the other two major long-lived greenhouse gases emitted as a results of land use change and agricultural activity—are methane (CH_4) and nitrous oxide. The IPCC–AR4 notes that while "the global increases in carbon dioxide concentration are due primarily to fossil fuel use and land-use change . . . those of methane and nitrous oxide are primarily due to agriculture." Livestock manure management, fertilizer application, tilling and growing practices are all human activities that lead to the emission of greenhouse gases.

Emissions produced by agricultural activities and by-products are measured through both bottom-up and top-down approaches. The IPCC conclusions are derived from an abundance of published studies, particularly those including isotopes, which allow scientists to identify and quantify the sources of these emissions. These studies involve from measurements associated with the atmosphere, ecosystem types, and specific human activities.

Q1c. Forest fires can be generated through either natural or human-induced means. How would these be counted?

A1c. For the purpose of national GHG reporting, emissions from forest wildfire, no matter whether of natural or man-caused origins, are currently included if they occur/are on "managed lands" and are not included otherwise. (Managed forest lands include all forests in the lower contiguous 48 States). Annual wildfire emissions are area-based, derived from estimates of area burned and estimates of average emissions per area from fire. These two numbers are multiplied together to arrive at an emissions due to fires estimate. Wildfire emissions from interior Alaska and rangelands have not historically been included in the estimates because it has only been in the last few years the entire land-base has been considered as good practice. Prescribed fire emissions are included also in the national inventories based on the same approach and data sources.

Q2. You state that NOAA maintains a "dense observation system in North America." Please describe what you mean by dense.

Q2a. What types of monitoring and observational sensors are currently deployed in North America?

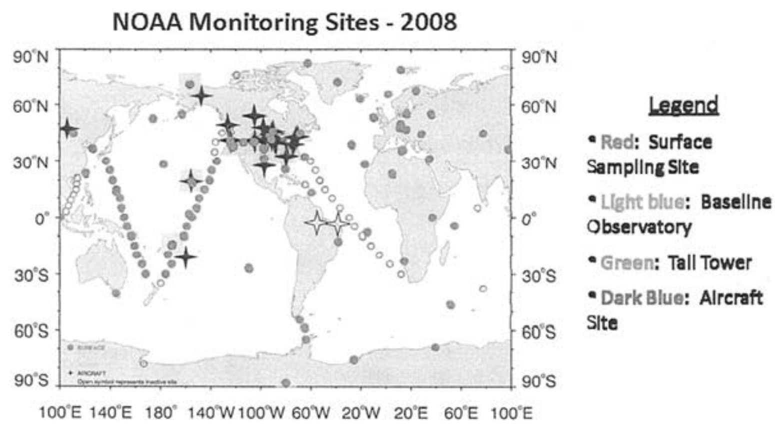
A2a. The NOAA observation system in North America is "dense" in that there are many more sites per unit area over North America than there are in the rest of NOAA's network. NOAA's sites constitute over half of the World Meteorological Organization (WMO)'s network for long-term global monitoring of greenhouse gases.

As part of its global monitoring network across North America, NOAA deploys tall tower systems, routinely deploys monitoring aircraft, and maintains surface sampling sites. Each tall tower system continuously monitors CO_2 and carbon monoxide (CO) at several heights from the ground up to 1,500 feet. Additionally, flasks are collected twice daily at these sites to obtain measures of other greenhouse gases and tracers and are subsequently analyzed for as many as 50 atmospheric gases and isotopic tracers. Aircraft fly every two weeks at each of our aircraft sites, filling flasks at 12 heights from take off up to 25,000–30,000 ft. These flasks are similarly analyzed for the full suite of greenhouse gases and tracers. NOAA also maintains one baseline observatory in North America in Barrow, Alaska.

In addition to these atmospheric observing sites maintained by NOAA, the Ameriflux program, primarily funded by the Department of Energy, operates a number of sites for measuring CO_2 fluxes from ecosystems. These measurements, though very useful, are not currently configured in such a way as to achieve the high quality, large footprint, and measurement continuity of the NOAA atmospheric observing network. NOAA is working with its Ameriflux partners to modify their sites to contribute measurements that also could be of use for top down inversions. NOAA also conducts flux measurements at some of these sites.

Q2b. How many sensors are there? How many per square mile?

A2b. Currently there are about 30 independent NOAA sampling sites in North America, which would represent about 300,000 square miles per sampling site, on average, if the sites were evenly spaced. Due to the scientific sampling design described in Question 2c that is used to site these sensors based on numerous factors including geography, the spacing of sensors on a per square mile basis is not evenly distributed across North America. A "per square mile" average, therefore, is not a useful descriptor of system coverage.



Q2c. What protocols were used to determine their placement?

A4c. The overall sampling design for North America, including the approximate number and location of air sampling sites, was developed with the U.S. scientific community and reported in the U.S. Carbon Cycle Science Plan (1999), the Report on the North American Carbon Program (2002), and the Science Implementation Strategy for the North American Carbon Program (2005). These reports were prepared by an interagency and multi-university group under the authority of the U.S. Global Change Research Program. As sites are added and models improved, however, site locations are adjusted to ensure maximum representation of each monitoring site in a comprehensive analysis. This is done with several considerations, but observing system simulation experiments are part of that process.

Q2d. Is the observation system complete enough to be considered an operational asset? What type of upgrades would be needed to make the system operational? How long would that take to implement? How much would it cost? Does your observation system interact, complement or easily integrate with observation systems built by other Federal Agencies? What is needed to make that happen?

A2d. While still considered a research and development, rather than a operational asset due to its low density, NOAA's observation system has provided a half century of highly accurate, globally distributed measurements that are routine, well calibrated, compared through a strong quality assurance program, and interconnected with and driving the course of the international observational network for greenhouse gases through the WMO. Up-to-date data from the network are available on the internet and dozens of publications using these data have been produced each year for decades. NOAA's CO_2 and CH_4 measurements are considered the "gold standard" for global measurements; its network is unparalleled. However, the network must be expanded and strengthened if it is to serve in an operational capacity.

For NOAA's observation system to be transitioned from research and development to an operational system that can discern the effectiveness of individual greenhouse gas mitigation strategies or the relative success of such efforts in specific regions, the network would need to be roughly 10 times denser than that of today. More broadly, at an interagency level, an operational system would also require higher resolution global emission transport models, better measurements of boundary layer meteorology, and higher resolution integrated land models. Finally, satellite measurements of greenhouse gases today are in their infancy and need to address issues of accuracy, precision, atmospheric interference, and regional bias. These improvements could enhance spatial coverage of CO_2, CH_4, and possibly other greenhouse gases. Validating satellite measurements properly will require a globally coherent observation and analysis system of surface- and aircraft-based measurements. Satellite measurements, once sufficiently precise and stable, could be particularly valuable for covering areas where ground-based or aircraft measurements are limited, but they will need to work together with a surface-based network, as is done for other satellite observations.

Existing information and measurement capabilities are adequate to support the initiation of national climate policies. The comprehensive interagency effort described above to improve our understanding of and ability to measure stocks and flows of carbon and nitrogen at global, regional and local scales will be important for building confidence among decision-makers and the public that we can assess whether our emission reduction and sequestration programs are effective towards mitigating climate change. We envision these tools ultimately being integrated into a comprehensive operational system of measurements.

This must be an interagency effort, as capabilities are spread among US agencies.

Q2e. Does your observation system duplicate observation or monitoring activities in other Federal agencies?

A2e. No, NOAA's observation system does not duplicate observation or monitoring activities in other Federal agencies. Observation and monitoring activities in other Federal agencies are generally complimentary to NOAA's observation system. In addition, we continue to work and collaborate with other Federal agencies engaged in greenhouse gas observation or monitoring to enhance our nation's greenhouse gas monitoring and observation network. For example, part of the NOAA greenhouse gas observation system's quality control requires comparison of results from independent measurement systems to ensure we are all on the right track. The National Science Foundation's program funds research involving longer-term greenhouse gas measurements of CO_2 at several sites, which is critical to that quality assurance effort for CO_2.

Similarly, the Department of Energy (DOE)'s Ameriflux system measures fluxes of CO_2 to improve "bottom-up" estimates; it does not duplicate NOAA's measurements, but rather is complementary. Ameriflux measurements, although extremely useful, are not currently configured in comparable quality, large footprint, and measurement continuity as the NOAA atmospheric observing network. NOAA is working with its Ameriflux partners to modify their sites to contribute measurements that also could be of use for top down inversions, thus improving the overall network.

Q3. The level of investment necessary to achieve significant emission reductions will be enormous. If the only verification of reduction policies is the fact that they are being complied with and not that they are actually helping to mitigate climate change, how can we be assured that the investments we make are the right ones?

A3. The IPCC–AR4 determined that costs for addressing climate change through the reduction of greenhouse gas emissions between now and 2050 range from an increase of 1% to a decrease of 5.5% of the global GDP, depending upon region, approaches taken, and the target value for atmospheric greenhouse gas concentrations. Models deriving these costs, however, do not consider the value of climate and economic benefits of mitigation measures, which could be significant.

The scientific evidence is very strong that the pronounced warming of the last part of the 20th century, continuing into the 21St, has been and is being driven primarily by the build-up in the atmosphere of CO_2 and other heat-trapping gases and particles caused by human activities.

There is however a distinction that needs to be made between ensuring that reduction policies are working (i.e., reductions are in fact taking place), and that the impacts of these policies are having their intended impact on the global climate system. On the first question, the federal government has a number of existing systems in place to accomplish much of the first task, including the national inventory and facility-level reporting, although there are improvements that will be needed, particularly with respect to land-use and agriculture. These improvements can be achieved through a thoughtful combination of bottom-up and top-down techniques that will necessarily vary depending on the nature of the sources and types of policies in place.

On the second question, how we detect changes in the climate as a result of emissions reductions will be addressed by numerous, diverse studies as has been done for the past several decades. Climate change is made evident not only by an overall temperature increase, but by melting of glaciers around the world, larger and more *sustained extreme* weather events, disrupted ecosystems, reduced water supplies, agricultural impacts, sea level rise, etc., as summarized and evaluated in the IPCC and national assessments. These assessments, driven by thousands of peer-reviewed publications, are typically performed every four years, although capturing sustained changes in climate trends due to human influences would likely require a longer term record of observations. Tackling human-caused climate change is a process that will require decades, at a minimum, so quadrennial evaluations of emission reduction strategies and climate change will be immensely valuable to society during the coming century.

Q4. Dr. MacDonald, in your testimony you state that objective, credible and specific information about the effectiveness of mitigation efforts is necessary to guide national policies. However, you also state that we cannot expect to see the effects of reduced emissions immediately on the rate of climate change. How do you reconcile these two concepts?

A4. The effect of greenhouse gas emissions on climate change has a built-in time delay—analogous to the time lag between when you turn up the dial on your electric blanket versus the time when the blanket actually reaches the selected temperature. In the Earth System, the amount of greenhouse gas in the atmosphere is the setting on the dial, whereas climate change represents the ultimate temperature of the blanket. Efforts to reduce greenhouse gas emissions are an attempt to stop turning up the dial. Effective greenhouse gas monitoring and information are critical to determining whether those efforts are succeeding, in other words,—is the dial continuing to be turned up and if so, what is causing it and how fast is it turning? This verification system does not verify the final temperature of the blanket (i.e., the ultimate climate change effects), but rather helps us determine what is working to stop the dial from turning up. Other information systems can provide the information on climate change effects, although this one would help in parts of those efforts as well.

Between now and roughly 2020, we have the opportunity to enhance our current observation and analysis capability and our understanding of tradeoffs and offsets to a level that will be needed over the subsequent decades. We also will establish baselines and gain information along the way that will help inform the relative success of early efforts. The myriad efforts to reduce greenhouse gas emissions and the skill with which we will be able to verify those successes will evolve and improve together with time.

Q5. Dr. MacDonald, you state that NOAA's science-based effort for monitoring greenhouse gases and aerosols in the atmosphere requires sustained, comparable measurements at an accuracy level of 0.05% or better. If this is the level of accuracy that NOAA has achieved for monitoring greenhouse gas emissions for scientific reasons, could the same level of accuracy be attained in monitoring greenhouse gas emissions in the bottom-up, individual source level that would form the basis for any mandatory emission reduction policy?

A5. The accuracies referred to in the question are for measurements of atmospheric concentrations, not source-specific emissions. Fortunately, bottom-up measurements of individual sources of CO_2. for example, do not require the high degree of accuracy required by atmospheric top down measurements of concentrations. The amount of CO_2 in a given volume of emissions from a power plant is proportionately huge compared to the amount of CO_2 that resides in the same volume of the atmosphere, on average. Because CO_2 readily disperses in the atmosphere after it is emitted, a much higher degree of accuracy is required to measure its atmospheric concentration, relative to the accuracy required to measure its emission at the source. A limitation of bottom-up measurements, however, is the accuracy of global estimates that are derived by extrapolating with bottom-up measurements.

For example, some greenhouse gas inventory estimates (e.g., transportation) do not require actual measurements, but rather are based on aggregate motor vehicle fuel consumption statistics. Others, such as estimates of forest carbon uptake, require considerable assumption about trunk and root storage. Further, emissions from soils are broadly dispersed and not readily suited to simple bottom-up measurements, and are typically addressed in greenhouse gas inventories using soil process models. Finally, as noted in the answer to question lb, methane and nitrous oxide emissions derive mainly from wetlands and agriculture. Bottom-up measurements of these emissions, while immensely valuable for understanding processes, have significant limitations with respect to capturing regional-scale or even global scale information.

Despite their limitations, these bottom-up measurements are extremely valuable and provide information at source-specific and local to regional scales that are not attainable with top-down measurements. It is only through a combination of top-down and bottom-up measurements; however, that we will be able to attain the accurate measures from source to regional to global scales that decision-makers and the public will ultimately want.

Q6. If there is currently no greenhouse gas monitoring network large enough for CarbonTracker to provide fine scale resolution with low uncertainty, what would *it take to get such a network in place? How long would it take and much would it cost?*

A6. Please also see response to questions 2d and 3.

As I noted in my written testimony, NOAA's CarbonTracker tool is widely acknowledged as the most open and effective approach to date for estimating CO_2 emissions and uptake, particularly at large spatial scales. When fully developed, CarbonTracker will make it possible to track regional emissions of CO_2 over long periods of time and to determine which areas are absorbing CO_2 from the atmosphere. Under its current configuration, CarbonTracker is effective in capturing large-scale, North American phenomena. A "top down" system like CarbonTracker helps independently validate the combined fluxes calculated from "bottom up" efforts such as estimated and measured fossil fuel emissions and biological sources. If estimates of sources and sinks do not agree with measured atmospheric concentrations, the "top down" approach provides the information needed to continually improve our understanding of the carbon cycle.

This must be an interagency effort, as the capabilities are spread among US agencies.

Q7. With the reduced functionality of the GOES–R satellite series, the never-ending problems with NPOESS that have jeopardized the ability of the program to succeed and the loss of NASA's Orbiting Carbon Observatory, how do these setbacks affect NOAA's ability to rely on space-based observations? How does this affect your assessment about NOAA's ability to assist in the development of an accurate baseline and maintaining of data continuity?

A7. Despite the challenges that NOAA, NASA and the Department of Defense are facing with the National Polar-Orbiting Operational Environmental Satellite System (NPOESS) program, the data that will result from the NPOESS instruments will significantly advance the ability to monitor global weather and climate. Similarly, NOAA and NASA are developing the Geostationary Operational Environmental Satellites-R series (GOES–R) program which will advance weather forecasting capabilities beyond what current geostationary weather satellites provide. NASA is currently assessing the next steps regarding the Orbiting Carbon Observatory and NOAA awaits its decision.

NOAA currently monitors the climate from a variety of ground-based, space-based, and airborne platforms. Existing platforms contribute significantly to an accurate greenhouse gas baselines. In fact, data continuity over time is guaranteed by the ground-based network, rather than the spacebased network. The GOES–R and NPOESS operational satellites and NASA's research satellites will provide advancements over the current monitoring platforms by providing enhanced data in areas that are remote and sparsely sampled. These new data sources will complement and improve NOAA's existing global observing capabilities. As such, NOAA will continue to use existing platforms to monitor climate changes and as data from the NPOESS, GOES–R, and NASA research satellite become available, NOAA will incorporate these data into its existing monitoring systems.

Questions submitted by Representative Pete Olson

Q1. If the rate of climate change is such that we will not see the effects of emission reductions except through monitoring and verification of anthropogenic emissions, how will science determine that the actions taken are actually effective? What type of time lag are we talking about here?

A1. The effect of greenhouse gas emissions on climate change has a built-in time delay—analogous to the time lag between when you turn up the dial on your electric blanket versus the time when the blanket actually reaches the selected temperature. In the Earth System, the amount of greenhouse gas in the atmosphere is the setting on the dial, whereas climate change represents the ultimate temperature of the blanket. Efforts to reduce greenhouse gas emissions are an attempt to stop turning up the dial. Effective greenhouse gas monitoring and information are critical to determining whether those efforts are succeeding, in other words,—is the dial continuing to be turned up and if so, what is causing it and how fast is it turning? This verification system does not verify the final temperature of the blanket (i.e., the ultimate climate change effects), but rather helps us determine what is working to stop the dial from turning up.

How fast climate itself is changing and how we detect it will be addressed by numerous, diverse studies as has been done for the past several decades. Climate change is expressed not only by an overall temperature increase, but by melting of glaciers around the world, larger and more sustained extremes in weather and climate, disrupted ecosystems, reduced water supplies, agricultural impacts, sea level rise, etc., as summarized and evaluated in the IPCC and national assessments. These assessments, driven by thousands of peer-reviewed publications, are typically performed every four years, although capturing *sustained changes* in climate trends due to human influences would likely require a longer term record of observations. It is important to keep in mind, however, that tackling human-caused climate change is a process that will require decades, at a minimum, so quadrennial evaluations of emission reduction strategies and climate change will be immensely valuable to society during the coming century.

The top-down and bottom up approach discussed in my testimony is that which will be needed to validate, on regional scales, the effectiveness of emission reduction and sequestration strategies of society's choosing. NOAA is in a unique position to contribute to this need, in addition to analyzing and monitoring the complex reactions of the climate system to increased greenhouse gases over time. Both efforts will further inform society's decisions regarding greenhouse gas emissions and climate change. By monitoring tracers of emissions as well as greenhouse gases, scientists will be able to determine not only how greenhouse gas emissions are changing, but what those changes can be attributed to with respect to changes in the climate.

Q2. What type of research is being conducted that ensures the investment on the scale of billions and trillions of dollars is actually in the areas that will have the most impact on mitigating climate change?

A2. There is little doubt that direct and indirect human emissions of greenhouse gases are responsible for climate change. Three fundamental IPCC–AR4 statements together support this: (1) "warming of the climate system is unequivocal", (2) "most of the observed increase in globally averaged temperatures since the mid-20th century is very likely due to the observed increase in anthropogenic greenhouse gas concentrations," and (3) "carbon dioxide is the most important anthropogenic greenhouse gas". Thus, the "area that will have the most impact on mitigating climate change" is that of reducing greenhouse gas emissions, with an emphasis on carbon dioxide. Considerable research is being conducted, and has been for decades, to understand the causes and consequences of climate change, leading in part to the three statements above. In the U.S., much of this research has been conducted under the authority of the U.S. Global Change Research Act of 1990 and the U.S. Clean Air Act of 1990. This research has involved understanding the interactions among atmospheric greenhouse gases, the ocean, and the terrestrial biosphere and the relative contribution of human emissions to the current and evolving atmospheric amounts of these gases. Research to date shows that CO_2 emissions, owing to fossil fuel burning and land use change, have accelerated over the past 200 years, doubling the rate of emission three times per century. If society begins making efforts to change this trend and reduce CO_2 and other greenhouse gas emissions, it will be well served by an enhanced monitoring system to ensure its efforts lead to success.

Q3. In years past we have frequently heard some measure of frustration from members of the research community about the challenge of transitioning NASA-developed technologies to an operational user. Researchers often find immense value in a new NASA-developed sensor, but then become discouraged when NASA chooses not to develop a serial mission to ensure a long-term data record. With specific regard to climate monitoring, measurement and verification, how would you describe the cooperation between NASA and NOAA on the issue of research to operations?

A3. NOAA and NASA have had a long history of cooperation and collaboration pursuing the United States' goal of providing sustained space-based monitoring of the global environment. NOAA scientists frequently evaluate the measurements from relevant NASA research satellites to determine if these research missions could provide improvements to NOAA's operational products and services. Research measurements are introduced into NOAA's operational product generation process as the first stage of a research-to-operations transition. When research measurements prove to add value to NOAA's operational services, efforts are initiated to sustain the measurements after termination of the research mission. When appropriate, NOAA's National Environmental Satellite, Data, and Information Service develops plans to bring these measurements into an operational mode either on a NOAA platform, through partnerships with other space agencies, or through a data buy from the aerospace industry. The process of transitioning NASA research satellites to NOAA operations programs involves joint planning, mitigation, collaboration, and the development of scientific studies and approaches for coordinating Earth science and operational Earth monitoring programs.

NOAA works with the research community to ensure that its science needs are considered in the joint NASA-NOAA planning efforts. NOAA and NASA have developed and are implementing plans to transition the following climate measurements, which represent sensors demanifested from the NPOESS platform, from research to operational space missions:

- Altimetry measurements
- Total Solar Irradiance measurements
- Earth radiation budget measurements
- Ozone measurements

NOAA and NASA are doing collaborative planning that could support a transition of other measurements to operations platforms in the future.

NOAA and NASA agree that the current research to operations transition planning is exploratory. Institutionalizing a robust and routine transition process requires additional work. Both agencies have benefited from clear recommendations provided by the National Academies of Science and the research community to improve this process. An example of a successful NOAA-NASA-Environmental Protection Agency (EPA) collaboration is the monitoring of depletion of stratospheric ozone over Antarctica. Title VI of the Clean Air Act of 1990 required U.S. agencies to marshal their resources and bring their capabilities to bear on the problem of stratospheric ozone depletion. This section was placed in the Act in support of the Montreal Protocol on Substances that Deplete Ozone, an international agreement to which the United States is a party. Scientific analysis has shown that human emissions of chlorofluorocarbons and a few other gases were primarily responsible for changing the chemistry of the stratosphere in such a way as to rapidly and deleteriously deplete Earth's protective ozone layer. Congress authorized EPA to regulate emissions and, in Section 603 of the Clean Air Act, NOAA and NASA to monitor and report on ozone and ozone depleting substances in the atmosphere. A combination of EPA's regulation and bottom-up inventories with NOAA and NASA's satellite monitoring and assessments was necessary for success. Today, the long-lived, ozone-depleting compounds are decreasing in the atmosphere, the ozone hole has virtually stabilized, and we anticipate complete recovery in several decades.

Part of the complex space-based and in-situ monitoring effort to address atmospheric ozone depletion involved using NOAA's operational satellites and NASA research satellites, in conjunction with NOAA's world-wide network of ground-based spectrometers and its World Calibration Center for ozone to ensure consistency and enable improvement of satellite ozone measurements over the years. We anticipate a similar arrangement with greenhouse gases and look forward to working with NASA in this effort. NOAA will continue to provide space-based ozone monitoring capabilities on its next generation polar-orbiting satellites.

ANSWERS TO POST-HEARING QUESTIONS

Responses by Dr. Beverly Law, Professor, Department of Forest Ecosystems and Society; Science Chair, AmeriFlux Network, Oregon State University

Questions submitted by Representative Ralph M. Hall

Q1. Many people look to forestry and agriculture as potential sources of carbon credits. Planting trees, switching to no-till farming practices and other projects are seen as a low-hanging fruit for greenhouse gas reductions. If you are unable to take direct measurements, how are these reductions verified? What would this mean in terms of generating offset credits in a mandatory regulatory regime?

A1. Because direct measurements do not cover 100% of the land surface, inventories and eddy covariance data need to be supplemented with moderate and high resolution remote sensing data and models to map carbon stocks and fluxes. The change in carbon flux say five years after planting a forest would be based on the same methods used for the baseline, thus the uncertainty would be related to change in area (from remote sensing data) that has been treated for the project. That uncertainty is estimated to be 10–25%. It would require annual to bi-annual monitoring with remote sensing data that are used to determine area afforested or deforested as input to modeling that produces the carbon stocks and flux estimates. In terms of generating offset credits, monitoring and audits of carbon sequestration will be necessary to determine status of carbon uptake, insurance will be necessary to protect past carbon sequestration from destruction by fire or windstorms, and penalty payments will be necessary if the forest is eventually cut. Such efforts will be costly to administer, diminishing the value of the rather modest carbon credits expected from forestry (Schlesinger 2006).

Q2. In your testimony, you indicate your organization monitors and evaluates the effects of changes in land use on carbon dioxide levels. To what extent is such monitoring being done in developing countries and how confident are you in the accuracy of such measurements?

A2. The distribution of flux sites is determined by national scientific research programs, with a relatively large number in many developed countries, but few or none in developing countries. China and India recently started their own networks. Over the past 10 years, the number of sites in the global network has increased to over 400 sites worldwide with ~103 in the AmeriFlux network. The regional networks operate independently, but protocols exist or are being developed to coordinate or standardize measurements across networks for various purposes. Evaluation of the current global dataset indicates that annual errors in eddy covariance tower data typically range from 30 to 100 grams carbon per square meter ground per year (Baldocchi 2008). The AmeriFlux network has a quality assurance group to help reduce measurement and analysis error, but many developing countries do not have this, so I would think the accuracy of measurements at recently installed sites in developing countries would not be as good as in the U.S. if they do not have a QA program. Currently, uncertainties in national inventories for the net CO_2 emissions from agriculture, forestry, and other land use often range from 50% to more than 100% using inventory data for the estimates and this could be reduced by incorporating eddy covariance data and remote sensing data in ecosystem modeling, as noted earlier.

Q3. Dr. Gallagher indicated that we have not yet developed quantification systems for continuous monitoring of emissions of extended geographical areas. How large an area is generally evaluated by your measurements? To what extent do you think your methods could be applied to provide measurements on a larger scale?

A3. The spatial scale of observations from one eddy covariance tower is about one kilometer. However, the information produced at each tower reaches far beyond its proximate geographical region due to its wider scale representativeness (Hargrove et al. 2003). The towers provide valuable information on trends in ecosystem responses to management and climate, and a subset could be maintained to support verification research at relatively low cost (~$100,000 per station per year). The greatest value of eddy covariance flux data for global carbon cycle modeling is evaluating process representation in the models or assimilation of the data into the models (which is an active area of research). The integrated methods of combining eddy covariance data, inventories and modeling could be applied over the U.S. This requires sustained observations over the long-term for the remote sensing data such as Landsat (extending beyond the Landsat Data Continuity Mission), the eddy covariance data, and improvements in the forest inventories for better carbon accounting.

Citations

Baldocchi, D.D. 2008. 'Breathing' of the Terrestrial Biosphere: Lessons Learned from a Global Network of Carbon Dioxide Flux Measurement Systems. *Australian Journal of Botany* 56:1–26.

Hargrove, W.W., F.M. Hoffman, B.E. Law. 2003. New Analysis Reveals Representativeness of AmeriFlux Network. *EOS Transactions* 84:529.

Schlesinger, W.H. 2006. Carbon Trading. Science 314:1217.

ANSWERS TO POST-HEARING QUESTIONS

Responses by Dr. Richard A. Birdsey, Project Leader and Scientist, USDA Forest Service; Chair, Carbon Cycle Scientific Steering Group

Questions submitted by Chair Bart Gordon

Q1. Many people look to forestry and agriculture as potential sources of carbon credits. Planting trees, switching to no-till farming practices and other projects are seen as low-hanging fruit for greenhouse gas reductions. If you are unable to take direct measurements, how are these reductions verified? What would this mean in terms of generating off-set credits in a mandatory regulatory regime?

A1. To estimate greenhouse gas reductions from forestry or agriculture without taking direct measurements, it is feasible and practical to use estimated reductions from validated models or default conversion factors, which are applied to the area of land that is treated. Such models and conversion factors are widely available for most of the common practices applied to farms and forests in the U.S., and are continuously updated as additional measurements and research studies are implemented. Default conversation factors are available for afforestation, reforestation, and deforestation. Carbon yield models would be needed to estimate effects of changes in specific management practices such as thinning or rotation lengths. As with any estimation approach, using models or default factors may require verification. Verification may focus on whether the practice has been appropriately implemented and the technical greenhouse gas calculation methods applied correctly, although actual measurement of reductions or sequestration may be required. Examples of these approaches are available. The Department of Energy greenhouse gas registry (known as "1605b) allows reporters to use 3 estimation approaches: direct measurement, modeling, and default factors. Variations on these 3 approaches are used by California's Climate Action Reserve and the Chicago Climate Exchange. Generally, uncertainty is likely to be lower for estimates generated from direct measurements compared against models or default conversion factors. However, when many projects are aggregated together, the uncertainty associated with models or default factors is often less than that of a single project. The value of offset credits will be quantified using methods consistent with the rules as stated in the guidelines that are adopted during the rule-making process, and they will receive credit if the rules and guidelines are followed.

Complementary to these verification approaches, measurements of atmospheric greenhouse gas concentrations can also shed valuable insight into the effectiveness of greenhouse gas management strategies. Regional-scale atmospheric greenhouse gas observations can further aid in the evaluation of how a reduction or offset approach or conglomerate of approaches is working. Such information can be provided through a comprehensive, integrated, interagency greenhouse gas observation and analysis system that can reliably test estimates and models against long-term atmospheric observations, be they the result of offsets or emission reductions.

A2. Since the passage of the Renewable Fuel Standard, the numbers of acres of land that participate in the Conservation Resource Program at USDA have decreased. How has this changed the amount of carbon that is able to be stored in America's farmlands?

A2. There are several factors that influence the amount of carbon stored in farmland vegetation and soil. These include the land use, tillage practice, crop rotation, and conservation management system employed. Your question refers to the farmland land use, and in particular the land enrolled in the Conservation Reserve program (CRP).

Enrollment in the CRP has declined from 36.8 million acres at the close of fiscal year 2007 to 31.1 million acres in October, 2009 (Table 1), a 5.7 million acre decline. This decline is a net of the contract expiration for 6.5 million acres plus new enrollment of 0.8 million acres. There are several factors that contribute to this decline. First although 26 million acres were set to expire between FY 2007 and FY 2009, these acres were all given an opportunity to re-enroll or extend their contracts, so any expirations during this time were due to contract holders choosing to opt out of CRP. Second, in late 2006 crop prices began to increase, peaking in the summer of 2008, so there was less demand for CRP enrollment. Third, the Food, Conservation, and Energy Act of 2008 reduced the maximum enrollment in the CRP to 32 million acres as of October 1, 2009.

However, an offer to extend contracts on 1.5 million expiring acres in FY 2009 resulted in the extension of contracts on 1.1 million acres. These are included in the October 2009 figure of 31.1 million acres.

When considering the potential for CRP to sequester carbon, it is important to remember that CRP contracts are not permanent—they last 10–15 years, and after the contract expires, farmers may always choose to put their land back in production. So CRP per se does not ensure permanent carbon sequestration. However, the carbon sequestered by CRP has decreased as the acres enrolled decreased. Between September 2007 and September 2009 annual carbon sequestration on CRP land decreased 3.5 million metric tons, from 50.4 mmt to 46.9 mmt. Another 2.8 million acres expired on September 30, 2009, reducing estimated carbon sequestration by an estimated 2.6 mmt to 44.3 mmt.

Table 1

	Acres Enrolled: (Millions)	Carbon Sequestered per year (Million Metric tons)
2005	34.9	47.6
2006	36.0	50.6
2007	36.8	50.4
2008	34.7	47.9
Sept 2009	33.8	46.9
Oct - 2009	31.1	44.3

Q3. Dr. Birdsey, you state "steps should be taken to better integrate monitoring programs and close current data gaps" while discussing several of NASA's ongoing and future satellite systems. Could you elaborate on what steps should be taken? Are they specific to NASA, or are you speaking more broadly?

A3. A recently published paper in *Eos* (Birdsey et al. 2009) summarizes the required steps to integrate monitoring programs and close current data gaps: "Three major observation systems need improvements and must be well-coordinated to support climate policy and management for the remainder of this century: (1) an Earth observing satellite system that provides continuous measurements of key carbon-related characteristics of the Earth's atmosphere, ocean, and lands; (2) an integrated terrestrial observation system of inventories coupled with a coordinated, permanent network of intensive land and atmosphere monitoring sites; and (3) a long-term, continuous, *in situ* ocean observation system with appropriate sensors and density of monitoring sites." These steps are not specific to NASA, but rather, require interagency coordination to implement efficiently. The USGS Climate Effects Network, the NOAA climate services, and integration initiatives within the Forest Service are examples of agency efforts underway to build collaborations and fill these data gaps. Additional detail about each of these steps may be found in the following paper:

Birdsey, Richard, Nick Bates, Mike Behrenfeld, Kenneth Davis, Scott Doney, Richard Feely, Dennis Hansell, Linda Heath, Eric Kasischke, Haroon Kheshgi, Beverly Law, Cindy Lee, A. David McGuire, Peter Raymond, Compton J. Tucker. 2009. Carbon Cycle Observations: Gaps Threaten Climate Mitigation Policies *Eos,* Vol. 90, No. 34 p. 292.

Q4. In your testimony, you mention the need to improve data from forest inventories, carbon in soil, dead wood, and down woody debris. You also mention that large wildfires and tornadoes present a need for additional sampling to assess impacts. To what extent has the Forest Service been able to observe specific changes in greenhouse gas levels after these events? In your estimation, what are the most important steps we can take to try to prevent wildfires in order to preserve these ecosystems and their ability to reduce emissions?

A4. After large disturbance events, the Forest Service Forest Inventory and Analysis (FLA) program often conducts a special damage assessment that involves remeasuring permanent monitoring sample plots in the disturbed area. These are traditional forest inventory remeasurements, augmented to provide specific information about damage that can be used to estimate the amount of CO_2 and other greenhouse gases emitted to the atmosphere during and after the event. Examples include special inventories conducted after hurricanes Hugo and Katrina, and after the large blow down event in the Boundary Waters wilderness area. After large fires on National Forest lands, damage intensity and restoration needs are assessed. Greenhouse gas emissions from individual fires are not usually estimated, although some individual fires have been studied intensively with regard to greenhouse gas impacts, and a national estimate of greenhouse gas emissions from all forest fires combined is reported annually in EPA's U.S. greenhouse gas inventory report. Note that even very large individual disturbance events will not have a measurable effect on globally averaged greenhouse gas concentrations, though the emissions from each event may be estimated. This is because the effect of a single event on the average concentration of global greenhouse gases is below the detection threshold of about 1 part per million (for CO_2).

Many ecosystems are naturally dependent on fire, so their viability may be best served by facilitating fires of a frequency and intensity that are consistent with these dependencies. Because fire has been suppressed for a long time in many areas, fuels (and carbon stock) have built up to very high levels. It may be impossible to return these ecosystems to a more natural state without releasing some stored carbon to the atmosphere. This effect can be minimized to some extent when removed carbon stocks can be substituted for energy from fossil fuels without requiring large inputs of fossil fuel for transportation of the wood to the site where it is used.

Regarding steps that can be taken to prevent wildfires, there are 3 major factors that govern the probability of a wildfire: weather, fuel, and ignition. Since we cannot control the weather, prevention is focused on managing fuels and human-caused ignitions. Of these, strategic management of fuels areas is probably the best approach.

ANSWERS TO POST-HEARING QUESTIONS

Responses by Dr. Michael H. Freilich, Director, Earth Science Division, Science Mission Directorate, National Aeronautics and Space Administration (NASA)

Questions submitted by Representative Ralph M. Hall

Q1. What is notional time and cost required to re-fly OCO, and how would it compare with other similar sensors, such as the ASCENDS or the LDCM missions?

A1. Following the loss of OCO in February 2009, the mission's science team concluded that an OCO reflight or a functionally equivalent mission was necessary to advance carbon cycle science and to provide the basis for thoughtful policy decisions and societal benefits, In response, NASA evaluated a range of options to develop and launch a replacement instrument or acquire data from international missions. Of the options under consideration, the most mature and best-understood option is to rebuild an OCO mission with as few changes as possible and launch the so-called "Carbon Copy" into its planned orbit as an element of the "A-Train." Such a mission would have a development time of 28 months and cost approximately $331M. NASA also evaluated either co-manifesting an OCO standalone mission on a shared launch vehicle with LDCM or flying an OCO-Thermal Infrared Sensor (TMRS) mission, but concluded that such options would have higher costs, increased technical risk, and would likely delay the launch of LDCM; these mission scenarios are no longer under consideration.

ASCENDS has a different mission concept and uses a different technology (i.e. lasers) to measure concentrations of CO_2 than OCO. When the ASCENDS mission was proposed in the 2007 Earth Science Decadal Survey, the NRC estimated that the mission would cost on the order of $400M and should launch in the 2013–2016 timeframe. Further study by NASA has estimated the rough life cycle cost estimate of ASCENDS to be $470M. The technology development advances required for the lasers on the ASCENDS mission preclude its early flight within the next several years, until at least 2015, although budget constraints could further delay the mission. It is important to note that NASA does not formally commit to a mission's cost and schedule until Key Decision Point (KDP)–C.

Q2. The Earth Sciences Decadal Survey recommended the ASCENDS mission to fly in the 2013–2016 timeframe. What are NASA's plans with respect to ASCENDS? Is the agency committed to flying the mission?

A2. NASA is committed to the Decadal Survey priorities and mission sequence. Thus, as a Tier 2 recommended mission, NASA is committed to developing ASCENDS for flight after the Tier 1 missions.

To lay the foundation for the ASCENDS mission, NASA sponsored an open science workshop in June 2008 in order to solicit feedback on the science goals, technology needs, and mission design options associated with the mission. In April 2009, NASA sponsored an observing system simulation experiment coordination meeting. Through NASA Earth Science's technology programs, NASA is investing in technology development efforts for the CO_2 column LIDAR, the corrugated mirror telescope, and the optical receiver. In summer 2009, NASA conducted airborne flights over the Total Carbon Column Observing Network (TCCON) *in-situ* CO_2 profile measurement site in Oklahoma to examine different measurement techniques. Future flights are planned in summer 2010 to test other measurement technologies. NASA is funding all Tier II mission early pre-formulation studies at ~$2M/year for each mission in FY 2010. A workshop will be held in FY 2010 to prepare draft Level I requirements for ASCENDS, examine pathways for further technology development, and initiate further studies.

Q3. In years past we have frequently heard some measure of frustration from members of the research community about the challenge of transitioning NASA-developed technologies to an operational user. Researchers often find immense value in a new NASA-developed sensor, but then become discouraged when NASA chooses not to develop a serial mission to ensure a long-term data record. With specific regard to climate monitoring, measurement and verification, how would you describe the cooperation between NASA and NOAA on the issue of research to operations?

A3. NASA and NOAA actively cooperate through the NASA-NOAA Joint Working Ground (JWG) on Research and Operations to transition advances from NASA's research satellites to NOAA. The JWG meets quarterly to prioritize NASA measurement capabilities for transition to NOAA, evaluate process, improve the transition process, and examine other coordination activities. In the area of climate monitoring, measurement, and verification, NASA and NOAA are working together to transition sea surface topography measurements, ocean surface vector wind measurements, ocean color radiometry measurements, and ozone.

Measurements of global sea level variations are an essential component of any climate change monitoring system. NASA, in collaboration with the French Space Agency (CNES) pioneered the measurement of sea surface topography with the Topography Experiment (TOPEX)/Poseidon mission, launched in 1992, and the Jason mission, launched in 2001, The follow-on Ocean Surface Topography Mission (OSTM)/Jason-2 provided the opportunity for NOAA and the European Organization for the Exploitation of Meteorological Satellites (EUMETSAT) to actively partner with NASA and CNES to provide operational data products to the world's meteorological and oceanographic forecast agencies. In FY 2009, NOAA concluded that a follow-on Jason-3 was the optimal platform to measure global sea level variations. NASA and NOAA agreed that NOAA will assume the lead for the United States' portion of the mission.

Ocean surface vector winds play a key role in regulating the Earth's water and energy cycles, which establishes and maintains both global and regionsl climate. NASA pioneered measurements of ocean surface vector winds with the Quick Scatterometer (QuikSCAT), which was launched in 1999 and recently ceased functioning. Since NOAA routinely used QuikSCAT data as an intrinsic part of its weather forecasting, the two agencies closely collaborated as the satellite's antenna began to show signs of age and failed to rotate properly. In the near-term, NOAA, in collaboration with NASA, has engaged in discussions with the Japanese Aerospace Exploration Agency (JAXA) to fly a NOAA scatterometer on the Global Climate Observing Mission—Water (GCOM-W2) mission. The NRC's Decadal Survey recommended that NOAA take the lead on the Extended Ocean Vector Winds Mission (XOVWM) and NASA has been providing its technical expertise to NOAA in support of this mission.

Ocean color measurements provide information on climate change effects on ocean plankton and the carbon cycle. The Moderate Resolution Imaging Spectroradiometer (MODIS) Instrument on NASA's Terra and Aqua satellites are currently used to provide this data. The National Polar-orbiting Operational Environmental Satellite System (NPOESS) Preparatory Project (NPP) will fly the Integrated Program Office provided VIIRS instrument, which may continue these measurements. Beginning in FY 2009, NOAA began to look at alternative means of acquiring future ocean color measurements. In addition, NASA, NOAA, and other Federal agencies are supporting the NRC in its assessment of options to sustain global color measurements that enable continuity with previous observations and support climate research and operational requirements.

NASA and NOAA have also collaborated extensively to add capabilities to NASA's NPP mission in order to maintain data continuity and advance scientific understanding. For example, when the ozone limb profiling capability was removed from NPOESS during the Nunn-McCurdy recertification process, NASA and NOAA collaborated to provide core funding to allow the Ozone Mapping and Profiler Suite (OMPS)-Limb instrument to be added back. Similarly, NASA and NOAA manifested the Clouds and the Earth's Radiant Energy System (CERES) radiation measurements instrument first demonstrated by NASA on the Tropical Rainfall Measuring Mission (TRMM), Terra, and Aqua onto the NPP mission.

Questions submitted by Representative Pete Olson

Q1. Dr. Freilich, just last month, a co-chair of the Earth Sciences Decadal Survey, appearing before another House Committee (Appropriations Subcommittee on Commerce, Justice, Science and Related Agencies) testified that OCO should not be rebuilt. His rationale was that new technologies developed since OCO's design would allow for more precise and broader day/night measurements. Your statement seems to contradict this advice. How would you respond? Is OCO's sensor obsolete? What is the trade with using a LIDAR sensor instead of OCO's passive sensor?

A1. Following the loss of OCO in February 2009, the mission's science team concluded that an OCO reflight or a functionally equivalent mission was necessary to advance carbon cycle science and to provide the basis for thoughtful policy decisions and societal benefits—The technology development advances required for the lasers on the ASCENDS mission preclude its flight within the next several years, whereas an OCO replacement mission could be ready in 28 months. Further, in preparing the Decadal Survey, the National Research Council correctly assessed that significant technology development was required for ASCENDS and thus it would not be ready to fly early in the program.

When compared to OCO, ASCENDS has a different mission concept and uses a different technology to measure concentrations of CO_2. OCO uses a passive approach to measure the intensity of reflected sunlight off of the Earth's surface, which correlates to the concentration of CO_2 near the Earth's surface. OCO was designed to fly in the A-Train formation, which would have enabled coordinated carbon cycle measurements with instruments aboard the Aqua and Aura spacecraft. The ASCENDS active measurement approach uses lasers as the light source instead of the Sun. Such a technique enables both daytime and nighttime measurements and measurements at high latitudes in the winter. Rather than being obsolete, the smaller and simpler OCO-like instrument is attractive for long-term monitoring of near-surface CO_2 levels and offset processes owing to the fundamental lifetime limitations of laser instruments.

Q2. How would the OCO compare to similar satellites flown by Canada and Japan? What were the cost differences between those countries' programs and the US. program? From a researcher's perspective, would obtaining data from Canada or Japan be an acceptable alternative to trying to re-fly OCO?

A2. While both Canada and Japan have recently launched greenhouse gas-monitoring missions, neither the Canadian Advanced Nanospace experiment (CanX)–2 mission nor the Greenhouse gases Observing SATellite (GOSAT, also named Ibuki) have the sensitivity or accuracy of OCO. CanX–2 also fails to provide the same level of coverage that would have been achievable with OCO. For cost comparison purposes, OCO's mission cost was $240M plus an. additional $30M had been budgeted for mission operations.

The CanX–2 nanosatellite, launched in April 2008 at a cost of approximately $300K, only records greenhouse data over Toronto where the data downlink occurs. The spectral resolution of the CanX–2 spectrometer is about 100 times less than that of OCO's spectrometer and is far too coarse to yield the sensitivity required for high-precision CO_2 measurements. Unlike OCO, CanX–2 does not measure oxygen to quantify the air mass, which is required to accurately calculate CO_2 concentrations from the spectrometer data and eliminates significant errors caused by uncertainties in the surface air pressure and by scattering by thin clouds and aerosols. To date, no CanX–2 greenhouse gas data have been distributed to the scientific community and no publications have resulted from data recorded by the satellite.

GOSAT was launched by Japan in January 2009 at a cost of approximately $206M. Both OCO and GOSAT were designed to measure the absorption of sunlight reflected from the Earth's surface. However, while OCO was designed to detect both sources and sinks of CO_2, GOSAT is designed to only detect localized strong emissions of greenhouse gases rather than to quantify natural, spatially extensive CO_2 sinks. Since CO_2 emission sources tend to be more intense and spatially localized than CO_2 sinks, GOSAT was designed with less stringent signal-to-noise requirements than OCO. While both GOSAT and OCO were designed to orbit the Earth ~15 times each day, OCO was designed to collect up to 1 million high spatial resolution ($3km^2$) measurements each day while GOSAT is capable of yielding approximately 18,700 measurements each day with a $85km^2$ footprint. OCO would therefore have provided many more measurements and each measurement would have represented a much smaller ground size compared with GOSAT.

Q3. What new capabilities does NASA's fleet of UAVs offer to the monitoring and measurement community? Will UAVs help advance the science in any meaningful way, and if so, how?

A3. NASA uses a number of unmanned aircraft systems (UASs), including the Global Hawk, the Ikhana, and the Sensor Integrated Environmental Remote Research Aircraft (SIERRA), for Earth Science research given their ability to stay aloft over a small geographic region for a long period of time, to fly in dangerous (for humans) atmospheric conditions, and to fly close to the Earth's surface or in the stratosphere. UASs are used to participate in calibration and validation tests of instruments flying on satellites, test concepts for satellite instruments, and participate in field campaigns designed to discover small-scale phenomena that satellites cannot.

Of the current field campaigns scheduled for NASA's UASs, the winter 2010 Global Hawk Pacific mission (GloPac) will study trace gases, including greenhouse gases, aerosols, and dynamics of the Upper Troposphere and Lower Stratosphere in association with NASA's Aura satellite. GloPac will be the first NASA mission using the Global Hawk, which is capable of carrying 1,500 pounds of instruments to an altitude of 65,000 feet. The Global Hawk can operate for 31 hours and has a range of 11,000 nautical miles. Future missions using the Global Hawk include the Genesis and Rapid Intensification Processes (GRIP) airborne campaign in Summer 2010 to study the formation of tropical storms and their evolution into hurricanes.

The Ikhana, which has an instrument payload capability of 2000 pounds and can operate up to 40,000 feet, has an endurance of 24 hours and a range of 3,500 nautical miles. NASA instruments on board the Ikhana have been used to detect wildfire outbreaks in the western United States over the past several years and this information has been transmitted in near-real time to fire incident commanders in the field.

The SIERRA, which has an instrument payload capability of 100 pounds and can operate at up the 12,000 feet, has an endurance of 10 hours and a range of 500 nautical miles. In June and July 2009, the SIERRA participated in the Characterization of Arctic Sea Ice Experiment (CASTE) by measuring sea ice roughness, sea ice thickness, and sea ice edge. Such information helps understand the loss or maintenance of perennial sea ice cover.

Q4. How well does the Earth Sciences Decadal Survey align with efforts to better model, monitor, and measure greenhouse gas emissions? Are there missions or sensors being contemplated for greenhouse gas monitoring that does not appear within the set of missions recommended by the decadal survey?

A4. In developing its *Earth Science and Applications from Space. National Imperatives for the Next Decade and Beyond,* the NRC assumed the sl3ccessful flight of 000, as well as the Landsat Data Continuity Mission (LDCM) and the National Polar-orbiting Operational Environmental Satellite System (NPOESS) Preparatory Project (NPP), which will observe carbon sources and sinks on the land and in the ocean. The Decadal Survey missions recommended by the NRC are designed to not only further measurements of atmospheric concentrations of greenhouse gases, but to also study land and ocean processes related to CO_2 release, transport, and absorption, and how they will change in a changing climate.

Within the NRC's recommended near-term missions, the Deformation, Ecosystem Structure and Dynamics of Ice (DESDynI) mission, and to a lesser extent the Ice, Cloud, and land Elevation Satellite–II (ICESat–II), will contribute to improved estimates of above-ground.

ANSWERS TO POST-HEARING QUESTIONS

Responses by Ms. Dina Kruger, Director, Climate Change Division, Office of Atmospheric Programs, Environmental Protection Agency

Questions submitted by Representative Ralph M. Hall

Q1. NOAA has stated that it is not responsible for (or capable of) verification at the individual source level or a "bottom-up" reporting scheme and only has a monitoring system in place for aggregate data. The "bottom-up" reporting and individual source monitoring would be EPA's job.

Q1a. Does EPA have a national monitoring system for all 6 greenhouse gases at the source level?

A1a. EPA has a national monitoring system for all 6 greenhouse gases at the source level. Under the Acid Rain Trading Program, EPA has been collecting hourly CO_2 emissions data from electricity generating facilities for many years. Electricity power plants emitted 34 percent of all U.S. greenhouse gas emissions in 2007. On September 22, 2009 EPA finalized a mandatory source-level reporting rule for greenhouse gas emissions. The Mandatory Reporting Rule (MRR) increases coverage of source-level monitoring to approximately 85% of national-level U.S. emissions through the inclusion of additional industrial sectors (e.g., refineries, cement plants, landfills etc.) and "upstream" suppliers of transportation fuels. Monitoring by approximately 10,000 facilities will commence in 2010, and monitored data will begin to be reported in 2011. The approximately 15% of emissions not covered at the source level come primarily from widely dispersed area sources such as agricultural soils and livestock, which do not lend themselves well to source-level reporting.

Q1b. Specifically, what types of instruments are currently deployed? How many are there?

A1b. The measurement instruments currently deployed varies according to the emissions process and the type of facility. Continuous measurement instruments (such as continuous emissions monitoring systems (CEMS)) are appropriate tools in some but not all situations. For CO_2 emissions that result from the combustion of fossil fuel (~80% of all GHG emissions), total emissions are directly linked to the amount of carbon content in the fossil fuel (i.e., carbon in = carbon out). For sources that burn natural gas, distillate fuel oil, and other homogenous fuels, EPA's reporting system requires measured fuel flow and periodic fuel sampling for large sources to establish the total amount of carbon and CO_2 emissions. For sources that bum coal, solid waste and other more variable fuels, EPA's reporting system requires direct emissions measurement for the largest sources. Facilities reporting other types of emissions to EPA (i.e., not fossil-fuel related) use a combination of direct measurement and verified plant-specific emission factors.

Qc. What upgrades to this system are required in order to implement a national emission reduction policy? How long will it take to implement the necessary upgrades or deploy the necessary instruments?

Ac. Monitoring requirements should serve the specific needs of specific emission reduction policies. EPA's *Inventory of U.S. Greenhouse Gas Emissions and Sinks* is already well suited to assess overall national' trends in greenhouse gas emissions and the contributions of aggregated sources and sectors. EPA's facility-level Mandatory Reporting Rule will provide more detailed information about specific sources, industries and regions that are needed to inform and implement a national emission reduction policy. Congress directed EPA to create a reporting program that could serve a broad variety of potential policies. Should Congress decide to create a cap and trade program, EPA may need to make incremental improvements to the facility-level reporting program, such as moving from annual to quarterly reporting, and upgrading monitoring equipment for some sources.

Qd. Are monitoring sensors currently in existence for all sectors of the economy? What research is currently being conducted to develop these types of instruments? How long will it take to get this technology from the research phase to the deployment and implementation phase?

Ad. Accurate monitoring sensors for fossil fuel consumption are in wide-spread use because of the importance of tracking fuel for economic reasons. CEMS for CO_2 emissions are in place for over ⅓ of national emissions and over 95% of coal related CO_2 emissions. Off-the-shelf measurement technologies are available for many types of non-fossil fuel related greenhouse gas emissions, particularly when the emissions go through a central stack or vent. Advanced monitoring and measurement techniques for vented and fugitive leaks show great promise and are starting to be used in a variety of situations, such as oil and gas production fields. EPA sees a need for more work on applying monitoring sensors to emissions and sequestration in forests and agricultural soils, and for tracking deforestation in tropical countries.

Q2. Other than the electric utility industry, what other industries and sectors of the economy are currently being monitored for greenhouse gas emissions with deployed monitoring instruments? What percentage of U.S. emissions is currently being monitored real-time? If this percentage is less than 100%, then how can you verify that this percentage is accurate if you are unable to verify the total amount of greenhouse gases the U.S. emits as a whole?

A2. It is not necessary to have real-time monitoring of emissions from all sources in order to obtain an accurate assessment of total U.S. GHG emissions. EPA and the Department of Energy use the national energy accounts to calculate total U.S. carbon dioxide emissions from fossil-fuel consumption (80% of national emissions). Both agencies have a high level of confidence in our national level energy accounts because DOE gets close agreement between the bottom-up reporting of energy use and the top-down tracking of aggregate energy production and imports. EPA's *Inventory of US. Greenhouse Gas Emissions and Sinks* estimates that our national level estimate of CO_2 emissions from fossil fuel combustion are accurate to within +/−5%. Given this highly accurate national level assessment, installing real-time monitoring sensors across the entire economy (including motor vehicles) to monitor fossil fuel related emissions would involve a high cost and not necessarily lead to improved national-level information. As noted above, real-time monitoring is in place for approximately 34% of all GHG emissions, and approximately 45% of non-transportation related GHG emissions.

Approximately 20% of total national GHG, emissions come from other types of sources, many of which are more difficult to monitor than fossil fuel combustion, e.g., fugitive methane leaks from oil and gas systems, methane from landfills, nitrous oxide form soils, and methane from rice paddies and livestock. In accordance with Intergovernmental Panel on Climate Change (IPCC) Guidelines, EPA uses a combination of peer reviewed modeling and emission factor approaches to estimate GHG emissions for these sources.

More direct measurement of these sources, including the use of remote observation technologies, could help improve the accuracy of this part of the national emissions inventory.

Q3. Several weeks ago, EPA submitted a national inventory of human-caused greenhouse gas emissions as part of our on-going commitment to fulfill our obligations under the United Nations Framework Convention on Climate Change. In your testimony, you admit that EPA only monitors greenhouse gas emissions emanating from electric utilities, which is estimated to be about one-third of total U.S. greenhouse gas emissions.

Q3a. If EPA does not currently monitor all of the human-caused emissions, what is the inventory based on? How accurate is it? How can you verify its accuracy?

A3a. Overall, the national-level Inventory of U.S. Greenhouse Gas Emissions and Sinks has a calculated range of uncertainty of +5% to −1% (when compared to total gross emissions), which is based on internationally accepted and comparable procedures for uncertainty assessments of national inventories. The underlying data used to prepare the national inventory come from long-established statistical gathering services of many federal agencies, particularly the Department of Energy and USDA. For the 80% of emissions resulting from fossil fuel combustion, DOE's energy consumption statistics match up closely with top-down accounts of energy production imports, and gives the U.S. government a high degree of confidence in the inventory. As noted above, direct emissions monitoring on each source of emissions is neither practical nor would it necessarily lead to improvements in accuracy.

Qb. What is EPA's definition of human-caused emissions? Do they include indirect emissions resulting from land-use change? Or from livestock emissions? Do forest fires that are set by people count as human-caused emissions, while forest fires started by natural causes are not?

Ab. The U.S. government, as a member of the Intergovernmental Panel on Climate Change (IPCC) has adopted the IPCC's definition of anthropogenic greenhouse gas emissions and removals: *"Anthropogenic emissions and removals means that greenhouse gas emissions and removals included in national inventories are a result of human activities. The distinction between natural and anthropogenic emissions and* *removals follows straightforwardly from the data used to quanta human activity. In the Agriculture, Forestry and Other Land Use (AFOLU) Sector, emissions and removals on managed land are taken as a proxy for anthropogenic emissions and removals, and interannual variations in natural background emissions and removals, though these can be significant, are assumed to average out over time."* [1] This definition has also been adopted by each of the 193 other member countries of the IPCC. Regarding the specific issue of forest fires, all fires occurring on managed land are assumed to be anthropogenic. Consistent with the IPCC Guidelines, the *Inventory of U.S. Greenhouse Gas Emissions and Sinks* includes direct emissions and carbon stock changes from land-use change. Emissions from domesticated livestock are considered anthropogenic.

Q4. I'm curious about the difference between the National Greenhouse Gas Inventory and EPA's proposed Greenhouse Gas Reporting rule. When describing the data collection and methodologies associated with that collection for the Inventory, you freely admit that the quality of the data used varies across source categories. At the same time, you state that EPA is confident that its ESTIMATES of emissions for smaller sources are both manageable and accurate. Aren't some of the data collection methods used in the Inventory going to be used for the reporting rule? If so, how can you state that the estimates provided for compliance with the reporting rule are accurate and potentially verifiable?

A4. EPA's Mandatory Reporting Rule uses a combination of direct measurement and facility-specific calculation approaches. The calculation approaches required site-specific emission factors based on periodic process and emissions measurement, and thus reflect the conditions onsite at specific facilities. The top-down emission factors used for some sources in the annual *Inventory of U.S. Greenhouse Gas Emissions and Sinks* are broadly representative of conditions across the country but may not be directly applicable to individual facilities. The source categories with the highest uncertainty in the Inventory of US. Greenhouse Gas Emissions and Sinks represent a small share of national emissions and most of them are not included in EPA's Mandatory Reporting Rule: e.g., agricultural soils, rice paddies, livestock, surface coal mines, etc.

All data submitted to EPA through the Mandatory Reporting Rule will be verified. EPA envisions a two step verification process with a view to ensuring the collection and dissemination of high quality data. First, EPA will conduct an initial centralized review of the data which will be largely automated. EPA intends to build into the data system an electronic data QA program to help assure the completeness and accuracy of data. In addition, to verify reported data and ensure consistency, EPA may review facility-level monitoring plans and procedures, and will perform detailed, automated checks on data utilizing recent and historical data submittals, comparison against like facilities and/or other electronic audit tools where appropriate. Second, EPA intends to follow-up with facilities should potential errors, discrepancies, or questions arise through the review of reported data and conduct onsite audits of selected facilities.

[1] See, "The 2006 IPCC Guidelines for National Greenhouse Gas Inventories (2006 Guidelines)", Volume 1, Chapter 1, page 4. http://www.ipcc.nggip.iges.or.jp/public/2006g1/pdf/1__Volume1/V1__1 Ch1__Introduction.pdf.

ANSWERS TO POST-HEARING QUESTIONS

Responses by Dr. Patrick D. Gallagher, Deputy Director, National Institute of Standards and Technology, U.S. Department of Commerce

Questions submitted by Representative Ralph M. Hall

Q1. How much does NIST currently spend on the measurement science activities you outlined in your testimony, and how do you determine funding priorities in this area? How much additional funding would be needed and how long would it take to perform the research necessary to ensure confidence in a Cap-and-Trade monitoring and enforcement regime?

A1. In FY 2009, NIST spent $18.2 million on all climate change related activities, which includes the $7.5 million in increases provided by FY 2009 appropriations for Climate Change Science and Climate Change Technology programs. NIST's role in this area is to:

(1) work closely with other federal agencies (the National Aeronautics and Space Administration, the National Oceanic and Atmospheric Administration, the Environmental Protection Agency, the Department of Energy, the United States Geological Survey, the United States Department of Agriculture, and the Department of Interior) to ensure the accuracy, comparability, and quality of their measurements, and

(2) assist industry, and state and local agencies that will need new measurement capabilities to meet the requirements of any enacted greenhouse-gas accounting and mitigation program.

Currently, the NIST Climate Change Program is focused in two areas:

(1) Provide the fundamental measurement science and standards to accurately quantify sources and sinks of greenhouse gases at various spatial scales; and

(2) Develop the critical metrology necessary to ensure that ground, air, ocean, and space-based climate measurements are accurate and comparable through traceability to the International System of Units (SI).

Predicting future funding needs for this area is complicated by the fact that the details for the proposed Cap-and-Trade monitoring program for carbon emissions are still being debated. I believe the existing information and measurement capabilities are adequate to support the initiation of national climate policies. Until an agreement is reached on the accuracy requirements for greenhouse gas monitoring and reporting; however, it is difficult to fully ascertain the measurement tools and standards that will be required by government agencies as well as industry. However, regardless of the climate-related legislation that is enacted, accurate measurements of greenhouse gas sources and sinks and their effects on the climate, will be necessary.

NIST is organizing an external needs assessment workshop, to be held in FY 2010, to help identify the major measurement priorities in greenhouse gas emission measurements, which will assist NIST in identifying the future priorities and resources necessary to support any proposed greenhouse gas accounting and mitigation program.

Q2. You note in your testimony that traceability of measurements is "critical for assessing accuracy and quality" of climate change data. What is the status of traceability for the sensors and measurements that are currently deployed in space? Do they all take SI-traceable measurements? If not, how are scientists accounting for the lack of confidence in their data when reporting results?

A2. Satellite sensors generally report SI (International System of Units)-traceable measurements. NIST has collaborated with the National Aeronautics and Space Administration, the National Oceanic and Atmospheric Administration, and the United States Geological Survey, to help ensure the SI traceability of satellite sensor measurements for operational and research environmental satellites. The robustness of the traceability, as established through the quality of the prelaunch and onboard calibration and extent of validation against ground, air, and other satellite sensors, determines measurement accuracy and confidence in this claimed measurement accuracy. Satellite sensors that target the lowest measurement uncertainties require the most extensive effort at prelaunch and onboard calibration and post-launch validation. In making conclusions about a climatic trend from a set of satellite measurements, i.e., from a satellite data record, scientists consider the robustness of the SI traceability, which varies with satellite sensor and type of measurement made.

Scientists recognize the advantages for strengthening the SI-traceability of some satellite climate measurements. The recognition has led NASA to consider the Climate Absolute Radiance and Refractivity Observation (CLARREO) satellite mission in its Decadal Mission planning. CLARREO's mission includes the establishment of benchmark SI-traceable climate measurements with extremely low uncertainties.

Q3. In your testimony you indicate that some emission quantification systems, such as continuous monitoring of geographical areas are currently not available. Do you have any estimate on when such monitoring capabilities could be possible?

A3. Continuous monitoring of geographical areas poses significant emissions quantification challenges that are driven by the range of source and sink types and spatial scales found in most geographical areas. Both industry and federal, state and local government agencies will be involved. Some, but not all, of the emissions quantification tools are available to the industrial community that must use them for emission inventory determination. The initial attempts to achieve area and regional emission quantification may not meet the requirements that may be set in potential future regulatory programs. However, putting the mechanisms in place for area or regional emissions quantifications should be started early in such an ambitious program to better identify:

- Improvements to the accuracy of the wide range of measurement technologies used in emissions quantification;
- Refinements to the methodologies used to develop the total emission profile for both individual areas and for the range of areas found in the U.S.; and
- Practical metrics by which to evaluate area and regional emission profiles and to judge the performance of the monitoring program for the U.S.

A successful continuous monitoring program will require the coordination of efforts by all parties involved, including those who own the sources or sinks in an area, federal, state and local governmental agencies, the global monitoring community (e.g., World Meteorological Organization, the NOAA global network with tall towers and aircraft profiles, NASA remote sensing), and those concerned with ensuring that emissions measurements perform with sufficient accuracy. The committee should consider the need to complete the development of an area emission quantification system profile in the first 3 to 5 years of any program which required it.

Questions from Representative Pete Olson

Q1. If the Cap-and-Trade legislation were to pass and go into effect, would we be capable of ensuring accurate and fair monitoring of greenhouse gas emissions from individuals and businesses? If not, wouldn't monitoring and enforcement be possible?

A1. If a cap-and-trade program for greenhouse gas emissions is enacted, NIST's capabilities focused on measurement accuracy, in cooperation with the work of other federal agencies, would enable accurate emissions determinations that promote reliable monitoring and verification of emissions at covered facilities. Furthermore, NIST efforts to ensure accurate quantification of emissions from multiple sources (such as coal combustion for electricity generation, process-related emissions from industrial facilities, and refining operations for vehicle fuels) would contribute to market confidence in the quantities of traded emission allowances.

NIST already has some experience in this role through its involvement in the Acid Rain Program, which was enacted as part of the 1990 Clean Air Act and includes a cap-and-trade program to reduce sulfur dioxide emissions from electrical power generation plants. To support the ability of the electrical power generation sector to comply with new environmental regulations, NIST, working with the specialty gas industry, established, in collaboration with the EPA, the NIST-Traceable Reference Materials (NTRM) program to supply industry with accurate gas-mixture reference standards necessary to calibrate pollution monitoring equipment. The NTRM program has been instrumental to the success of the Acid Rain program.

Q2. How confident are you in the quality of the measurement standards established in developing countries such as China and India?

A2. The National Institute of Standards and Technology (NIST), as well as the National Measurement Institutes (NMIs) of both the Peoples Republic of China (NIM-National Institute of Measurements) and India (NPLI-National Physical Laboratory of India) are members of the International Committee of Weights and Measures (CIPM), which helps to ensure the world-wide uniformity of measurements and standards through their traceability to the International System of Units (SI). Participation of these NMIs in CIPM-sponsored comparisons of national measurement standards, as well as NMIsponsored round robins, helps to promote the quality and consistency of measurement standards throughout the world.

Q3. Could National Measurement Institutes in other countries be subjected to political pressures to falsify measurement data or standards to produce better outcomes?

A3. The integrity of climate measurements is critical to the success of any new environmental policies and regulations that are enacted. The primary method of ensuring the integrity and comparability of climate measurements from around the world is to require traceability to the International System of Units (SI). Traceability requires the establishment of an unbroken chain of comparisons to stated references that are agreed to through the International Committee of Weights and Measures (CIPM). The National Institute of Standards and Technology (NIST), as well as National Measurement Institutes (NMIs) from 53 countries, are members of the CIPM and work together to improve the accuracy and comparability of measurements and standards through SItraceability. Falsification of measurement data and standards would most likely be detected by a number of NMIs through key CIPM-sponsored measurement comparisons. The results and levels of comparability established through these rigorous comparison procedures are publically available on the CIPM website.

ANSWERS TO POST-HEARING QUESTIONS

Responses by Dr. Albert J. Heber, Professor, Agricultural and Biological Engineering Department, Purdue University

Questions submitted by Representative Ralph M. Hall

Q1. You state that emissions from animal feeding operations cannot be directly measured but can only be estimated or calculated through other measurements. Such estimations are a source of uncertainty in the monitoring results. How would these uncertainties affect the ability of these farms to comply with a mandatory reduction policy?

A1. I stated that while direct on-farm measurements are difficult and costly, they are needed to validate scientific emission models, and they allow us to test mitigation strategies. For example, direct measurements were made in the National Air Emission Monitoring Study and the data is being used to develop and validate process-based emission models.

Direct measurements, like all measurements, have an associated uncertainty as clearly explained by Dr. Gallagher in his testimony. Higher uncertainties can limit the ability of the farms to comply with mandatory reduction policies, but the uncertainties of direct measurements of emissions at confined animal feeding operations are reasonable.

Q2. Many people look to forestry and agriculture as potential sources of carbon credits. Planting trees, switching to no-till farming practices and other projects are seen as a low-hanging fruit for greenhouse gas reductions. If you are unable to take direct measurements, how are these reductions verified? What would this mean in terms of generating off-set credits in a mandatory. regulatory regime?

A2. As indicated above, direct measurements can be conducted at livestock farms, but they are relatively expensive.

Q3. Dr. Gallagher's testimony emphasizes the importance of measurements science research to ensuring the accuracy and comparability of quantitative measurements of climate change data. With respect to measurement confidence, what is the quality of the data that we currently collect? Are our sensors and data collection systems backed by the necessary measurement science noted by Dr. Gallagher? If not, how do scientists quantify and account for the lack of confidence in their data when reporting results?

A3. The measurements conducted by the National Air Emissions Monitoring Study were governed by an EPA-approved Quality Assurance Project Plan which included NIST traceability. Scientists can determine the uncertainty of their measurements and this is being done for the national study.

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