Stabilizing the Concentration of Greenhouse Gases
Implications for the Near-Term

Statement to the
Senate Committee on
Environment and Public Works

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Thank you Mr. Chairman and members of the Committee for the opportunity to testify here this morning on energy and climate change. My presence here today is possible because the US Department of Energy has provided me and my team at PNNL long-term research support. Without that support much of the knowledge base upon which I draw today would not exist. That having been said, I come here today to speak as a researcher and the views I express are mine alone. They do not necessarily reflect those of any organization. I will focus my remarks on two matters: 1. The timing of the global response to climate change needed to stabilize the concentration of greenhouse gases in the atmosphere, and 2. The need to expedite the development of technologies to achieve this goal at reasonable cost.

My remarks are grounded in a small number of important observations. First, the United States is a party to the Framework Convention on Climate Change (FCCC). The FCCC has as its objective the "stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system." (Article 2) This is not the same as stabilizing emissions. Because emissions accumulate in the atmosphere, the concentration of carbon dioxide will continue to rise indefinitely even if emissions are held at current levels or slightly reduced. Limiting the concentration of CO_2, the most important greenhouse gas, means that the global energy system must be transformed by the end of the 21^{st} century. Given the long life of energy infrastructure, preparations for that transformation must start today.

Second, research that I have conducted with Tom Wigley at the National Center for Atmospheric Research and Richard Richels at EPRI indicates that, to attain global CO_2 concentrations ranging from 350 parts per million volume (ppmv) to 750 ppmv, global emissions of CO_2 must peak in this century and then begin a long-term decline. Recall that the average concentration in 1999 was 368 ppmv and pre-industrial values were in the neighborhood of 275 ppmv. The timing and magnitude of the peak depends on the desired CO_2 concentration as well as on a variety of factors shaping future US and global technology and economy.

In 1997 global fossil fuel carbon emissions were approximately 6.6 billion tonnes of carbon per year with an additional approximately 1.5 billion tonnes of carbon per year from land-use change such as deforestation. (The values for land-use change emissions are known with much less accuracy than those of fossil fuel emissions.) Values taken from the paper Drs. Wigley, Richels and I published in *Nature* in 1996 for alternative CO_2 concentrations, peak emissions and associated timing are given in the table below:

CO_2 Concentration (ppmv)	**350**	**450**	**550**	**650**	**750**
Maximum Global CO_2 Emissions (billions of tonnes carbon per year)	8.5	9.5	11.2	12.9	14.0
Year in which Global Emissions Must Break from Present Trends	Today	2007	2013	2018	2023
Year of Maximum Global Emission	2005	2011	2033	2049	2062
Year 2100 Global Fossil Fuel Emissions (billions of tonnes carbon per year)	0	3.7	6.8	10.0	12.5

The time path of emissions will have a profound effect on the cost of achieving atmospheric stabilization. The emissions paths we developed were constructed to lower costs by avoiding the premature retirement of capital stocks, taking advantage of the potential for improvements in technology, reflecting the time-value of capital resources, and taking advantage of the workings of the natural carbon cycle—regardless of which concentration was eventually determined to "prevent dangerous anthropogenic interference with the climate." It is also important to note that the transition must begin in the very near future. For example, for a global concentration of 550 ppmv, global CO_2 emissions must begin to break from present trends (i.e. deviations of more than 100 million tonnes of carbon from present trends) within the next 10 to 15 years. Given that it takes decades to go from "energy research" to the practical application of the research within some commercial "energy technology" and then perhaps another three to four decades before that technology is widely deployed throughout the global energy market, we will likely have to make this deflection from present trends with technologies that are already developed. To reduce global emissions even further will require a fundamental transformation in the way we use energy and that will only be possible if we have an energy technology revolution and that will only come about if we increase our investments in energy R&D.

The table above shows that the global energy system, not just the United States energy system, must undergo a transition from one in which emissions continue to grow throughout this century into one in which emissions peak and then decline. Coupled with significant global population and economic growth, this transition represents a daunting task even if a concentration as high as 750 ppmv is eventually determined to meet the goal of the Framework Convention. A credible commitment to limit cumulative emissions is also needed to move new energy technologies "off the shelf" and into wide spread adoption in the marketplace.

Stabilizing the concentration of greenhouse gases in the atmosphere will require a credible commitment to limit <u>cumulative</u> global emissions of CO_2. Such a limit is unlikely to be achieved without cost. The cost of stabilizing the concentration of greenhouse gases will depend on many factors including the desired concentration, economic and population growth, and the portfolio of energy technologies that might be made available. Not surprisingly costs are higher the lower the desired concentration of greenhouse gases. They are higher for higher rates of economic and population growth. And, they are lower the better and more cost effective the portfolio of energy technologies that can be developed.

It is not well recognized that most long-term future projections of global energy and greenhouse gas emissions and hence, most estimates of the cost of emission reductions, assume dramatic successes in the development and deployment of advanced energy technologies occur for free. For example, the Intergovernmental Panel on Climate Change developed a set of scenarios based on the assumption that no actions were implemented to mitigate greenhouse gas emissions. The central reference case that assumes technological change as usual is called IS92a. This central reference scenario assumes that by the year 2100 three-quarters of all electric power would be generated by non-carbon emitting energy technologies such as nuclear, solar, wind, and hydro, and that the growth of crops for energy (commercial biomass) would account for more energy than the entire world's oil and gas production in 1985. Yet with all these assumptions of technological success, the need to provide for the growth in population and living standards around the world drive fossil fuel emissions well beyond 1997 levels of 6.6 billion tonnes of carbon per year to approximately 20 billion tonnes of carbon per year. Subsequent analysis by the IPCC as well as independent researchers serves to buttress the conclusion that even with optimistic assumptions about the development of technologies that the concentration of in the atmosphere can be expected to continue rise throughout the century.

My second point follows directly from the preceding observations. Technology development is critical to controlling the cost of stabilizing CO_2 concentrations. Improved technology can both reduce the amount of energy needed to produce a unit of economic output and lower the carbon emissions per unit of energy used.

The Global Energy Technology Strategy Program to Address Climate Change is an international, public/private sector collaboration[1] advised by an eminent Steering

[1] Sponsors of the program were: Battelle Memorial Institute, BP, EPRI, ExxonMobil, Kansai Electric Power, National Institute for Environmental Studies (Japan), New Economic and Development Organization (Japan), North American Free Trade Agreement–Commission for Environmental Cooperation, PEMEX (Mexico), Tokyo Electric Power, Toyota Motor Company, and the US Department of Energy. Collaborating research institutions were: The Autonomous National University of Mexico, Centre International de Recherche sur l'Environnment et le Developpement (France), China Energy Research Institute, Council on Agricultural Science and Technology, Council on Energy and Environment (Korea), Council on Foreign Relations, Indian Institute of Management, International Institute for Applied Systems Analysis (Austria), Japan Science and Technology Corporation, National Renewable Energy Laboratory, Potsdam Institute for Climate Impact Research (Germany), Stanford China Project, Stanford Energy Modeling Forum, and Tata Energy Research Institute (India).

Group[2]. Analysis conducted at the Pacific Northwest National Laboratory as well as in collaborating institutions during Phase I supports the need for a diversified technology portfolio. No single technology controls the cost of stabilizing CO_2 concentrations under all circumstances. The portfolio of energy technologies that is employed varies across space and time. Regional differences in such factors as resource endowments, institutions, demographics and economics, inevitably lead to different technology mixes in different nations, while changes in technology options inevitably lead to different technology mixes across time.

Technologies that are potentially important in stabilizing the concentration of CO_2 include energy efficiency and renewable energy forms, non-carbon energy sources such as nuclear power and fusion, improved applications of fossil fuels, and technologies such as terrestrial carbon capture by plants and soils, carbon capture and geologic sequestration, fuel cells and batteries, and commercial biomass. Many of these technologies are undeveloped or play only a minor role in their present state of development. Energy research and development by both the public and private sectors will be needed to provide the scientific foundations needed to achieve improved economic and technical performance, establish reliable mechanisms for monitoring and verifying the disposition of carbon, and to develop and market competitive carbon management technologies. For example, advances in the biological sciences hold the promise of dramatically improving the competitiveness of commercial biomass as an energy form.

Recent trends in public and private spending on energy research and development in the world and in the United States suggest that the role of technology in addressing climate change may not be fully understood nor appreciated. Although public investment in energy R&D has increased slightly in Japan, it has declined somewhat in the United States and dramatically in Europe, where reductions of 70 percent or more since the 1980s are the norm. Moreover, less than 3 percent of this investment is directed at technologies that, although not currently available commercially at an appreciable level, have the potential to lower the costs of stabilization significantly.

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[2] Richard Balzhiser, President Emeritus, EPRI; Richard Benedick, Former US Ambassador to the Montreal Protocol; Ralph Cavanagh, Co-director, Energy Program, Natural Resources Defense Council; Charles Curtis, Executive Vice President, United Nations Foundation; Zhou Dadi, Director, China Energy Research Institute; E. Linn Draper, Chairman, President and CEO, American Electric Power; Daniel Dudek, Senior Economist, Environmental Defense Fund; John H. Gibbons, Former Director, Office of Science and Technology Policy, Executive Office of the President; José Goldemberg, Former Environment Minister, Brazil; Jim Katzer, Strategic Planning and Programs Manager, ExxonMobil; Yoichi Kaya, Director, Research Institute of Innovative Technology for the Earth, Government of Japan; Hoesung Lee, President, Korean Council on Energy and Environment; Robert McNamara, Former President, World Bank; John Mogford, Group Vice President, Health, Safety and Environment BP; Granger Morgan, Professor, Carnegie-Mellon University; Hazel O'Leary, Former Secretary, US Department of Energy; Rajendra K. Pachauri, Director, Tata Energy Research Institute; Thomas Schelling, Distinguished University Professor of Economics, University of Maryland; Hans-Joachim Schellnhuber, Director, Potsdam Institute for Climate Impact Research; Pryadarshi R. Shukla, Professor, Indian Institute of Management; Gerald Stokes, Assistant Laboratory Director, Pacific Northwest National Laboratory; John Weyant, Director, Stanford Energy Modeling Forum; and Robert White, Former Director, National Academy of Engineering.

In summary, stabilizing the concentration of greenhouse gases at levels ranging up to 750 ppmv represents a necessary but daunting challenge to the world community. Energy related emissions of CO_2 must peak and begin a permanent decline during this century. The lower the desired concentration, the more urgent the need to begin the transition. Both a credible global commitment to limit cumulative emissions and a portfolio of technologies will be needed to minimize the cost of achieving that end including technologies that are not presently a significant part of the global energy system. Their development and deployment will require enhanced energy R&D by both the public and private sectors. Unfortunately, current trends in energy R&D are cause for concern.

Mr. Chairman, thank you for this opportunity to testify. I will be happy to answer your and the committee's questions.