THE FUTURE OF FOSSIL FUELS: GEOLOGICAL AND TERRESTRIAL SEQUESTRATION OF CARBON DIOXIDE

JOINT OVERSIGHT HEARING

BEFORE THE

SUBCOMMITTEE ON ENERGY AND
MINERAL RESOURCES

JOINT WITH THE

SUBCOMMITTEE ON NATIONAL PARKS,
FORESTS AND PUBLIC LANDS

OF THE

COMMITTEE ON NATURAL RESOURCES
U.S. HOUSE OF REPRESENTATIVES

ONE HUNDRED TENTH CONGRESS

FIRST SESSION

Tuesday, May 1, 2007

Serial No. 110-23

Printed for the use of the Committee on Natural Resources

Available via the World Wide Web: http://www.gpoaccess.gov/congress/index.html
or
Committee address: http://resourcescommittee.house.gov

U.S. GOVERNMENT PRINTING OFFICE

35-059 PDF WASHINGTON : 2007

For sale by the Superintendent of Documents, U.S. Government Printing Office
Internet: bookstore.gpo.gov Phone: toll free (866) 512–1800; DC area (202) 512–1800
Fax: (202) 512–2104 Mail: Stop IDCC, Washington, DC 20402–0001

COMMITTEE ON NATURAL RESOURCES

NICK J. RAHALL II, West Virginia, *Chairman*
DON YOUNG, Alaska, *Ranking Republican Member*

Dale E. Kildee, Michigan
Eni F.H. Faleomavaega, American Samoa
Neil Abercrombie, Hawaii
Solomon P. Ortiz, Texas
Frank Pallone, Jr., New Jersey
Donna M. Christensen, Virgin Islands
Grace F. Napolitano, California
Rush D. Holt, New Jersey
Raúl M. Grijalva, Arizona
Madeleine Z. Bordallo, Guam
Jim Costa, California
Dan Boren, Oklahoma
John P. Sarbanes, Maryland
George Miller, California
Edward J. Markey, Massachusetts
Peter A. DeFazio, Oregon
Maurice D. Hinchey, New York
Patrick J. Kennedy, Rhode Island
Ron Kind, Wisconsin
Lois Capps, California
Jay Inslee, Washington
Mark Udall, Colorado
Joe Baca, California
Hilda L. Solis, California
Stephanie Herseth Sandlin, South Dakota
Heath Shuler, North Carolina

Jim Saxton, New Jersey
Elton Gallegly, California
John J. Duncan, Jr., Tennessee
Wayne T. Gilchrest, Maryland
Ken Calvert, California
Chris Cannon, Utah
Thomas G. Tancredo, Colorado
Jeff Flake, Arizona
Rick Renzi, Arizona
Stevan Pearce, New Mexico
Henry E. Brown, Jr., South Carolina
Luis G. Fortuño, Puerto Rico
Cathy McMorris Rodgers, Washington
Bobby Jindal, Louisiana
Louie Gohmert, Texas
Tom Cole, Oklahoma
Rob Bishop, Utah
Bill Shuster, Pennsylvania
Dean Heller, Nevada
Bill Sali, Idaho
Doug Lamborn, Colorado

James H. Zoia, *Chief of Staff*
Jeffrey P. Petrich, *Chief Counsel*
Lloyd Jones, *Republican Staff Director*
Lisa Pittman, *Republican Chief Counsel*

SUBCOMMITTEE ON ENERGY AND MINERAL RESOURCES

JIM COSTA, California, *Chairman*
STEVAN PEARCE, New Mexico, *Ranking Republican Member*

Eni F.H. Faleomavaega, American Samoa
Solomon P. Ortiz, Texas
Rush D. Holt, New Jersey
Dan Boren, Oklahoma
Maurice D. Hinchey, New York
Patrick J. Kennedy, Rhode Island
Hilda L. Solis, California
Nick J. Rahall II, West Virginia, *ex officio*

Bobby Jindal, Louisiana
Louie Gohmert, Texas
Bill Shuster, Pennsylvania
Dean Heller, Nevada
Bill Sali, Idaho
Don Young, Alaska *ex officio*

SUBCOMMITTEE ON NATIONAL PARKS, FORESTS AND PUBLIC LANDS

RAÚL M. GRIJALVA, Arizona, *Chairman*
ROB BISHOP, Utah, *Ranking Republican Member*

Dale E. Kildee, Michigan
Neil Abercrombie, Hawaii
Donna M. Christensen, Virgin Islands
Rush D. Holt, New Jersey
Dan Boren, Oklahoma
John P. Sarbanes, Maryland
Peter A. DeFazio, Oregon
Maurice D. Hinchey, New York
Ron Kind, Wisconsin
Lois Capps, California
Jay Inslee, Washington
Mark Udall, Colorado
Stephanie Herseth Sandlin, South Dakota
Heath Shuler, North Carolina
Nick J. Rahall II, West Virginia, *ex officio*

John J. Duncan, Jr., Tennessee
Chris Cannon, Utah
Thomas G. Tancredo, Colorado
Jeff Flake, Arizona
Rick Renzi, Arizona
Stevan Pearce, New Mexico
Henry E. Brown, Jr., South Carolina
Louie Gohmert, Texas
Tom Cole, Oklahoma
Dean Heller, Nevada
Bill Sali, Idaho
Doug Lamborn, Colorado
Don Young, Alaska, *ex officio*

CONTENTS

OVERSIGHT HEARING ON THE FUTURE OF FOSSIL FUELS: GEOLOGICAL AND TERRESTRIAL SEQUESTRATION OF CARBON DIOXIDE.

Tuesday, May 1, 2007
U.S. House of Representatives
Subcommittee on Energy and Mineral Resources, joint with the Subcommittee on National Parks, Forests and Public Lands
Committee on Natural Resources
Washington, D.C.

The Subcommittee met, pursuant to call, at 2:06 p.m. in Room 1324, Longworth House Office Building, Hon. Jim Costa [Chairman of the Subcommittee] presiding.

Present: Representatives Costa, Grijalva, Sarbanes, Inslee, Rahall, Pearce, Brown, Shuster and Lamborn.

Mr. COSTA. The joint oversight hearing of the Subcommittee on Energy and Mineral Resources as well as the Subcommittee on National Parks, Forests and Public Lands will now come to order. This subcommittee meeting this afternoon is to deal with the future of fossil fuels, particularly the geological and terrestrial sequestration of carbon dioxide which is an issue that I think concerns many.

Before we get into my opening statement and my colleagues', the Subcommittee Chair on National Parks, Forests and Public Lands and, of course, we are very honored to have the real Chairman of the Natural Resources Committee, Chairman Rahall, here this afternoon for his opening statement as well. There are a few housekeeping functions which they inform me that I must do at each of these subcommittee meetings.

So without further ado, under Rule 4(g), the Chairman and the Ranking Member may make an opening statement. If any of the Members have any other statements, they will be included in the record under unanimous consent. Of course, that will include our other two Chairs who are here this afternoon. Additionally, under Committee Rule 4(h), additional material for the record should be submitted by Members or witnesses within 10 days after the hearing and, as I suggest at each of these subcommittee hearings, we ask that the witnesses really be helpful with our staff members and not wait until the 9th or 10th day when you provide that information because it is helpful to staff, both Minority and Majority staff. So we appreciate that cooperation.

STATEMENT OF HON. JIM COSTA, A REPRESENTATIVE IN CONGRESS FROM THE STATE OF CALIFORNIA

Mr. COSTA. Let me now take the opportunity to recognize my colleagues here but before I do let me make a brief statement. I think we all know that 50 percent of the country's electricity—in essence over two trillion kilowatt hours per year—is generated by coal. Although often thought of as a fuel of the past, obviously the facts do not hold up in that sense because there is more coal mining today in this country than ever before. The fact is that coal will continue, in my opinion and I think many others, to remain an essential part of our country's energy future, therefore the importance of this afternoon's hearing.

It has been said—but I think again it deserves repeating—the Chairman taught me this a number of years ago—that the United States is the Saudi Arabia of coal, and no one should know better than he who comes from a part of the country that is rich in coal resources. Unfortunately, we also know that coal produces the most carbon dioxide of any of the fossil fuels that we use today—roughly a third more than petroleum, double that of natural gas. So we have an issue here.

We have a challenge. Maintaining our nation's energy security as we try to reduce our dependency on foreign sources of energy while protecting the impacts of climate and climate change means that we need to use the ingenuity of American technology to figure out how we can more efficiently and cost effectively deal with the carbon dioxide emissions. Because of the importance of coal to this country and its plentiful supply, I think we need to do this sooner rather than later—and I think many of my colleagues, on a bipartisan basis, feel that way.

Therefore, that is the purpose of today's hearing, to look at how we can keep carbon dioxide out of the atmosphere, certainly significantly reduce it, and avert the impacts that it has on our climate. I live in an area in California that is moving from severe to extreme non-attainment designation status by both the Federal Environmental Protection Agency as well as the state area. Unfortunately, it is a closed-in air basin with the same challenges the south coast air basin has in southern California.

So we are concerned about CO_2 emissions and other issues that deal with both mobile and stationary sources of emissions. So one of the particular interesting avenues in geological carbon is carbon sequestration, as the scientists tell us literally taking the carbon dioxide out of the fuel and sticking it underground where it can stay sequestered, we believe, for thousands of years. The United States is currently surveying a number of areas where we think carbon dioxide could be stored underground in saline formations for literally hundreds of years in a safe fashion.

So we will be looking forward to the witnesses today. The Department of Energy has been doing a lot of interesting work that we will look forward to hearing about. We will also see what is happening in the commercial sector by a number of the witnesses in the second panel who will testify about the commercial efforts. We also will be hearing about terrestrial sequestration which is the application of the biological efforts of trees, plants and soil to help take additional carbon dioxide out of the atmosphere. I think President Reagan spoke of that many, many years ago.

So this hearing is about our future and how we deal with the importance of coal as a source of energy as we talk about our future energy needs, at the same time trying to protect the environment. So we look forward to the witnesses today. I look forward to working with my colleagues as I always do, and I will now defer to the Subcommittee on National Parks Chair, my dear friend from Arizona, Mr. Raúl Grijalva.

STATEMENT OF HON. RAÚL M. GRIJALVA, A REPRESENTATIVE IN CONGRESS FROM THE STATE OF ARIZONA

Mr. GRIJALVA. Thank you very much, Mr. Chairman, and I am pleased to join with you, Mr. Ranking Member, and the Chairman of the full committee and our colleagues in welcoming the witnesses and the audience to this joint subcommittee oversight hearing. Today's hearing covers the topic of carbon sequestration, and in doing so we are addressing both geological and terrestrial carbon sequestration. Concern about climate change has led many to take a closer look at the ability of our national forests to sequester carbon, how to account for and measure for its carbon, coupled with different forest management practices has been a difficult issue.

Certain forest management practices and land use changes, particularly timber harvest and deforestation, can have major impacts on carbon storage. Some have argued that in order to sequester more carbon in the National Forest System we should cut older forests and replace them with young tree plantations. To do so would be a grave mistake. A number of studies have confirmed that there is a substantial amount of carbon stored in old growth forests. Old growth forests store carbon in their soil and biomass on the forest floor, and when an old growth forest is cut, a net release of carbon dioxide is released into the atmosphere.

Science confirms for us that any effort to reduce carbon emissions to the atmosphere should include strong conservation measures for our nation's old growth forests. I would like to especially welcome one of our witnesses today, Dr. Robert Schlesinger, from Duke University. I look forward to hearing more from him about the importance of old growth forest conservation and carbon sequestration.

Mr. Chairman, I also note that last Friday, April 27, was Arbor Day. J. Sterling Morton founded Arbor Day in 1885 as an annual observance dedicated to planting and the conservation of trees. Today we will also learn more about the role of reforestation in forest carbon sequestration.

In the context of this debate, I think it is important that we address the ecological principles of reforestation. Our understanding about the dynamic nature of forest ecosystems has evolved since the days of tree plantations. Thank you, Mr. Chairman. I look forward to hearing from our witnesses today.

[The prepared statement of Mr. Grijalva follows:]

Statement of The Honorable Raúl Grijalva, Chairman, Subcommittee on National Parks, Forests and Public Lands

I'm pleased to join Chairman Costa in welcoming our witnesses and audience to this joint oversight hearing of the National Parks, Forests and Public Lands Subcommittee and the Energy and Mineral Resources Subcommittee.

Today's hearing covers the topic of carbon sequestration, and in doing so we are addressing both geological and terrestrial carbon sequestration.

Concern about climate change has lead many to take a closer look at the ability of our National Forests to sequester carbon. How to account for and measure forest carbon, coupled with different forest management practices, has been a contentious issue. Certain forest management practices and land use changes, particularly timber harvest and deforestation, can have major impacts on carbon storage.

Some have argued that in order to sequester more carbon in the National Forest System, we should cut older forests and replace them with young tree plantations. To do so would be a grave mistake. A number of studies have confirmed that there is a substantial amount of carbon stored in old growth forests. Old growth forests store carbon in their soil and biomass on the forest floor, and when an old growth forest is cut, a net release of carbon dioxide is released into the atmosphere.

Science confirms for us that any effort to reduce carbon emissions to the atmosphere should include strong conservation measures for our nation's old growth forests.

I would like to especially welcome one of our witnesses today, Dr. Robert Schlesinger (Shh-less-inger), from Duke University. I look forward to hearing more from him about the importance of old growth forest conservation in carbon sequestration.

Mr. Chairman, I also note that last Friday, April 27th, was Arbor Day. J. Sterling Morton founded Arbor Day in 1885 as an annual observance dedicated to the planting and conservation of trees. Today we will also learn more about the role of reforestation in forest carbon sequestration. In the context of this debate, I think it is important that we address the ecological principles of reforestation. Our understanding about the dynamic nature of forest ecosystems has evolved since the days of tree plantations.

Thank you, Chairman Costa. I look forward to hearing from our witnesses today.

Mr. COSTA. Thank you, Mr. Chairman, for your concise statement and your points of fact, and now we will hear the gentleman from West Virginia who is the Chairman of the Natural Resources Committee, and we are very honored that he would take the time this afternoon to sit in on our joint subcommittees for this very important hearing. Chairman Rahall.

STATEMENT OF HON. NICK J. RAHALL, II, A REPRESENTATIVE IN CONGRESS FROM THE STATE OF WEST VIRGINIA

Mr. RAHALL. Thank you, Chairman Costa, for allowing me to speak to you as Subcommittee Chair on Energy and Mineral Resources, and to Chairman Grijalva the Chairman of the Subcommittee on National Parks, Forests and Public Lands, and to Ranking Member, Mr. Pearce. I commend all of you for being here today and having this very important hearing.

In my view, it is one of the most important hearings being conducted under the auspices of the Natural Resources Committee this year. Of all carbon emissions in this country, about one-third comes from power plants and other large industrial sources. If we are really going to get serious about reducing emission of greenhouse gases that give rise to climate change, then we are going to have to make the same type of commitment to carbon sequestration that this nation made decades ago in sending a man to the moon.

And when it comes to carbon emissions, there is another consideration here as well and that is of enhancing this country's national security interests. The sun does not always shine and the wind does not always blow, and even if the harvest from every single acre on which corn is grown in this country were dedicated strictly to ethanol, only about 12 percent of current gasoline usage would be displaced. So this means that if we are going to reduce our dependence on foreign sources of energy, domestic coal must remain a part of the mix and in alternative forms such as liquid and gas that can replace imported oil.

With carbon sequestration and the use of biomass feedstocks in combination with coal, liquification can provide a major source of transportation fuel with lower well-to-wheel emissions than conventional motor fuels in use today. Carbon sequestration can take place by the capture and storage of carbon dioxide in suitable geological formations such as oil fields, saline formations and aquifers and unminable coal seams or it can be accomplished by enhancing natural sinks through forest management practices.

We have been conducting enhanced oil recovery through carbon dioxide injection for years in this country but the Bureau of Land Management cannot provide us with any information on the amount that has been sequestered in this manner on public lands. This is something that I think we need to look at more closely, and I am particularly pleased that EnCana is with us here today to discuss its Weyburn Field project.

Another area I believe we need to investigate is the sequestration capacity of lands throughout this country, and I deeply appreciate Carl Bauer with the National Energy Technology Laboratory from Morgantown, West Virginia, for being with us at this hearing today, as he is at the forefront of the Federal government research efforts on carbon sequestration.

I am also pleased that the Massachusetts Institute of Technology is here to discuss part of its widely acclaimed report on the future of coal. That report notes that a nationwide program is necessary to conduct a geological assessment of the capacity for carbon capture in this country. The report also recommends that the U.S. Geological Survey play a role in that effort which would be comparable in scope to the national oil and gas assessments the Survey has conducted.

In my view, such an endeavor would complement and greatly enhance the work the Energy Department is doing so I am pleased again that MIT and the Survey are represented here as well today, and finally we should not underestimate the role of natural carbon sinks play in carbon capture. It is my understanding that Professor Schlesinger from my alma mater of Duke University is here to discuss this area as well as the National Mitigation Bankers.

In conclusion, I thank all the witnesses for being with us this afternoon and sharing their expertise, and again I thank the two Subcommittee Chairs for conducting this important hearing. Thank you, Mr. Chairman.

Mr. COSTA. Thank you, Chairman Rahall. Every time I hear you speak on coal, I learn something new, and it is our pleasure—I know I speak on behalf of my colleagues both Chairman Grijalva, myself and Mr. Pearce—it is an honor to serve with you as members of the Natural Resources Committee. So without further ado, the gentleman from New Mexico, Congressman Pearce.

STATEMENT OF HON. STEVAN PEARCE, A REPRESENTATIVE FROM THE STATE OF NEW MEXICO

Mr. PEARCE. Thank you, Mr. Chairman, and Mr. Chairman, and Mr. Chairman. All three of you. This is a heavyweight conference today. To the Chairman, as Mr. Costa referred, the Chairman, he says that the sun does not always shine and the wind does not always blow. I would recommend, sir, you come to New Mexico. The sun may not shine but about 350 days a year but the wind blows every single day. I can guarantee you that.

I really look forward to hearing from our witnesses. I think there are a lot of questions about carbon sequestration that we need to have a better understanding of. You know there is no bigger threat to our coal industry today than the current controversy surrounding climate change. Fifty-two percent of our nation's electricity comes from coal, and climate change activists want nothing more than to stop that, even if it means doubling or tripling constituents' power bills that are already very high, sending more jobs to China.

The title of today's hearing refers to carbon sequestration as the future of fossil fuels. Indeed the entire coal industry's future, and our American way of life, is being staked on the whole subject of carbon sequestration. This Congress is being urged to adopt climate change legislation with a promise that it will not be the death of the coal industry because we are going to sequester the carbon emissions.

I worry about this promise prematurely. I am not opposed to the carbon sequestration. However, as indicated in the written statement of our witnesses, there remains much to learn before carbon sequestration becomes economically practical and environmentally sound, and in case you might think that I am only coming to this question lately, it was in the 1980s when I flew the first airplane—I was flying with the head of one of the oil companies—and we were looking for CO_2. We eventually found the field that they wanted to look at in northern New Mexico.

The company laid a pipeline that went all the way from northern New Mexico to southern New Mexico, about 500 to 600 miles, in order to sequester, to inject the carbon dioxide in order to have tertiary recovery from the oil fields. I will tell you that in the last 24 to 48 months we began pumping carbon dioxide into the oil fields underneath my home in Hobbs, New Mexico, and I will tell you that the results are very, very difficult. It is a hard technology.

Almost every well head has had to be replaced with stainless steel because every time the carbon dioxide touches water it forms carbolic acid, and it literally eats away the pipelines. So as we are talking about moving carbon dioxide from the sources, let us keep in mind the technical difficulties that have not yet been solved, and when we say that we are going to put a penalty in place or we are going to put a legislation in place and the technology will come, I just want us to remember the catalytic converters on our cars.

They are to take elements out of the airstream, and one of the charts I would like to refer to is the Wall Street Journal that makes this process seem so simple, so easy. They simply show a large plant. You are going to capture all the carbon and then just pour it into the ground. That is about as far from reality, about as simplistic, and yet we are willing to—in our major newspapers—declare this is the salvation for coal. If we pass legislation that has a technology that is unproven and is very, very difficult technology to implement, then I worry about what the long-term results are going to be.

You know California mandated a couple of years ago—in 1990—that they were going to require that 10 percent of vehicles be electric, battery operated. That was to be by 2003. What California ended up doing was giving away a free golf cart with every SUV sold in order to accomplish their emissions objectives. I want us to really remember those elements that have been tried in our society but have been complete failures because of technology that does not yet exist.

I think that we must remember that there are three elements in carbon sequestration: The capturing of the carbon dioxide; the difficulties in transporting it is the second problem; and third the technologies involved in injecting and maintaining that. As policymakers, we have an obligation to base our policies on fact not popular or rhetorical spin. There is too much at stake. Too many jobs and the American economy is at stake. Too much of our consumers' pocketbooks are at stake.

You know we have often heard how Brazil has gotten energy independence through ethanol. The truth is they have been increasing their oil and gas production by 9 percent a year. Oil and gas is 85 percent of Brazil's economy, and yet we are led to believe by popular story that ethanol has caused them to be independent. I think that we owe it to the American people to seek every renewable option that we can, to do everything that we can to improve the climate, but we also have a tremendous responsibility to be concerned about what is happening to American jobs in that process.

I especially appreciate Mr. Bauer's presentations. I appreciate the fact that he shows in one of his slide shows that the U.S. has 42 times what the Middle East does in energy. I appreciate his concepts in that PowerPoint presentation that talk about energy interdependence. I think that is a very powerful concept and look forward to hearing him. Mr. Chairman, I yield back the balance of my time. Thank you.

Mr. COSTA. Thank you very much. The gentleman from New Mexico never disappoints me. You always have an illustration or some sort of a presentation.

Mr. PEARCE. We have two more if you would like to see them too.

Mr. COSTA. I am sure you do, and that always gives us a better pictorial outlook on what we are talking about here. Mr. Brown, do you have an opening statement?

Mr. BROWN. No, not at this time.

Mr. COSTA. All right. Well now we will proceed with the main event which is our witnesses, both with the first panel and the second panel. It is my honor to introduce Mr. Pat Leahy with the U.S. Geological Survey. Members, I think we owe an appropriate acknowledgment. I understand this is Mr. Leahy's last day. So he can say anything he wants. I thought it was 33 years because I know he is a young fellow but I am told actually when he counts the years that he was a student when he worked for the U.S.

Geological Survey, it is actually 40 years. So we want to honor and recognize you, Mr. Leahy, for your contributions. That is as good as it gets.

Now we want to hear your opening statement, and we have the five-minute rule even though sometimes we do not always follow it. We would like to encourage our witnesses to follow it, and we do have your written statement.

STATEMENT OF PATRICK LEAHY, ASSOCIATE DIRECTOR, UNITED STATES GEOLOGICAL SURVEY

Mr. LEAHY. Thank you, and that was very nice. It is sort of a nice capstone on a Federal career. I am pleased to get it. First of all, Chairman of the full Committee and the Chairmen and members of both Subcommittees, thank you for the opportunity to appear here today and represent the U.S. Geological Survey. I have had the privilege to serve as a witness before this subcommittee on numerous occasions throughout my career with the USGS, and I have enjoyed working with the committee staff over the years on issues of great importance to the U.S. Geological Survey, Department of the Interior and our nation.

Today I am pleased to present testimony on terrestrial sequestration and geologic capture and storage of carbon dioxide, and their role in reducing atmospheric carbon. Let me begin by saying that the challenges of addressing carbon dioxide accumulation in the atmosphere are significant. Fossil fuel usage, a major source of carbon dioxide emissions to the atmosphere, will continue in both the industrialized and developing nations of the world.

Therefore, a variety of strategies are being investigated to reduce emissions and remove carbon dioxide from the atmospheres. Such strategies include the facilitated sequestration of carbon from the air to terrestrial biomass, and the capture and storage of carbon dioxide in geologic formations. The 2005 interagency panel on climate change special report on carbon dioxide capture and storage concluded that in emission reduction scenarios, striving to stabilize global atmospheric carbon dioxide concentration at targets ranging from 450 to 750 parts per million the global storage capacity of geologic formations may be able to accommodate most of the desired captured carbon dioxide.

However, geologic storage capacity may vary on a regional and on a national scale and a more refined understanding of geologic storage capacity is needed to help address this knowledge gap. The USGS possesses the capability to develop geologically based methodologies to assess the national capacity for geologic sequestration because of our experience with national and international assessments of natural resources.

We envision the national geologic carbon dioxide storage assessment methodology would be largely analogous to the peer reviewed methodologies that the USGS has used in the assessment of oil, gas and coal resources.

In addition, the USGS' knowledge of regional groundwater aquifer systems and groundwater chemistry would allow USGS to develop methods to assess potential storage in saline aquifers. Previous studies have postulated the existence of very large storage capacities and saline aquifers but the extent to which these capacities can be utilized remains unknown. The USGS can create a scientifically based multidisciplinary methodology for geologic carbon dioxide storage assessment that can be consistently applied on a national scale.

Changing gears a little bit and talking about terrestrial carbon sequestration, their practices seek to effect the transfer of carbon between the atmosphere and the terrestrial biosphere to reduce atmospheric concentrations. Land management practices in the United States can affect the transfer of carbon from terrestrial systems into the atmosphere or good land stewardship practices can enhance the biological uptake of carbon dioxide from the atmosphere.

The knowledge gained on the benefits of terrestrial sequestration will improve our understanding of the duration and extent to which the biological uptake of the atmospheric CO_2 can be enhanced to reduce atmospheric concentrations. There are a number of research efforts that are ongoing in the USGS, and research that is needed include the capabilities of seals to retain carbon dioxide, the role of abandoned wells that may mitigate or act as migration pathways for CO_2, defining the potential mobilization of trace metals and organic materials that may be affected by carbon dioxide reactions with minerals, and also in the terrestrial area research on soil carbon dynamics focused on soil development and the build up and stabilization of soil organic matter which is critically important in explaining the process affecting the flow of carbon dioxide.

Thank you for the opportunity to present this testimony. I am pleased to answer questions you and other members of the Subcommittee may have.

[The prepared statement of Mr. Leahy follows:]

Statement of Dr. P. Patrick Leahy, Associate Director for Geology, U.S. Geological Survey, U.S. Department of the Interior

Messrs. Chairmen and Members of the Subcommittees, thank you for the opportunity to present testimony on terrestrial sequestration and geologic capture and storage of carbon dioxide and their role in reducing atmospheric carbon. In addition to these topics, I also plan to discuss in my statement today the role of science in evaluating the potential geologic storage capacity for industrial carbon dioxide and in furthering our understanding of the carbon cycle.

Introduction

Let me begin by saying that the challenges of addressing carbon dioxide accumulation in the atmosphere are significant. Fossil fuel usage, a major source of carbon dioxide emissions to the atmosphere, will continue in both industrialized and developing nations. Therefore, a variety of strategies are being investigated to reduce emissions and remove carbon dioxide from the atmosphere. Such strategies include the facilitated sequestration of carbon from the air to terrestrial biomass, including soils and the capture and storage of carbon dioxide in geologic formations.

The current atmospheric carbon dioxide concentration is approximately 380 parts per million volume and rising at a rate of approximately 2 parts per million volume annually, according to the most recent information from the Intergovernmental Panel on Climate Change (IPCC). The fraction of carbon emissions from all sources that must be eliminated or sequestered to impact the magnitude of climate change is large. For example, to stabilize carbon dioxide concentrations at about 550 parts per million volume, the extent to which carbon dioxide emissions would need to be reduced may be as much as 70 percent. Reductions of this magnitude could involve implementation of several mechanisms, including geologic storage and biological sequestration, fuel shifts from fossil sources to renewable biological sources, increased electricity generation from solar and wind systems and nuclear power, and increased efficiency of power generation, transmission, and end use. Each of these mechanisms has distinct geological, hydrological, ecological, economic and social implications that should be assessed on a wide range of scales, from molecular to basin scales, to allow informed policy discussions and decisions on implementation and deployment of technologies.

Geologic Storage of Carbon

The 2005 IPCC Special Report on Carbon Dioxide Capture and Storage concluded that, in emissions reductions scenarios striving to stabilize global atmospheric carbon dioxide concentrations at targets ranging from 450 to 750 parts per million volume, the global storage capacity of geologic formations may be able to accommodate most of the captured carbon dioxide. However, geologic storage capacity may vary on a regional and national scale, and a more refined understanding of geologic storage capacity is needed to address this knowledge gap.

Geological storage of carbon dioxide in porous and permeable rocks involves injection of carbon dioxide into a subsurface rock unit and displacement of the fluid or formation water that initially occupied the pore space. This principle operates in all types of potential geological storage formations such as oil and gas fields, deep saline water-bearing formations, or coal beds. Because the density of injected carbon dioxide is less than the density of formation water, carbon dioxide will be buoyant in pore space filled with water and rise vertically until it is retained beneath a non-permeable barrier (seal). A critical issue for evaluation of storage capacity is the integrity and effectiveness of these seals.

Terrestrial Carbon Sequestration

Terrestrial carbon sequestration practices seek to effect the transfer of carbon between the atmosphere and terrestrial biosphere (the earth and the living organisms that inhabit it) to reduce atmospheric carbon dioxide concentrations. Land management practices in the United States can affect the transfer of carbon from terrestrial systems into the atmosphere. Land conversion, especially deforestation, continues to be a significant source of global carbon dioxide emissions. Good land stewardship practices can reverse this and enhance biological uptake of carbon dioxide from the atmosphere, an approach termed terrestrial sequestration. Many of these practices, including tree planting and conservation tillage, are widely adopted and well understood. The Department of Agriculture is promoting the adoption of these practices through conservation programs implemented under the Farm Bill. The knowledge gained on the benefits of terrestrial sequestration will improve our understanding of the duration and extent to which the biological uptake of atmospheric carbon dioxide can be enhanced to reduce atmospheric concentration of carbon dioxide.

Role of the U.S. Geological Survey

While the USGS currently has no experience assessing the national geologic storage capacity, USGS-generated data and information were included in the Carbon Sequestration Atlas of the United States and Canada developed by the Department of Energy. In addition, our experience with national and international assessments of natural resources could allow USGS to develop geologically based methodologies to assess the National capacity for geologic storage of carbon dioxide. We envision the national geologic carbon dioxide storage assessment methodology would be largely analogous to the peer-reviewed methodologies used in USGS oil, gas, and coal resource assessments. In addition, the USGS' knowledge of regional groundwater aquifer systems and groundwater chemistry would allow USGS to develop methods to assess potential carbon storage in saline aquifers. Previous studies have postulated the existence of very large carbon dioxide storage capacities in saline aquifers, but the extent to which these capacities can be utilized remains unknown.

The USGS could create a scientifically based, multi-disciplinary methodology for geologic carbon dioxide storage assessment that can be consistently applied on a national scale. Some potential areas for further study include understanding the capabilities of seals to retain carbon dioxide and the role of abandoned wells that may act as migration pathways for carbon dioxide and formation water; defining the potential for mobilization of trace metals and organic materials by carbon dioxide reactions with minerals or dissolution of organic compounds; and understanding the role of bacteria and other microorganisms in water-rock-carbon dioxide interactions relevant to storage.

There are also a number of potential issues for further study pertaining to terrestrial sequestration, including the natural processes that affect carbon cycling. It is now widely recognized that the global carbon cycle and climate varied together, before human influence, as interactive components in a highly complex system of global feedbacks. These feedbacks have profound implications for the response of climate to anthropogenic carbon dioxide emissions, and for the potential response of the carbon cycle to changes in climate.

Along with our partners in the Department of Agriculture and other agencies, ongoing USGS research addresses these issues. In particular, USGS research on soil carbon dynamics focuses on soil development and the buildup and stabilization of soil organic matter, a large carbon reservoir in the terrestrial biosphere, which play key roles in water distribution, and in turn control both sediment transport and carbon production and respiration. This research is critically important in explaining the processes affecting the flow of carbon dioxide from soils. The response of soils to human land use is a significant component in the global carbon dioxide budget, and their response to climate change may cause significant feedback on a global scale. Land use—particularly agriculture—significantly alters patterns of terrestrial carbon storage and transport, nutrient cycles, and erosion and sedimentation. Current models of the terrestrial carbon cycle do not adequately account for the interactions among changes in erosion, sedimentation, and soil dynamics. Additional research on variable scales (local to global) of carbon flow would provide a more thorough understanding of the carbon cycle.

Conclusion

It is clear that addressing the challenge of reducing atmospheric carbon dioxide and understanding the effect of global climate change is a complex issue with many interrelated components. A better understanding of geologic storage potential for carbon dioxide combined with research to understand the implications of terrestrial carbon sequestration on the carbon cycle would provide a scientific foundation for future decisions regarding carbon management. We believe additional study of geologic and terrestrial opportunities will better prepare decision makers as they deal with these issues. Thank you for the opportunity to present this testimony. I am pleased to answer questions you and other Members of the Committee might have.

Mr. GRIJALVA. Thank you, Mr. Leahy. And now let me turn for your testimony, sir, Mr. Bauer.

STATEMENT OF CARL BAUER, EXECUTIVE DIRECTOR, NATIONAL ENERGY TECHNOLOGY LABORATORY

Mr. BAUER. Mr. Chairman and Chairmen of the Subcommittees, I thank you for the opportunity to be here. I represent the Department of Energy and the matter of carbon sequestration technologies and the program. It is a very important program, and as a citizen I applaud and appreciate already the knowledge you all have gained and demonstrated. So I am very encouraged as a citizen for this country that we have an opportunity to do the right thing as quickly as possible but not too fast.

The economic prosperity of the United States over the past century has been built upon our abundance of fossil fuels in North America, and the use of fossil fuels results in the release of emissions of CO_2. The economic growth of our country and the projected growth of the United States and the world energy demands is huge, and therefore the problem is huge and greatly challenging, and as a necessity we must continue to use fossil fuels to address the energy demands of this world and our country.

By capturing CO_2 before it is emitted to the atmosphere and stored in deep and underground geologic formations, fossil fuels can be used with dramatically reduced potential for impact on climate change and, depending on cost, potentially without over constraining our economic growth. This is a challenging issue to address since the technologies to capture CO_2 and fuel projects required to demonstrate the efficacy of long-term storage need to be developed and demonstrated at very large scales.

DOE has been working in three technology areas that could mitigate greenhouse gas. These areas are reducing the carbon intensity or switching to lower carbon fuels and renewables, improving efficiencies both at the supply and demand side, and developing and deploying carbon sequestration technologies on a wide scale.

Also fossil fuel energy has been supporting R and D and demonstration of CCS technologies for the past 10 years, and the Office of Science also supports basic research toward improving our understanding scientifically. CCS has a technical potential to mitigate up to 55 percent of the future U.S. CO_2 emissions as recognized in the report by the IPCC that my colleague mentioned. For CCS to have a significant impact on reducing the contribution of CO_2 in the atmosphere, however, it requires that several hundred or several thousand CCS facilities be constructed around the world using different geologic formations. This is a very significant understanding.

Just within our country—to get an understanding of what that would mean—it would be equivalent to the whole natural gas transmission storage system. It is a huge undertaking, great infrastructure required, and obviously something we need to do with great scientific care and understanding. DOE has taken a leadership role in developing these technologies through this program. The Department is developing both the core and supporting technologies through which CCS could potentially become an effective and economically viable option for reducing CO_2 emissions.

The carbon sequestration program works in concert with other programs that are developing complimentary technologies that are integral to fossil fuel power generation with carbon capture: Advanced integration, combined gas mutations, advanced turbines, fuel cells, gas to liquids and coal to liquids programs and advanced research for the materials. Successful R and D could enable carbon control technologies to overcome the technical and economic barriers in order to achieve cost effective CO_2 capture and sequestration.

The program leverages applied basic research with field verification to assess the technical and economic viability of the greenhouse gas mitigation options. Successful carbon sequestration technology development and deployment will provide the means by which fossil fuels can continue to be used into the future carbon constrained world.

There are two major elements: Coal R and D program develops the technologies and the validation deployment assures that what is done is done safely, wisely, and in a way that we can have responsibility for the future generations that we are taking care of the environment as well as the economy.

Collectively we have set up seven partnerships around the country and regions. These regions encompass 97 percent of coal-fired CO_2 emissions, 97 percent of industrial CO_2 emissions, and 97 percent of total land mass and essentially all the geologic storage sites in the United States potentially available. There were three phases. The first phase began with an understanding through the region and looking at areas. The second phase began with small evaluations and small injections, and the third phase—which is about to begin this year—will be looking at larger scale—up to a million ton per year—carbon sequestration injections. That will take place over the next 5 to 10 years.

In a recent assessment by our partnerships, we came forth with a carbon sequestration atlas of the United States and Canada. DOE worked with United States Geological Survey, the Office of Surface Mining, United States Forest Service, and a number of oil and gas experts as well as state geological offices and state academic institutions. The atlas identifies hundreds of years of storage of potential deep saline formations, depleted oil and gas reservoirs, and unminable coal seams, over 35 billion tons of potential storage capacity. I have provided a copy on CD for Members to have for their use. It will be downloaded at our website.

[NOTE: The CD has been retained in the Committee's official files.]

DOE has been working with EPA on its permitting structure for regional carbon sequestration partnership field tests and the regulatory compliance areas are a very important area to consider as well as we go forward. With that, you have my written testimony, as you have mentioned, Mr. Chairman, and I would be available to any questions you would like to ask. Thank you for the time.

[The prepared statement of Mr. Bauer follows:]

Statement of Carl O. Bauer, Director, National Energy Technology Laboratory, U.S. Department of Energy

Mr. Chairman, Members of the Committee, it's a pleasure for me to appear before you today to discuss DOE's development of carbon sequestration technologies to mitigate climate change.

The economic prosperity of the United States over the past century has been built upon our abundance of fossil fuels in North America. The use of fossil fuels results in the release of emissions that can impact the environment, including the emission of carbon dioxide (CO_2) from power plants that contribute to global climate change.

Economic growth in the United States and the projected growth of United States and world energy demands provide an incentive for the development of technologies that permit the use of fossil fuels, such as coal, to continue to serve as a strategic resource to meet our future energy needs. Carbon capture and storage (CCS) technologies promise great opportunities to reduce the potential environmental impacts of CO_2 emissions from fossil fuel power plants. By capturing CO_2 before it is emitted to the atmosphere, and then storing it in deep underground geologic formations, fossil fuels can be used with dramatically reduced potential for impact on climate change and, depending on cost, potentially without constraining economic growth. This is a challenging issue to address, since the technologies to capture CO_2, and field projects required to demonstrate the efficacy of long-term storage, need to be developed and demonstrated at appropriate scales.

CCS and Climate Change Mitigation

DOE has been working on three technology areas that could mitigate greenhouse gas emissions. These areas include (1) reducing carbon intensity by switching to renewable or low-carbon fuels, (2) improving efficiency both on the supply and demand sides, and (3) developing and deploying CCS technologies. Wide-scale adoption of these technological solutions could substantially reduce atmospheric CO_2 releases. The Office of Fossil Energy has been supporting research, development, and demonstration (RD&D) of CCS technologies for the past 10 years. The DOE Office of Science also supports basic research towards improving our scientific understanding of the behavior of CO_2 at potential geological sites and research towards the development of methods for enhanced terrestrial sequestration in plants and soils.

CCS has the technical potential to mitigate up to 55 percent of future U.S. CO_2 emissions, as reported in the special report of the International Panel on Climate Change (IPCC) on Carbon Dioxide Capture and Storage. For CCS to have a significant impact on reducing the contribution of CO_2 into the atmosphere, however, it would require that several hundred to several thousand CCS facilities be constructed around the world using different geologic formations. This would be a significant undertaking but one that is achievable with the appropriate policy and technology developments. As greenhouse gas emissions are a global problem, carbon sequestration technology could also be very important for China, which also has very substantial coal resources, and is projected to overtake the United States to become the world's largest emitter of greenhouse gases in 2007 or 2008.

Importance of CCS to the United States

Fossil fuels will continue to play an important role in the Nation's future energy strategy. In a scenario of a carbon-constrained world, there is a strong need and also a strong incentive to develop technologies to mitigate the release of CO_2 into the atmosphere while still continuing to permit the use of coal—currently our Nation's most abundant fuel source.

CCS is a very promising technology that could allow the continued viability of fossil fuels as an energy source. CCS—the capture, transportation to an injection site, and long-term storage in a variety of suitable geologic formations—is one of the pathways that the Department of Energy is pursuing to reduce atmospheric CO_2 emissions.

DOE Carbon Sequestration Program

DOE is taking a leadership role in the development of CCS technologies through its Sequestration Program. The Department is developing both the core and supporting technologies through which CCS could potentially become an effective and economically viable option for reducing CO_2 emissions. The Carbon Sequestration Program works in concert with other programs within the Office of Fossil Energy that are developing the complementary technologies that are integral to coal-fueled power generation with carbon capture: Advanced Integrated Gasification Combined Cycle, Advanced Turbines, Fuels, Fuel Cells, and Advanced Research. Successful research and development (R&D) could enable carbon control technologies to overcome technical and economic barriers in order to achieve cost-effective CO_2 capture and enable widespread deployment of these technologies.

The DOE Carbon Sequestration Program (Program) leverages applied basic research with field verification to assess the technical and economic viability of CCS as a greenhouse gas mitigation option. Successful carbon sequestration technology development and deployment could provide the means by which fossil fuels can continue to be used in a future carbon-constrained world.

The Program encompasses two main elements: Core R&D and Validation and Deployment. The Core R&D element focuses on technology solutions that can be validated and deployed in the field. Lessons learned from field tests are fed back to the Core R&D element to guide future R&D. Through its Integrated Gasification Combined Cycle, Fuels, Sequestration, and Advanced Research programs, DOE is investigating a wide variety of separation techniques, including gas phase separation, absorption, and adsorption, as well as hybrid processes, such as adsorption/membrane systems. Current efforts cover not only improvements to state-of-the-art technologies but also development of several revolutionary concepts, such as metal organic frameworks, ionic liquids, and enzyme-based systems. The program is also investigating the development of alternative combustion technologies such as Oxycombustion and chemical looping. The ultimate goal is to drive down the energy penalty associated with capture so that coal power plants achieve 90 percent carbon capture at a cost of less than a 10 percent increase in the cost of electricity compared to a power plant without CCS.

The other key components to DOE's Sequestration Program include having the ability to store CO_2 in underground formations with long-term stability (permanence), the ability for monitoring and verifying the fate of CO_2, and public acceptance. These key attributes are being pursued by DOE's seven Regional Carbon Sequestration Partnerships. The Partnerships are engaged in an effort to develop and validate the technology to implement DOE's CO_2 Sequestration Program in different geologies of the Nation. Conducting geographically diverse tests provides information on how to apply CCS to storage sites with different geologic characteristics.

Collectively, the seven Partnerships represent regions encompassing 97 percent of coal-fired CO_2 emissions, 97 percent of industrial CO_2 emissions, 97 percent of the total land mass, and essentially all of the geologic storage sites in the United States potentially available for CCS. The Partnerships are evaluating numerous CCS approaches to assess which approaches are best suited for specific geologies of the country, and are developing the framework needed to validate and potentially deploy the most promising CCS technologies.

The Regional Partnership initiative is using a three-phased approach. The first phase, the Characterization Phase, was initiated in 2003 and focused on characterizing regional opportunities for CCS, and identifying regional CO_2 sources and storage formations. The Characterization Phase was completed in 2005 and led to the current Validation Phase. This second phase focuses on field tests to validate the efficacy of CCS technologies in a variety of geologic storage sites throughout the

United States. Using the extensive data and information gathered during the Characterization Phase, the seven Partnerships identified the most promising opportunities for CCS in their regions and are performing widespread, multiple geologic field tests. In addition, the Partnerships are verifying regional CO_2 storage capacities, satisfying project permitting requirements, and conducting public outreach and education activities.

The third phase, or Deployment Phase, involves large-volume injection tests. This phase is scheduled to begin in Fiscal Year 2008, and will demonstrate CO_2 capture, transportation, injection, and storage at a scale equivalent to potential future commercial deployments. Given the opportunities provided by the FY 2007 Operations Plan, DOE will initiate these activities in 2007. The geologic structures to be tested during these large-volume storage tests will serve as potential candidate sites for the future deployment of technologies demonstrated in the FutureGen Project as well as the Clean Coal Power Initiative, which will complete a solicitation for carbon capture technologies at commercial scale in 2008.

Geologic Storage Potential

In the recent assessment completed by DOE's Regional Carbon Sequestration Partnerships, titled the Carbon Sequestration Atlas of the United States and Canada, DOE worked with the United States Geological Survey (USGS), the Office of Surface Mining, the United States Forrest Service, and a number of oil and gas experts. The Atlas identifies hundreds of years of storage potential in deep saline formations, depleted oil and gas reservoirs, and unmineable coal seams. Over 3,500 billion tons of potential storage capacity exists throughout these regions and represents a potential significant resource for CCS. The geological sequestration experts from the Partnerships, the National Carbon Sequestration Database and Geographical Information System—or NATCARB—and the National Energy Technology Laboratory (NETL) created a methodology to determine the capacity for CO_2 storage in the United States and Canada, and an Atlas from data generated by the Partnerships and other databases, including the USGS.

The information collected during the second phase (the Validation Phase) will be used to update the capacity estimates throughout the United States, and revise and issue an updated version of the Atlas in 2009. DOE expects to continue the effort to characterize additional geologic formations after 2009 during the third phase (the Deployment Phase) of the program. In addition, the data collected during the Validation phase field tests and Deployment phase large volume CCS tests will be used to validate the capacity estimates presented in the Atlas. Future work on the Atlas will seek more active involvement with expert organizations like the USGS. Their expertise will complement and strengthen existing DOE efforts. More active involvement of USGS also would improve future versions of the Atlas and allow more detailed assessment of Federal lands.

Regulatory Compliance

DOE has been working with the Environmental Protection Agency (EPA) on its permitting structure for the DOE Regional Carbon Sequestration Partnerships field tests. DOE worked closely with EPA on the development of an Underground Injection Control Class V permitting guidance document that will guide the EPA Regions and State regulators when issuing permits for the RD&D injection projects. DOE and EPA meet regularly to review the status of field projects, to share technical information, and to identify areas of future collaboration.

Closing Remarks

CO_2 storage can play an important role in reducing carbon dioxide emissions. At the same time, it will increase the Nation's ability to use its domestic energy resources to meet our energy needs and increase economic prosperity throughout the United States.

Mr. Chairman, and members of the Committee, this completes my prepared statement. I would be happy to take any questions you may have at this time.

Response to Questions submitted for the record by Carl Bauer

Ql. In the Senate hearing on this topic two weeks ago, Secretary Shope said he expected to see wide scale deployment of carbon capture and sequestration on power plants by 2045. Is that timescale based on the absence of a regulatory scheme for carbon dioxide emissions? If so, do you have any estimates of what would happen to that timeline if there was a carbon regulatory scheme that resulted in a price for carbon dioxide emissions?

Al. Stating a specific time frame for the deployment of carbon capture and sequestration (CCS) technology is difficult as there are many variables that can influence technological adoption. These variables include the pace of technology development, regulatory framework, public acceptance, liability, and the ability of power generation integrated with CCS to compete against alternative technologies in the marketplace. Any carbon regulatory scheme that results in a price for carbon dioxide must also consider these other variables that can act to either accelerate the deployment of CCS or impede its penetration into the market.

Any timescale assumes a regulatory scheme that is consistent with the timing for the commercial availability of affordable carbon capture and sequestration (CCS) technology along with the required power plant technology to enable the commercial deployment of such CCS equipped systems. If required technology is not commercially available at the time of enactment of CO_2 emission regulations, it is possible that such regulations will not enable technology deployment but could rather lead to unintended consequences, such as fuel switching to natural gas—which could be a short-term benefit, but would also greatly increase the difficulty of achieving the long-term CO_2 reduction goals.

To accelerate the development of CCS technologies for clean power production, the Department of Energy has been focused primarily on addressing two of the greatest challenges: (1) reducing the cost of carbon capture, and (2) proving the safety and efficiency of long-term geologic storage of CO_2. DOE supports a robust RD&D program specifically designed to address these challenges. The Department's core coal technology program includes the development of advanced technologies for pre-combustion (or gasification), post combustion, and oxy-combustion multiple pathways to produce power and capture CO_2—as well as a robust program for carbon sequestration to prove the viability of long-term geologic storage.

Our 2012 goal is to show that we can develop advanced technology to capture and store 90 percent of the potential CO_2 emissions from coal-fired power plants, with less than a 10 percent increase in the cost of electricity. This is an ambitious and significant goal, considering that commercially available technology to do this today will add from 30 to 70 percent to the cost of electricity.

EIA predicts that more than 40 gigawatts of new coal-based plant capacity will be added in the United States between 2005 and 2020, while only about 6 gigawatts is retired from the more than 300 gigawatts of generating capacity in the existing fleet. We have a fast-approaching opportunity to introduce a "new breed" of power plant—one that is highly efficient, capable of producing multiple products, and is virtually pollution-free ("near-zero" atmospheric emissions, including carbon). In addition to technology for new plants, we may also employ technology for capture of carbon dioxide emissions from the existing fleet. DOE's research and development program is aimed at providing the technological foundation for carbon capture and storage for both new and existing coal-fueled power plants.

DOE's seven Regional Carbon Sequestration Partnerships are engaged in an effort to develop and validate CCS technology in different geologies across the Nation. The Partnerships are evaluating numerous CCS approaches to assess which approaches are best suited for specific geologies, and are developing the framework needed to validate and potentially deploy the most promising technologies.

The Regional Partnership initiative is using a three-phased approach. The first phase, the Characterization Phase, was initiated in 2003 and focused on characterizing regional opportunities for CCS, and identifying regional CO_2 sources and storage formations. The Characterization Phase was completed in 2005 and led to the current Validation Phase. The second phase focuses on field tests to validate the efficacy of CCS technologies in a variety of geologic storage sites throughout the United States. The third phase, or Deployment Phase, involves large-volume injection tests. This phase was initiated this fiscal year and will demonstrate CO_2 injection and storage at a scale necessary to demonstrate potential future commercial deployment. The geologic structures to be tested during these large-volume storage tests will serve as potential candidate sites for the future deployment of technologies demonstrated in the FutureGen Project as well as the Clean Coal Power Initiative

(CCPI). The Department expects to issue a CCPI solicitation for carbon capture technologies at commercial scale in 2007.

By working in partnership with utilities, coal companies, research organizations, and nongovernment organizations, we hope to make coal technology with near-zero atmospheric emissions a cost-effective and safe option to help meet our future power needs.

Beyond DOE's efforts in the development of CCS technologies, the Environmental Protection Agency is also working on the regulatory issues. Permitting CO_2 injection wells as Class V is a short-term solution for regulation of CO_2 storage projects. The Environmental Protection Agency (EPA) has finalized Underground Injection Control (UIC) Program Guidance #83 Using the Class V Experimental Technology Well Classification for Pilot Carbon Geologic Sequestration Projects. This guidance was designed to help UIC and state programs in processing permit applications for CCS projects and providing regulatory agencies enhanced flexibility in expediting these projects.

Q2. Given that it is estimated that the carbon dioxide for the large-scale tests will cost on the order Of $20 million per test per year, has there been any consideration of using that money to partner with an existing carbon dioxide emissions source and retrofitting that plant to provide the carbon dioxide necessary for the tests?

A2. The Department's Carbon Sequestration Regional Partnerships are pursuing anthropogenic sources of CO_2 for the planned large-scale field injection tests. Examples of CO_2 sources include retrofit of existing power plants with capture technology, natural gas processing, ethanol plants, and refineries. The cost of large-scale tests is driven in large part by the cost of the CO_2, which depends significantly on the source.

Q3. During the hearing, you stated that a 500 MW power plant emits about 4 million tons of carbon dioxide per year, and the large-scale tests will only involve injections of 1 million tons of carbon dioxide per year, (a) will these tests give us enough information about our ability to sequester commercial scale volumes of carbon dioxide? Particularly with respect to injectivity and a reservoir's behavior under high carbon dioxide loads, (b) Do we know whether reservoirs can absorb carbon dioxide fast enough to handle a power plant running at full capacity?

A3. The information gained from these large-scale projects will provide the necessary data and field validation required for commercial-scale projects. An injection volume of one million tons per year is equivalent to several commercial projects already underway at Weyburn (Canada), Sleipner (Norway), and In Salah (Algeria). Although these injection rates are lower than those expected from a large-scale power plant, the proposed injection rates are sufficient to validate geologic performance for larger injection applications.

The Department's Carbon Sequestration Regional Partnerships are conducting detailed assessments to determine the capacity and injectivity of regional geologic formations. Results to date have shown that the injectivity rates and available capacity in formations throughout the United States can likely store hundreds of years of CO_2 emissions from existing coal-fired power plants.

Q4. Will we need to go back and conduct new tests using commercial-scale volumes after running the 1 million ton tests? Would it be quicker and cheaper to begin conducting commercial-scale tests now?

A4. The Department of Energy (DOE) believes that one million tons per year injection tests are adequate for technology validation prior to commercial deployment. Large-scale injection tests are being implemented at a scale adequate to demonstrate the operational issues associated with sustained injection of CO_2, with respect to adequate injectivity and capacity for commercial deployment. These projects will also determine the fate of the injected CO_2 after injection ceases by applying appropriate monitoring technologies and protocols.

The largest cost component for a large-scale injection test is purchasing the carbon dioxide. DOE believes that injecting quantities on the order of one million tons per year is the most cost effective injection level to validate technology. Injecting larger volumes of CO_2 will substantially increase the cost of the project.

Q5. Is there anything keeping us from doing larger-scale tests, and doing them more quickly? Would any of the bills that have been introduced in the House or the Senate help accelerate things? Would additional money for the carbon sequestration program help to move things along faster?

A5. There are several challenges associated with large-scale deployment of carbon capture and sequestration (CCS) technologies including: cost-effective capture; geographical diversity; storage permanence; monitoring, mitigation, and verification processes; integration and long-term performance; permitting, liability, NEPA; public acceptance; and infrastructure requirements. The Department's Carbon Sequestration Program is addressing these challenges through applied research, proof-of-concept technology evaluation, pilot-scale testing, and stakeholder involvement. The largest cost component for a large-scale injection test is purchasing the carbon dioxide. DOE believes that injecting quantities on the order of one million tons per year is the most cost effective injection level to validate technology. Injecting larger volumes of CO_2 will substantially increase the cost of the project without adding commensurate value for the American taxpayer.

Q6. In a number of written testimonies, the importance of public outreach regarding carbon sequestration is stressed. Does DOE have any ideas for how to handle that, or are you doing anything currently in that regard?

A6. Many of the research and development projects funded by the Department of Energy (DOE) have an outreach component. For example, the Regional Partnerships engage regulators, policy makers, and interested citizens at the state and local level through innovative outreach mechanisms. The Regional Partnerships also implement action plans for public education in the form of mailing lists, public meetings, media advertising, local interviews, and education programs available at libraries, schools, and local businesses. DOE's efforts in public education and outreach include: Carbon Sequestration webpage on the National Energy Technology Laboratory's website; Carbon Sequestration Technology Roadmap and Program Plan (revised annually); Carbon Sequestration Newsletter (distributed monthly); Middle School and High School Educational Curricula on Greenhouse Gas Mitigation Options (disseminated through workshops at National Science Teacher Association conferences); and the annual National Conference on Carbon Capture and Sequestration. In addition, carbon capture and sequestration information is distributed at technical conferences through presentations, panel discussions, breakout groups, and other formal and informal venues.

Q7. Do you believe that a Class 5 permit under the underground injection control program is a viable long-term approach? Or is this only appropriate for these demo projects?

A7. Permitting CO_2 injection wells as Class V is a framework to demonstrate the viability of CO_2 storage projects. The Environmental Protection Agency (EPA) has finalized Underground Injection Control (UIC) Program Guidance #83 Using the Class V Experimental Technology Well Classification for Pilot Carbon Geologic Sequestration Projects. This guidance was designed to help UIC and state programs in processing permit applications for CCS projects and providing regulatory agencies enhanced flexibility in expediting these projects. The Department of Energy (DOE) expects that as pilot carbon capture and sequestration (CCS) projects move forward, a great deal of knowledge about sub-surface CO_2 behavior, well construction, and operational procedures will be gained. To ensure that efforts are coordinated and communicated effectively, DOE participates in quarterly meetings at a high management level with EPA. In addition, both DOE and the Regional Partnerships were involved in providing comments for EPA's UIC Guidance.

DOE considers the UIC Program Guidance #83 to be appropriate for any research, development and demonstration sequestration project implemented in the United States.

Q8. Who do you think would be the appropriate federal agency to handle a certification process that would ensure long-term safe storage of carbon dioxide?

A8. DOE believes the administration of any certification process will be dependent on the nature of future regulations, incentives, or accounting schemes that would be used for CO_2 emissions. The Department's Energy Information Administration is developing reporting requirements and managing the 1605B registry of projects that register greenhouse gas offsets for geologic and terrestrial storage projects. In addition, the projects in the Carbon Sequestration Program are developing accounting protocols for geologic and terrestrial storage projects that will be used to register credits with the Chicago Climate Exchange. This work could be used as a framework once a Federal agency is identified to manage the certification process.

Q9. A common quote used by oil and gas production opponents is that America consumes 25% of the world's oil supply and only has 3% of the world's oil resource. I was given some presentation materials that appear to have been prepared by you regarding U.S. hydrocarbon resources and how those compare with OPEC hydrocarbon resources. In those materials, U.S. hydrocarbon resources appear to dwarf OPEC hydrocarbon resources. What can you tell us about our country's hydrocarbon endowment compared to OPEC? Do we have more or less hydrocarbon resource than OPEC? Could the U.S. become energy independent if we accessed these resources? What type of investment will be required to access these resources?

Al. The presentation material entitled U.S. Endowment of Solid, Liquid, and Gaseous Fuels Resources, represents the cumulative perspective of U.S. hydrocarbon resources, the total of which is converted into common barrels of oil equivalent (b.o.e.) units. These resource estimates include estimates of large unconventional energy resources, such as U.S. methane hydrates and oil shale, which are not currently economic. Along with U.S. coal resources, each of these three energy resources has the theoretical potential to translate into energy reserves that exceed today's estimate of global conventional oil reserves (approximately 1,200 billion barrels according to the BP 2006 Statistical Review of World Energy). This figure includes the conventional oil reserves of OPEC (912 billion barrels (76%)) and non-OPEC countries (289 billion barrels (24%)). The total of this broad estimate of U.S. hydrocarbon resources is 51 trillion barrels; however, it must be noted that much of these estimated U.S. resources will not ultimately be deemed economically recoverable, due to the high cost of production. A significant share of the resources is identified as "undiscovered," indicating that current resource estimates are speculative. However, these resources, if producible and economic, could have significant implications for U.S. energy security and global environmental issues, particularly global climate change and sea floor stability.

Since OPEC countries such as Saudi Arabia do not allow independent verification of energy reserves and resources, we do not know the extent to which our resources exceed theirs. The energy resources of OPEC countries are not noted for similarly large unconventional energy resource potential; thus their energy resources are largely constrained to their conventional oil and natural gas resources. If methane hydrates and oil shale resources were economic, the energy potential could theoretically advance the nation's energy independence. Since the private sector in America pursues the lowest cost fuel options to stay competitive in a global economy, it generally chooses not to develop resources such as methane hydrates and oil shale that are more expensive than competing sources. However, to the extent that industry believes these resources could be economic, industry is investigating potential extraction of these resources. The investment required would depend strongly on the amount of the resource that was economically recoverable, which could vary by orders of magnitude.

Q10. What are the political and legal obstacles related to waiving the legal liability of companies that sequester carbon dioxide geologically? In your opinion, can we have an effective national carbon sequestration program without a waiver of liability?

A10. For an effective carbon sequestration program, there are a variety of options for addressing risk in the near term. The petroleum industry has borne the risk of CO_2 injection for enhanced oil recovery for many years; however, risk differences may exist between enhanced oil recovery and permanent sequestration of power plant and industrial CO_2. A series of large-scale permanent sequestration projects are needed to better understand the risks and how to manage them. DOE is beginning large-scale testing this fiscal year, which should help answer these questions.

Q11. Can you estimate how long you believe it will take to develop the geological data to know where sequestration is feasible?

A11. The Department's Carbon Sequestration Program and the Regional Carbon Sequestration Partnerships have collected data demonstrating that storage of carbon dioxide is feasible in geologic basins throughout the United States. This is summarized in the "Carbon Sequestration Atlas of the United States and Canada" issued by the Department in March 2007. The data presented in the Atlas shows that hundreds of years of future CO_2 emissions could be potentially stored in these geologic formations. These estimates could be further refined through enhanced methodology used to assess geologic sinks and additional information on geologic formations and data, e.g., from DOE's small- and large-scale CO_2 storage projects. Sequestration is certainly feasible at a few well-defined locations throughout the United States. However, for sequestration technology to play a key role in future climate change mitigation, thousands of sequestration sites must be feasible at numerous locations in the United States. Through efforts of the Department's Sequestration Program and Regional Partnerships, in coordination with other Federal agencies, we believe that we will continue to increase the confidence and detail of our assessments of where and to what degree sequestration on such a large scale is feasible.

Mr. GRIJALVA. Thank you very much. Let me remind the Members that under Committee Rules each Member is going to have a five-minute limit on the questions, and at this point let me recognize Chairman Rahall for any questions he might have.

Mr. RAHALL. Thank you, Mr. Chairman. Thank you both for your testimony, and Assistant Director Leahy, congratulations on your career, and we wish you well wherever your new endeavors take you. Carl Bauer, let me ask you where you left off there and it may be in your prepared testimony. You were talking about the permitting process. I assume this is on public lands where carbon sequestration has been identified by DOE as doable?

Mr. BAUER. The permitting process I alluded to was working with EPA. Right now presently EPA in March of 2007, of this year in other words, they put out a memo from the director of both the injection groundwater department as well as the air department on the ability to inject CO_2 into the ground wherever, and as guidance to allow the regional administrators as well as hopefully Geological Survey and the states to use it as guidance in allowing experimental wells.

Experimental wells could be as much as a million tons of CO_2 per year. It is not specifically to Federal lands, and access to Federal lands would be responsible to the various agencies that hold authority over those lands, like BLM, MMS, and those also need to be worked out. There is also the issues around liability. So the EPA regulatory guidance is just that. How do you comply with the injection well requirements of the law presently?

Mr. RAHALL. That is what I was going to ask about. On public lands where as I understand there could be up to 600 years worth of storage capacity, the permitting process, of course, involves the relevant agency that has jurisdiction but then there is still the EPA environmental assessments, et cetera process that has to be filed as well, is that correct?

Mr. BAUER. That is correct, sir.

Mr. RAHALL. OK. Let me switch to Mr. Leahy, if I might, and ask you if you have reviewed the bill that has been filed by Representative Bart Gordon in this body and Senator Salazar in the other body that appears to follow the MIT recommendations, and if so, do you have any comments on that legislation?

Mr. LEAHY. Yes. I have looked at that legislation. It calls for a national assessment much like in line with my testimony. We are very supportive of those bills, of course, because we feel a national assessment is needed. There are a couple issues associated with the timeline. The development and methodology I think is called for to be completed in 270 days. One of the important things I think is the methodology has to be quite open otherwise the results will be controversial or suspect or something.

So what we want to do is to find a methodology much like we do with our oil and gas assessments where the methodology is as open and transparent as possible, and so 270 days to do that is challenging, and we feel that a year is probably more appropriate.

Mr. RAHALL. OK. Either gentlemen, and again this question or rather this question might be more appropriate for one of the future panelists this afternoon, but where enhanced oil recovery is occurring today and carbon sequestration is being used, is the oil industry buying the CO_2, and could you explain that process of where this would be profitable for the oil industry if it does indeed help them enhance the oil recovery from their depleted fields?

Mr. BAUER. Presently the enhanced oil recovery CO_2 is purchased. It depends on the price but the average market price, as I understand it presently, is about $20 a ton, and obviously it is profitable to the oil industry if they pay $20 a ton and make enough oil out of it and, of course, it depends on the field. Some fields are not worthy.

But as the price of oil comes up, of course, economics shift on that. So yes, presently it is to their advantage. That CO_2 would be more largely captured and available would probably reduce the value of the commodity because there would be people looking for places to get rid of their CO_2. So that would change that dynamic but it would also produce more oil.

Mr. RAHALL. Thank you. Thank you, Mr. Chairman.

Mr. GRIJALVA. [Presiding.] Thank you. Let me ask a couple of questions. Mr. Leahy, you mentioned on page 2 of your testimony that land conversion, especially deforestation, continues to be a significant source of global carbon dioxide emissions. Later today we will hear from a panelist who says old growth forests retain large stores of carbon, and we should make every effort therefore to retain them. Is the U.S. Geological Survey taking a closer look at measures to protect old growth forests on public lands based on the amount of carbon that they store?

Mr. LEAHY. I think the challenge is the fact that land use changes can either have a positive effect or a negative effect, and certainly deforestation and agricultural use can put more CO_2 into the atmosphere. One of the things we actually have a research study going on with our colleagues from Energy is looking at the prairie pothole region out in the Dakotas, and some of the results that have come out of that is when agricultural lands are let to go back to wetlands that I believe the report says over a ton of carbon is sequestered on an annual basis per acre.

Mr. GRIJALVA. Thank you. Mr. Bauer, what is the financial split between terrestrial and geological sequestration in the regional partnerships? How much money is being spent on one versus the other? Is there a figure or an estimate?

Mr. BAUER. I would have to give you an estimate. If you would like a more exact one I will come back in written response, Mr. Chairman.

Mr. GRIJALVA. I appreciate that. Thank you.

Mr. BAUER. But the initial phase one and phase two it would be several million dollars was on terrestrial and maybe one and a half times that much was on geologic. Initially we had quite a few terrestrial projects. Some of them were also involved with USGS and also with states on reclaimed mine land and other damaged lands to use foresting and overgrowth to both capture CO_2 but also to restore the lands to viability, and those have demonstrated actually quite a great deal of success in carbon capture through terrestrial sequestration methodology.

The issue with terrestrial is the magnitude of CO_2 from power generation and the period in which it is generated is overwhelming. We are also doing some algae capture of CO_2 from power plants, and that is looking very promising.

Mr. GRIJALVA. Yes. Maybe for both. No. Let me stick with Mr. Bauer on this. I noticed that we are in the validation phase for both the geological and terrestrial sequestration, and that the geological sequestration enters the deployment phase in the next few years. Is there a deployment phase for the terrestrial part of it?

Mr. BAUER. The deployment phase for terrestrial is already seemingly have begun but not in a formal sense that we identified a deployment phase for terrestrial. It has begun in the sense that people are already doing it. There is carbon trading in terrestrial sequestration, and one of the technologies that we have funded from DOE and developed at one of the laboratories in Los Alamos has actually been able to begin to measure the carbon improvement in the soil so that they are working with the Department of Agriculture to use that to demonstrate and value the carbon that is captured, and therefore cap and trade or trading of CO_2 credits would be possible. You would be able to measure the terrestrial CO_2 capture.

Mr. GRIJALVA. Thank you, and I do not have any other questions. Mr. Pearce.

Mr. PEARCE. Thank you, Mr. Chairman. Mr. Bauer, how long do you think it would be before the technology is available to dispose of significant amounts of carbon dioxide?

Mr. BAUER. The economic viability is really the problem. The technology, for example capture of CO_2, exists today. The ability to put large volumes into the ground through EOR exists today. So in one sense you could do things today but the economics, and I was just in a meeting with a power plant company who is interested and it is one of the major ones in this country, in doing a capture and sequestration, and the economics around it are daunting even to get up to 25 percent of the CO_2 they produce reduces the plant efficiency or increases the cost, depending on how you want to look at it, by almost 30 percent presently.

And they have through the seven regional partnerships they actually have a reservoir under that plant that has already been proven at a small scale. So the ability to move there rapidly—to get to your question—is probably a decade away at the fastest and economically probably more like 15 to 20 years in a broader commercial application in my opinion. We need to do some of these larger demonstrations to gather data because we need the regulatory information and the public acceptance that would come only with that.

Mr. PEARCE. You mentioned in your report that it would take hundreds or thousands of reinjection facilities. Now I am viewing the reinjection facilities in the oil field, and I can see these banks of compressors sitting there. I mean we reinject tremendous amounts of water, and frankly it is similar when they start reinjecting the CO_2. Is that the same sort of technology you are already using?

Mr. BAUER. I think that is a reasonable analogue. It may not be quite as harsh as what you are aware with the water reinjection because the CO_2 may not be as viscous at the point of injection as water. It is not a hollow chamber you are putting the CO_2 in. You are putting it into permeable rock so it does take a lot of effort.

Mr. PEARCE. Have you considered the liability question? In other words, I visualize my wife taking her groceries in the other day and the Dr. Pepper fell off, and just a pinhole opened up and it spewed around. Now we see the same thing in oil wells.

My company worked on that kind of thing. We did not own any oil wells but we worked on them, and constantly you are putting the CO_2 in, and it is just sitting there under pressure. Occasionally you will see a picture of a string of tubing 6 and 8,000 feet long, two and seven-eighths inch diameter tubing that has just been catapulted out of the well and has corkscrewed around. Is that kind of volatility something that you bump up against in your reinjection partnerships?

Mr. BAUER. I think the challenges you mention are accurate, and I think, as is done in greater scale, it will be dealt with just like most technologies make things routinely much more plausible. But it is not something you rush into.

Mr. PEARCE. Right.

Mr. BAUER. And the liability issue you asked the question on is something that is continuing to be a challenge with the industry. In EOR it is a set of rules but when you say that I am putting CO_2 in the ground for longevity, 100 years or 200 years, there are not many companies that are staying in existence that long to really back up the commitment.

Mr. PEARCE. Right. Now, Mr. Leahy, and so we are going to take these and use these comments as a backdrop for you. You mentioned that fossil fuel use is just a major source of carbon dioxide. Now when I look at the major uses, fossil fuels falls fourth in a list. In other words, ocean out gassing has about 100 gigatons per year, soil bacteria 60 and then respirations from humans about 52. So that is more or less in the range of 200 gigatons, and then human emissions come up to 7.5.

In other words, you hear of the technological difficulty years and 30 percent decrease in deficiency or increase in cost or whatever, so you are hearing a possibility of reducing by 25 percent. Then you look at the small percentage. You have 200 gigatons and the amount of potential savings. Can we achieve what we want to achieve here given the small amounts that we are actually talking about incrementally changing versus the large amounts that are being plugged into the atmosphere anyway by nature?

Mr. LEAHY. I think the key thing is——

Mr. PEARCE. Can you get on your mic?

Mr. LEAHY. The key thing here is there is a global carbon cycle, and we need to understand how the global carbon cycle works because there are emitters and there are parts——

Mr. PEARCE. If you would not mind, when it turns to red I have to quit talking, but just if you would address the question of the percentages. You have some very high emitters above fossil fuels, fossil fuels being down the list quite a ways.

Mr. LEAHY. We can provide that for the record.

Mr. PEARCE. I would appreciate that. Thank you very much. Thank you, Mr. Chairman.

Mr. GRIJALVA. Thank you, Mr. Pearce. Mr. Inslee, any questions?

Mr. INSLEE. Thank you. Could you discuss what you think are the most important changes to the regulatory climate to allow sequestration to move forward?

Mr. BAUER. Well, I think the changes to recognize that the rules under EOR would be acceptable—which I do not think will be the resolution—or to come forward with regulations and who would apply those regulations, whether it is the state level which is where EOR is most often managed or at the EPA level, and then on public lands is it BLM, how do these play together, so that there is some business certainty for decisions by the industry to figure how their best path forward is. That will help move things along.

Mr. INSLEE. And should we pick one agency as the lead agency in development of those regulations?

Mr. BAUER. I think if we want to accomplish this in a rapid manner, I think it winds up being several agencies coming together and forming actually an aggressive team to formulate the material that is needed.

Mr. INSLEE. What would be the best way to do that? Say EPA and Bureau of Land Management and a third yet to be renamed player? Instruct them to give a date or what is the best way to do it?

Mr. BAUER. Well, presently EPA has the regulatory authority on pollutants, airborne and others, and as we know from the Supreme Court finding, they were charged to go back and look at what their management of CO_2 and the regulations around it would be. However, I think the land management organizations from the Department of the Interior which have public lands that would have access required are going to have to play, even if it is just to address how access is provided—and perhaps EPA then on how injection would take place and validation and verification. DOE, I think, would have a substantial contributing partnership there but they are not a regulatory body as a whole.

Mr. INSLEE. Is there any model for the best way to do this to centralize a permitting system? Is there any model?

Mr. BAUER. I would say——

Mr. INSLEE. Here is the reason I ask. We have to move on this. You know we do not have a lot of time here to diddle. What is the best Federal model for centralizing a permitting system to get the job done?

Mr. BAUER. Congressman, that is a difficult question. I agree with you that we do not have time to lose. I would say maybe the closest thing we can think about would be the Clean Air Act as a starting point but there was not a matter of what you did with the emissions you took care of there. That was dealt with under separate rules.

Mr. INSLEE. OK. Well that is I guess my job too. So I will have to fulfill it. A second question. Could you give us some idea what the Federal government is spending on sequestration technology broadly speaking now, and the reason I ask is many of us believe we need something akin to the original Apollo project to skin this cat on global warming and energy security, and that was about $18 billion a year we were spending on the original pilot project. Give us some idea ballpark what we are spending on sequestration technology Federally, either in R and D or looking at permitting or exploring what the asset is.

Mr. BAUER. I would have to get back for the record on that, Congressman. I know the area that has the most direct in the technology development and the sequestration evaluation is less than $100 million a year, and in fact up until this past year it has been less than about $70 million a year but there is also office of science and Department of Agriculture and other departments that are spending money on various aspects. So let me take that and get back to you if I may.

Mr. INSLEE. And what level of increase could be profitably but usefully spent to really go out and find out what sequestration geology we have and to look at compression technology? I will give you examples. A little company called Ramjan that has developed a sonic way of compressing CO_2 that may reduce compression costs by 30 to 40 percent because it is just much more efficient.

Mr. BAUER. I am familiar with that technology.

Mr. INSLEE. You know if you said you wanted to have the same level of national commitment as we did when we went to the moon, what budget could be usefully spent in the next couple of years?

Mr. BAUER. I would like to get back to you for the record on that.

Mr. INSLEE. I would appreciate that actually because I think it is a serious question. I think the challenges—our country is so great—that we have to look at it in those terms.

Mr. BAUER. Yes, sir. I understand the question is you need a recommendation on what a serious, aggressive program would require for sequestration, for capture, and for the work with industry that is required to move this forward as well as with the other agencies as far as regulatory permitting and other——

Mr. INSLEE. You bet. I would like you to tell me if we were as serious about solving global warming as we were getting to the moon what would we spend in the next couple of years on this technology? I would appreciate your thoughts on that.

Mr. BAUER. Yes, sir.

Mr. INSLEE. You mentioned algae capture. There was some promising information about that. Could you talk about that because we think that may be a biodiesel source at some point.

Mr. BAUER. Yes. We are presently working with Arizona Power Systems and several other power companies. They are capturing a slip stream off of their fossil fuel plant, and passing that CO_2 through bioreactors that have been designed and in fact in one of the reactors is an MIT original design. It has been modified since then, not by NETO. That looks very promising in an area that you have large surface area. It is not a pond based system so you get much more production.

We actually have had the algae formulated into biodiesel and run vehicles on biodiesel. So it does look and the company thinks that they can possibly get it to the point of paying for itself and maybe make a little money.

Mr. INSLEE. Which company?

Mr. BAUER. Arizona Power Systems.

Mr. INSLEE. Thank you, sir. Thank you.

Mr. GRIJALVA. Congressman Shuster.

Mr. SHUSTER. Thank you, Mr. Chairman. I thank both of you for being here today, and again my regards to Mr. Leahy as you move on to something different, bigger, better or slower. Whatever it is, good luck to you. I am new to the Resources Committee, and I am trying to get my hands around, my brain around global warming issue, and the more I see the more I read. The facts that come to me are startling to me, and one thing I am following along the lines of Mr. Pearce's questioning.

And tell me if I am wrong but 96 percent of the carbon put in the atmosphere does not come from cars and plants. It comes from the ocean, humans and animals, and soil, bacteria. That is accurate?

Mr. BAUER. That is fairly representative, correct. The anthropogenic portion is a very small percentage of the total.

Mr. SHUSTER. Right. So as we are trying to find solutions to global warming and 4 percent of the carbon is coming from our cars and plants, as we work through to try to develop sequestration, how much of an impact is that going to have in solving the global warming situation?

Mr. BAUER. I think part of the thing is to recognize that the concern is that the anthropogenic which is adding to the global CO_2 inventory is at an increasing level, and it is changing the equilibrium. So the theory is that the change of equilibrium is exacerbating the problem, making it warm up more rapidly and that is the issue. Going to your question about dealing with that issue——

Mr. SHUSTER. So that 4 percent is throwing everything out of kilter?

Mr. BAUER. Well it is 4 percent of a very large number, and it is growing because the CO_2 goes into the atmosphere, and it does not just stay up there for 10 years. It stays up there for a long period of time, and so it keeps being added to, and so that is the theory that has caused kind of a greenhouse effect capturing heat in.

Mr. SHUSTER. And the 96 percent is doing what? I am not sure.

Mr. BAUER. Well the theory is that the 96 percent would have maintained equilibrium without the additional help of the anthropogenic contribution over the last 100 years.

Mr. SHUSTER. Again I am not very smart on this. So you are saying to me that the 4 percent is what is causing all the problem. The 96 is a huge amount of carbon that is really not contributing that much to the situation?

Mr. BAUER. I do not think that is what it is saying. I am just saying that the 4 percent may be the tipping point that is pushing it to the extreme.

Mr. SHUSTER. OK. I am still not quite sure.

Mr. BAUER. Yes.

Mr. SHUSTER. Like I said, I am trying to get my brain around it. You know you hear on TV one side, you hear the other side. So again I am just trying to understand. Coming from a guy that is not a scientist, not a chemistry major, it is very difficult. Next question. On the sequestration, are there areas of the country that are better suited for it and others that are not well suited? Can you talk about why and some of the characteristics?

Mr. LEAHY. Well, I will take that one, at least starting, but I mentioned three areas—coal seams, unminable coal seams, the oil and gas reservoirs, and also saline aquifers. Now there are deep saline aquifers, particularly if they have good seals, that are vast reservoirs; and the estimates have been about an order of a magnitude different in terms of what you read.

The point is the challenge is I do not think we know much about those. During my scientific career, I was a hydrologist. Hydrologists do not succeed by finding salt water. They succeed by finding fresh water.

Mr. SHUSTER. Right.

Mr. LEAHY. So the data we have on the saline systems are very, very sparse. So I think again a national assessment would look at all three of these potential geologic repositories or reservoirs and essentially be able to look at them on a regional basis, compare and contrast from coal to oil and gas to saline aquifers so that the policymakers can make a decision—and the managers and industry—can make a decision in terms of what is the best target at a particular location.

Mr. SHUSTER. And you talk about coal. Does the topography come into it? West Virginia and Pennsylvania are very different topography and Wyoming and places. So are there areas of the country that are better suited for it or not? I am not a geologist either.

Mr. LEAHY. Well the coal has to be there number one, and there are maps that show where the coal is in this country. We have done a national assessment of coal resources, released a few years ago, but the key thing is it is a catch-22. We want to mine this coal to make electricity but on the other hand you want to use it for carbon sequestration. So you have to look at the unminable coal. So there would have to be a separation out of that resource.

Now unminable coal—maybe it is too deep. Maybe it is too thin in terms of today's technology. Very hard to put a number on it because the technology changes, and what is unminable today a decade from now may become minable. There are new modern technologies that are coming to play. In situ mining where you inject things into deep basins and it changes and you get fuel out. So it is very difficult. This will be a very challenging issue in terms of——

Mr. SHUSTER. Thank you very much.

Mr. GRIJALVA. Mr. Sarbanes, do you have questions, sir?

Mr. SARBANES. Briefly. Thank you, Mr. Chairman, and I am going to compete with Mr. Shuster here in terms of my position on the learning curve because I am listening and learning as fast as I can on this subject. Just to follow up on the brief discussion on saline aquifers, can you imagine a time or use that we would be wanting to go to those saline aquifers for some other reason or with some other kind of technology for something totally unrelated to what we are talking about here where the fact that they are being used for sequestration purposes would be an obstacle to that?

Mr. LEAHY. I think one would have to define the criteria. We are seeing more saline water used in this country. Much like energy demands, our water demands are increasing with time, and frankly in some parts of the U.S. we will be looking to saline aquifers. Shallow ones probably brackish, and again it is a matter of setting the criteria and having some foresight to basically look at the ones that have the highest potential for other uses versus carbon sequestration.

Mr. SARBANES. Thank you.

Mr. BAUER. If I could add to that, Congressman.

Mr. SARBANES. Yes.

Mr. BAUER. The reservoirs we are looking at are very deep, below 8,000 feet, and that is a concern that they possibly have a future use. These are very, very—not brackish—but very salty saline aquifers that do seem to have large capacity to deal with this and probably have no substantial future benefit. But we are concerned about deep groundwater being used in the future, and trying to make sure those are not problems for us.

Mr. SARBANES. The other question I had is I am interested in this monitoring mitigation verification concept and the layperson coming to this subject, the one thing that can make them sit up straight is the discussion of leaks—leaks of this sequestered CO_2. So I just thought maybe you could spend a minute or two talking about the science around leakage and what you do.

For example, I would imagine that CO_2 coming into the atmosphere in the normal course does not do it with the same level of intensity that a leak could produce if it was coming out of a place where the CO_2 was being sequestered and stored in a concentrated fashion. I wonder what the environmental ramifications of that are.

Mr. BAUER. When we talk about saline aquifers we are talking about a void. We are talking about basically a rock, a rock that has some porosity but porosity not in the area of big holes but just small. Maybe even molecular only. Just the same as oil or gas would be found in.

So if you cracked it, it would not be a big rush out of it. The other thing is it would be below an impermeable layer. Having said that, leaks where wells and other things have penetrated down would allow it to come up. So the probability is not absolutely never but almost never that any kind of a huge out-rush would happen.

Where there have been out-rushings of CO_2 naturally it has been more around volcanic voids where there was a pocket of gas that came forward rather than leakage out. Having said that, we have technologies already that we can trace, and we do this for some of the oil companies—our lab does actually—when they want to inject CO_2 for EOR they want to make sure that there is no unintended loss of CO_2 for two reasons. One is they do not want to have to worry about a pocket of CO_2 which is heavier, forming a low area where people or animals might want to go to or vegetation, and two, CO_2 was worth something to them. They cannot afford to have $20 a ton CO_2 just leaking out. They want to recycle it if it is going to move through the system.

So we go through and we check, and they grout—grout with like a cement—to close those holes. Now having said that, it still is obviously, as you say, something to be sensitive about. That is why it is important for the public to understand what the issues are, what the protections are, and the methodologies to ensure that there are no leaks or that if any leakage were to happen it could be readily dealt with, and that is a very important part of the whole process of scientific development using the tools of carbon capture and storage.

Mr. SARBANES. What is the best analogy to a substance that is sequestered naturally below the surface that you would say well if that "leaked" out it would create harm? So in other words when I am talking to someone and they sort of say well you know you are putting the CO_2 down there, and it could leak out. You can say well in fact there are these other examples of things that are "sequestered" underground that could be harmful if they come out to give some context to this. I guess natural gas would fall into that category. Is that the best example? Are there others?

Mr. LEAHY. I will answer the question, Mr. Congressman. Artesian water systems are basically water that has a seal over it. So when a well taps it, the pressure makes the well flow, at least for a period of time until that pressure is reduced. Oil and gas are more buoyant than water. So, ideally, it would all go to the atmosphere sooner or later. In geologic time it would out gas but there are seals, and the integrity of those seals is an absolutely critical piece in terms of carbon sequestration because you want tight seals over these zones you pick.

The other thing that I think is very important here is the fact that gases are highly compressible. Water is not compressible. It is very lowly compressible, and the point is you can put the gas down into these saline aquifers to displace some of the water but you are also deforming the rock matrix, and if you do not have knowledge of those seals, you can fracture them, and in fact sometimes that is desirable, and it is done commercially. But again, knowing the geologic properties is absolutely critical in terms of some of the technology design so you do not make a mistake and have an outcome that is not desired.

Mr. SARBANES. Thank you.

Mr. GRIJALVA. Thank you. Mr. Brown.

Mr. BROWN. Thank you, Mr. Chairman. I thank the panel for their informative information, and I am too, like some of the other members of the panel, I am a little bit not learned in the process. Going back to my friend, Mr. Shuster, but I believe the numbers are more like 97 percent, we could have 3 percent of controllable carbons, and in a country with 300 million people, in a world that is 6.6 billion, so the fraction of what we might be able to do here is relative I guess to the whole picture of the world.

We have less than 5 percent of the people controlling or having input on 3 percent of the problem. It looks like to me if we do not get all of the other countries involved in the process, there is not much we can do. We could basically be put out of business and still not make an impact on the process. But how do you collect the CO_2 before you can sequester it?

Mr. BAUER. Well with power generation, as we presently do it, whether it is natural gas combined cycle or coal power generation, the flue gas or the exhaust gas has got a very dilute amount of CO_2 in it. So it is a very big challenge, and the technologies that are available to do it presently are awfully expensive at that volume with a very low concentration.

So what we are doing is looking at ways for future power generation—to find ways to make a more concentrated CO_2 stream at the end. One of the ways is when we use gasification of coal, we have a higher concentration of CO_2. We have a greater ability to separate it. That looks with promise at a potential way to both generate the power we need and to capture CO_2. However, having said that, the pulverized coal or combustion approaches using oxygen also have a higher concentration of CO_2. So then—we are back into that being comparable—how do we separate the CO_2? And that is still a challenge because in both cases the cost of separation even at concentration are substantial because of the large volumes.

Mr. BROWN. OK. Not to interrupt you, but we feel that coal is the major producer of CO_2 and maybe we ought to go to some alternative fuel other than coal? Is that what you recommend?

Mr. BAUER. No. I do not recommend that because the reality is that with power generation, the electricity generation demand is too great to move over there anything in the next 20 or 30 years at earliest.

Mr. BROWN. How about like nuclear power?

Mr. BAUER. I am sorry?

Mr. BROWN. Nuclear power.

Mr. BAUER. Nuclear power I think has got a lot of promise. I, in my early part of my career, was a nuclear power engineer.

Mr. BROWN. OK.

Mr. BAUER. So I think nuclear power has a tremendous amount of promise. Again the quantity of power we need requires all sources. We cannot just pick a silver bullet because we need too many bullets.

Mr. BROWN. OK. Let me ask either one of you a question. I guess the net problem we have with CO_2 is global warming. That is correct?

Mr. BAUER. Right.

Mr. BROWN. How long have we been in this global warming cycle?

Mr. BAUER. Well the literature indicates it has been since the beginning of the industrial revolution it has been adding up but it is in the last 100 years that the impact has become more substantially noticeable and gone up not in a linear manner but in a more exponential manner.

Mr. BROWN. I have this science paper here dated Newsweek April 20, 1975, and it addresses the cooling world.

Mr. BAUER. I remember that.

Mr. BROWN. OK. And I guess what I am saying there has been so much hype about this problem, about the global warming and the ocean rising and is this not a cyclical thing that is happening in the world? The ocean has not always been at the shorelines we are seeing today, is that correct?

Mr. LEAHY. I will take it. That is absolutely correct. I mean if you look back at some of the ice cores, you will see that temperatures have varied for the last 400,000 years.

Mr. BROWN. Sure.

Mr. LEAHY. And you can even go back deeper in geologic time. The record gets more suspect because the observations get harder but the earth goes through changes in terms of its atmosphere and so forth. I think the issue at hand is the unprecedented rise that has occurred in the last few hundred years.

Mr. BROWN. I think we almost have an obligation to try to make a difference. I know for instance I am from South Carolina, and I represent about 175 miles of the ocean, and I also have a farm that is about 25 miles inland from the ocean, and I was digging a pond the other day and this is a seashell that we dug up, some 12 feet below the surface of the topsoil. We also had some oyster shells and some shark teeth, which indicated at some point in time the ocean was not where it is down in Charleston or the border. The only reason I am bringing this up——

Mr. GRIJALVA. Will the gentleman yield?

Mr. BROWN. Mr. Chairman, I am sorry to carry over, but I know my time has expired, but I would hope we would not get in an emotional position to address a problem and cause a lot of industrial exploitations of some other foreign country and cause the quality of our life to go down and we probably might not be able to solve it. Thank you.

Mr. COSTA. [Presiding.] Thank you. Mr. Lamborn.

Mr. LAMBORN. Thank you, Mr. Chairman. Mr. Bauer, if I have the facts and figures correct as you testified, under current technology it would increase overhead by 30 percent to capture 25 percent of the CO_2, is that correct?

Mr. BAUER. That was a company that I was talking to just a week ago today. That is why the development and R and D for technology is so essential. The present technology is quite expensive at this scale.

Mr. LAMBORN. And you also stated that the ultimate goal is to drive down the energy penalty associated with capture so that coal power plants achieve 90 percent carbon capture at a cost of less than 10 percent increase in the cost of electricity.

Mr. BAUER. That is correct. That is the goal.

Mr. LAMBORN. Now that last figure sounds very optimistic. Sounds like a very ambitious goal. I think we would all love to see that but is that something you just pulled out of thin air? Is that wishful thinking or how confident are you that we could ever get to that point?

Mr. BAUER. That is the basis of analysis and also looking at kind of the learning of past experience. If you go back to the Clean Air Act and the technologies that had to come into effect to remove sulfur and reduce nitrous oxide (NO_x), those technologies were on a path of improvement so that the numbers we are using for CO_2 capture seem to be fairly realistic in what is technologically plausible and what we see happening. So I think those goals are achievable in the timeframe. Of course then from that timeframe achievement going into commercial broad utilization takes more time too because of the size of the capital investments.

Mr. LAMBORN. Thank you. And I am also going to build on something my colleague, Mr. Brown from South Carolina, alluded to, and that is there are other countries that are not doing anything basically, and I know that when the Kyoto Protocol—which the last Administration President Clinton, Vice President Gore—when they were in the White House we had the Kyoto Protocol turned down by our Senate 95 to 0.

And part of the reason it was turned down 95 to 0 was because we would be subjecting ourselves to an economic penalty when other countries like China who are in the so-called developing category were not having to do anything, and I see that China next year is predicted to become the leading emitter of carbon dioxide in the whole world.

So do you not think more attention should be given to a country like China that is doing nothing basically? I mean as opposed to us putting ourselves with the whole burden on our own shoulders?

Mr. BAUER. I understand your point, and it is a good point that the whole challenge of greenhouse gas management is a global issue truly. Yet having said that the need for technology—wherever it is going to be deployed—exists, and in the past, the United States has often developed the technology such as with sulfur removal and nitrous oxide (NO_x) reduction, now mercury reduction, that has wound up providing export to other countries other technology as well as other countries taking place.

I know the Chinese have not done much but I do also know that over the last two years—and I was part of a Clean Air for Asia group that worked with four countries, Japan, China, India and the United States—there is an increasing understanding and a recognition of their need for attention to these things, and they are beginning to rapidly pursue them, and I think we will see changes over the next several years. Having said that, the United States alone taking action will not solve the world's greenhouse gas problem but it will have a substantial impact.

Mr. LAMBORN. Thank you. I am glad to hear that part of your question because it would be great to share technology with them but if we are the only ones taking action at an economic cost and they are not, there is a sense of fairness there that I think we have to worry about. Thank you.

Mr. COSTA. Chairman Rahall for a follow-up question, and then I will take my time.

Mr. RAHALL. Thank you, Mr. Chairman. Carl, I was asking you earlier about the commercial applications of CO_2 and the fact that the oil industry has been purchasing it for EOR and how profitable it is for them to do that, and thinking a little further, what other commercial applications do you see? I am wondering today where do companies like Coca Cola and Pepsi and all these soda companies get their CO_2? And is it possible if you capture and clean it that it would not have commercial applications in the soda pop industry? I mean Appalachian Power selling to Coca Cola. What better scenario than that?

Mr. BAUER. Well actually there is CO_2 used commercially, and you are correct, Congressman, that there are applications. The problem is the volume of CO_2 produced is so great that it more than swamps our present use, and having said that though, I think rather than looking at it as a problem we also need to look at it as an opportunity and think about ways to use it. I have been in communication with a Berkeley lab about some papers that they have done on geothermal heat recovery for power generation. The use of water is excessive, and so you lose a lot of water, and it does not make sense because most of the geothermal sources are in areas that are fairly arid.

But you could use CO_2 as a working fluid and thereby take a full plants every year of CO_2 because you would leave some of it behind which forms a carbonate, stays there, but you could bring the heat up with CO_2 cap, keep the CO_2 under control, and use it as a working fluid, and I think we need to start looking at those things—more rapid growth of plants like algae—but also I know a grower in Arizona that uses CO_2 to produce tomatoes hydroponically. He can sell all he can make, and he makes them all year round because they have sun all year round. So there are ways to use it but there are not enough ways to use the magnitude we produce so we have to look at both ways I think.

Mr. RAHALL. So that could be a part of our R and D efforts in the future on it?

Mr. BAUER. Yes, sir, I believe there are opportunities. That is why we are doing the algae one. We are looking for alternatives, creative ways to find other ways to use it.

Mr. RAHALL. Thank you. Thank you, Mr. Chairman.

Mr. COSTA. Not a problem, Mr. Rahall. Mr. Bauer, places like New Mexico where they have sunshine all the time, that sounds like a place to go. Mr. Leahy, I understand that the United States Geological Survey has been collaborating with the Department of Energy with the production of their national atlas. Where are you on that?

Mr. LEAHY. We have done some preliminary work in terms of methodology a few years ago that was used to inform the atlas production. We feel that the atlas is the first step in terms of getting a true national——

Mr. COSTA. Do we have a timeline when we will get that atlas with the methodology?

Mr. LEAHY. The methodology for the national assessment?

Mr. COSTA. I assume you are working on that. But when will we have the atlas after the methodology is worked out between the two?

Mr. LEAHY. I think we are talking past each other a little bit here. I was referring to a more quantitative national assessment in terms of developing a methodology. The DOE assessment we have worked closely with them in terms of them coming up with a first cut. I think you called it an overview or high level overview of the potential for carbon sequestration. So I think a second generation product is needed here.

Mr. COSTA. OK. But I have been told that the atlas is done, is that correct?

Mr. BAUER. Congressman, I left a CD copy of the present just-released atlas for each Member. That will be updated again in about two years and with additional, more detailed work with USGS, as well as the projects. The projects bring either confirmation of what is prospected there or new information.

Mr. COSTA. OK. My time is going here. Have you been getting cooperation from the oil and gas companies that have done I understand a lot of work on the data for the potential of the carbon dioxide sinks?

Mr. BAUER. Yes, sir, we have. We have gotten both from oil and gas experts and from various companies working through the regional partnerships.

Mr. COSTA. Because that would save you time logically.

Mr. BAUER. That is correct, sir.

Mr. COSTA. OK. Good. I am not sure which, Mr. Bauer or Mr. Leahy, which is most appropriate to ask this question. I was reading and talked on the material about the geological storage of carbon, and if this question has been asked already I apologize. Having had some experience in my district with problems with permeability of layers of what we call Corcoran clay and issues that deal with levels of selenium, I mean we used to think that that was an impermeable seal that existed some 5,700 feet below the surface but I am told here in looking at the water and rise vertically where you look at trying to store this carbon dioxide until you reach a nonpermeable barrier or seal, and it is critical for an issue and our evaluation of the storage capacity for the integrity or the effectiveness of those seals.

And I am told that really given the nature of the ground layers there is nothing that is impermeable. What is your take on this?

Mr. LEAHY. I agree entirely with you. There is nothing that is impermeable. Everything has a permeability. The point is you want the lowest possible permeability, and clays tend to be those as well as granites or something like that. The key thing is you need the geologic information and the data to basically understand those confining units and those seals, and you also have to know the properties, the physical properties of them so that when you go into development of CO_2 sequestration you do not fracture them, and I think the key with the Corcoran and I know that unit pretty well——

Mr. COSTA. Yes.

Mr. LEAHY. There are some issues out there with the movement of water through the Corcoran that was related to the selenium issue, and I think it is not, as I recall, not as aerially extensive. There are fractures in it. The permeability——

Mr. COSTA. I was just extracting that as an example.

Mr. LEAHY. Right. It is a very good example, Mr. Congressman.

Mr. COSTA. Yes. Quickly before my time is out. Mr. Bauer, I understand that in the deployment phase the Department is going to be looking at conducting field tests of a million tons of carbon dioxide per year, is that correct? And if it is, how does that compare with a good sized coal power plant that puts out a year maybe 500 megawatts?

Mr. BAUER. It is——

Mr. COSTA. Four million tons per year.

Mr. BAUER. Yes. It is correct we are looking for projects for about a million tons per year of CO_2, and a 500 megawatt power plant would produce a little bit over four million tons per year of CO_2. That is why a million is about 25 percent.

Mr. COSTA. Well my time is expired, and we do need to get to the next panel but I have some additional questions I would like to submit to you, Mr. Bauer and to you, Mr. Leahy, but I do not want to take up the time of the committee because we do have some witnesses who have been patient and are waiting. So thank you again. Thank you for your good testimony this afternoon, and Mr. Leahy, we want to thank you for a public service career that has withstood numerous decades, a lot of trials and tribulations, on a job well done. Thank you very much.

Mr. LEAHY. Thank you very much.

Mr. COSTA. All right. Moving right along to our next panel. We will get the new group up here and hear from our new set of witnesses.

[Pause.]

Mr. COSTA. We are all ready. Good. The first witness that we have in the second panel is Judy Fairburn, the Vice President of Downstream Operations for EnCana Corporation who is going to give us some sense on their efforts on sequestration of carbon dioxide. Ms. Fairburn.

STATEMENT OF JUDY FAIRBURN, VICE PRESIDENT, DOWNSTREAM OPERATIONS, ENCANA CORPORATION

Ms. FAIRBURN. Good afternoon. Thank you.

Mr. COSTA. You might want to lower the mic so you speak right into it. You know the five-minute rule.

Ms. FAIRBURN. Terrific.

Mr. COSTA. You are on.

Ms. FAIRBURN. Thank you very much, Mr. Chairman and Subcommittee members. I am pleased to be here. I am representing EnCana. It is a large independent oil and gas producer, second largest natural gas producer in North America as well as integrated oil sands developer. Through our recently announced venture with Conoco Phillips, we also co-own two refineries in the states, in Texas and Illinois, and we produce 1.2 billion cubic feet a day of natural gas in Colorado, Wyoming and Texas, headquartered in Denver.

Previous to my current position of head of our downstream refining operations, I was Vice President of the Weyburn business unit which is both the largest CO_2 enhanced oil recovery project in Canada as well as the world's largest CO_2 sequestration project. So I speak on that capacity today, and prior to that I worked in the Canadian Federal government. So it is a pleasure to be here.

At the invite of the Chairman, I would like to talk about the Saskatchewan project that we have. Our project is just about 30 miles north of the North Dakota border, to put it in perspective. I will provide some brief comments here, and you have my written testimony and as well I have a DVD and some brochures that can provide more visual aids.

Mr. COSTA. We will submit them for the record. Thank you very much.

Ms. FAIRBURN. Thank you. The geological storage of CO_2 in oil zones represents in our mind a great win-win between being able to recover additional oil from mature oil fields and successfully store carbon dioxide. We like the quote of Julio Friedmann and

Thomas Homer-Dixon in a recent foreign affairs article. They refer to it as, “This technology may be the only realistic way to satisfy the world’s gargantuan energy needs while responsively mitigating their side effects.”

In terms of our project, we inject carbon dioxide a mile under ground and have been doing so since 2000. So we have quite a bit of experience in this. This CO_2 that we are using is coming from North Dakota, about 200 miles to the south of our field. It is CO_2 that otherwise would have been emitted to the atmosphere by Dakota Gasification, and theirs is a coal gasification facility that produces a good quality CO_2 for us.

We are able to recover we are forecasting over the projects 30-year life an additional 155 million barrels of oil as well as being able to store 30 million metric tons of CO_2. To put that in perspective, that is about the equivalent of approximately 6.7 million cars that we could deal with the emissions of for one year. About a quarter of that CO_2 has been injected already, and we are currently at production levels of about 30,000 barrels a day.

I want to reinforce that this project is commercial scale, and we have also been the test site for what is referred to as the IEA, International Energy Agency, greenhouse gas Weyburn and CO_2 monitoring and storage project since the year 2000 as well. This international multiparty study, of which the DOE has contributed to it extensively, proved in 2004 through its phase one results the storage of CO_2 at Weyburn is viable and safe over the long-term. The findings indicated that 99.8 percent of this CO_2 would remain well underground with high probability for 5,000 years.

EnCana is very proud of our Weyburn project. It took a lot of effort to get to where we are today in terms of a lot of years of technical analysis, substantial capital investment, a viable CO_2 supply which could be economic, as well as very lengthy negotiations with partners, with the CO_2 suppliers, and with governments to put it all together. We think there are opportunities to do this in other sites, and like the panelists said before, you have to be very cautious though. The geology must be right, and a lot of study must go there, and it is important when one does embark on this to have extensive monitoring.

We are now pleased to be participating in the final phase of that IEA project whereby we will look to transfer the knowledge gained at Weyburn toward other fields in the future, and also set a good foundation for policy, sound regulation and good operating practices. I would be very pleased to answer any questions that you have at the completion of the talks here.

[The prepared statement of Ms. Fairburn follows:]

Statement of Judy Fairburn, Vice President Downstream Operations, EnCana Corporation, Calgary, Alberta, Canada

My name is Judy Fairburn. I am Vice President of Downstream Operations for EnCana Corporation. EnCana is a dynamic North American industry leader in unconventional natural gas and integrated oilsands development. I am currently responsible for EnCana’s co-ownership in two United States refineries, a result of the recently announced Oilsands partnership with ConocoPhillips.

Previously to my current position I was Vice-President of EnCana’s Weyburn Business Unit, a technology driven business that is both Canada’s largest enhanced oil recovery project as well as the world’s largest CO_2 geological storage project. In that capacity I was responsible for all aspects of the Weyburn business including strategy, business development, technology, drilling, operations and stakeholder relations. Prior to my Weyburn responsibilities. I was Vice-President, Portfolio Management for EnCana Upstream operations.

I come here today at the invitation of the Chairman to discuss the technology that EnCana developed in the storage of carbon dioxide and our experiences at our Weyburn Enhanced Oil recovery operation in Saskatchewan, Canada.

Introduction

The Weyburn oilfield, operated by EnCana, is demonstrating that oil production can be increased in an environmentally responsible manner through underground injection of carbon dioxide (CO_2). CO_2 has been injected into this oilfield since 2000, making valuable use of a by-product that would have otherwise been emitted from Dakota Gasification Company's coal gasification facility located in the northern United States. The field is projected to store 30 million tonnes of CO_2 over the EOR life, equal to taking about 6.7 million cars off the road for one year. I will discuss in more depth how EOR is prolonging the life of the Weyburn oilfield, while at the same time contributing to reducing CO_2 emissions.

The Weyburn oilfield has also served as the highly coveted, commercial-scale laboratory for the International Energy Agency (IEA) Green House Gas Weyburn CO_2 Monitoring and Storage Project. This multi-party, international research project, run under the auspices of the International Energy Agency, recently concluded that storage of CO_2 in an oil reservoir is viable and safe over the long term, thus providing a good foundation for the development of solid policy, regulations and operating practices for future CO_2 storage/EOR. The results of the first phase of the IEA project will be covered as well as the key elements of the final phase, which has recently been launched.

EnCana Corporation—An Overview

EnCana was formed in 2002 from the merger of two highly respected Canadian companies, PanCanadian Energy and Alberta Energy Company. Headquartered in Calgary, Canada, EnCana is one of North America's largest natural gas producers. It is uniquely positioned as an industry leader in unconventional natural gas and integrated oilsands development, focused on creating long-term value. EnCana's portfolio of long-life resource plays includes 12 key plays in Canada and the United States, with nine producing natural gas and three focused on oil. In 2006, total sales volumes were 4.4 Billion cubic feet equivalent per day (about 725 Million barrels oil equivalent per day). EnCana has extensive operations in the United States (approximately one third of total production) with EnCana USA headquarters in Denver, Colorado.

EnCana strives to increase the net asset value of the company for shareholders, make efficient use of resources and minimize its environmental footprint. The company's success is determined not only through its bottom line but also through its behaviour. Weyburn is an example of that commitment

Weyburn Oilfield—Enhanced Oil Recovery

Located in the southeast corner of the province of Saskatchewan in Western Canada, Weyburn is a 180-square-kilometer (70-square-mile) oil field discovered in 1954. It is part of the large Williston sedimentary basin, which straddles Canada and the U.S. Production is 25- to 34-degree API medium gravity sour crude. The reservoir is a Mississippian-aged Midale Marly zone, a low permeability chalky dolomite overlying the Midale Vuggy zone, a highly fractured and permeable limestone.

Water-flooding to increase oil recovery was initiated in 1964 and significant field development, including the extensive use of horizontal wells, was begun in 1991. In September 2000, the first phase of a CO_2 enhanced oil recovery scheme was initiated. The EOR project is to be expanded in phases to a total of 75 patterns over the next 15 years. The CO_2 is a purchased byproduct from the Dakota Gasification Company's (DGC) synthetic fuel plant in Beulah, North Dakota. If this CO_2 had not been used for EOR and stored, it would have otherwise been emitted into the atmosphere. It is transported through a 200 mile pipeline to Weyburn then injected into the reservoir, one mile underground. The CO_2 is 95% pure and Weyburn's current take is 6600 tonnes/day (equivalent to 125 mmscfd).

EOR has given the Weyburn field a new life. It currently produces over 30,000 bbls/d of light crude oil, the highest production level in 30 years, with 155 million gross barrels of incremental oil slated to be recovered over the project life. Without EOR, only 13,000 bbls/d would have been produced leaving a huge resource untapped. The environmental benefits are also significant. CO_2 storage contributes to mitigating emissions. The Weyburn project has stored approximately 7 million tonnes of CO_2 to date and over the lifetime of the EOR project, it is projected that an additional 23 million tonnes of CO_2 will be sequestered.

IEA Green House Gas Weyburn CO_2 *Storage & Monitoring Project—Phase I*

Project description

The IEA Green House Gas Weyburn CO_2 Storage and Monitoring Project is a significant CO_2 monitoring and storage R&D effort that has run in parallel with the commercial Weyburn EOR project. Phase 1 of this project was designed to contribute significantly to the understanding of greenhouse gas management, specifically the technical feasibility and long term fate/security of CO_2 storage in geological formations.

Initiated in 2000 by the Saskatchewan Ministry of Energy and Mines (now Saskatchewan Industry and Resources), the federal Department of Natural Resources, and PanCanadian (now EnCana), this $40 million multi-disciplinary project has been endorsed by the International Energy Agency GHG Research and Development Programme. It has been managed by the Petroleum Technology Research Centre (PTRC) of Saskatchewan.

This project constitutes the largest, full-scale, in-the-field scientific study ever conducted in the world involving carbon dioxide storage. Weyburn has become the international flagship project on GHG geological storage research, routinely receiving senior level business and government personnel, as well as media, from around the globe.

This collaborative research was funded by 15 public and private sector institutions. In addition to the two previously mentioned government departments, other government partners included the United States Department of Energy (US DOE), the European Union, and the province of Alberta through the Alberta Energy Research Institute. Industry sponsors included EnCana, BP plc, ChevronTexaco Corp., Dakota Gasification Company, Engineering Advancement Association of Japan, Nexen Inc., SaskPower, TransAlta Corporation and Total SA of France. The project also involved 24 research and consulting organizations in Canada, Europe and the United States.

The overall objective of Phase 1 of the project was to predict and verify the ability of an oil reservoir to securely store and economically contain CO_2. The scope of work focused on understanding the mechanisms of CO_2 distribution and containment within the reservoir into which the CO_2 is injected and the degree to which the CO_2 can be permanently sequestered.

Phase 1 results [1]

Completed in 2004, Phase 1 successfully concluded that CO_2 can be securely stored underground in an oil reservoir such as Weyburn. Through extensive geological, geophysical and hydrogeological work, as well as deterministic and stochastic (probabilistic) modeling, the work concluded that after 5000 years, 99.8% of the CO_2 injected into the Weyburn field would remain trapped underground.

A key feature of the project was the pre-injection baseline monitoring that was done prior to CO_2 injection at the field. While there are already commercial applications of CO_2 EOR in the United States, the Weyburn oilfield and the IEA project are unique, due to the comprehensive knowledge of pre-injection reservoir conditions as a result of an extensive historical database of geological and engineering information. This has proven critical to following the movement of CO_2 in the Weyburn reservoir over the four years of the Phase 1 project.

Excellent monitoring techniques were progressed through the project; the movement of the CO_2 was predicted, monitored and verified by different methods. The greatest success was encountered with four-dimensional time lapse seismic surveys, which can reliably detect relatively small volumes of CO_2 underground. Geochemical fluid sampling also gave good insights into the movement of CO_2 within the reservoir and can detect any CO_2 breakthrough at wells.

IEA Green House Gas Weyburn CO_2 *Storage & Monitoring Project—Final Phase*

Phase 1 of the IEA project has provided a good foundation for the development of solid policy, regulations and operating practices for future CO_2 storage/EOR projects; however, there is more work to be done. The September 2004 final report identified a number of important gaps and recommended a follow-up "Final Phase" to enable transfer of knowledge and technology gained in Weyburn to a more widespread industrial implementation of this technology and to ensure public confidence in geological long-term storage of CO_2. We foresee a future where Weyburn has paved the way and future projects will not need to expend nearly as much research and monitoring resources to be assured of safe geological storage.

Next steps: Technical

Extensive investment and effort have been expended to get to the current level of understanding of geological storage at Weyburn but additional work is still necessary to develop cost-effective protocols to enable efficient site selection, design, operation, risk assessment and monitoring of future projects.

The key gaps identified in Phase I and the measures being taken in the Final Phase to address them and achieve win-win solutions include:

(I) Drafting of firm protocols for storage site selection.

(ii) Final selection of the most effective underground monitoring methods for CO_2 movements.

(iii) Identifying the most effective reservoir methods for maximizing storage capacity and oil recovery.

(iv) Finalizing the development of the most cost-effective and credible risk assessment methods and risk mitigation techniques to ensure the integrity of the storage medium.

Next steps: Non-technical

Advancement of the technical aspects of CO_2 storage is a necessary but insufficient requirement for the management of geological storage of CO_2 on a large scale. A successful CO_2 geologic storage "industry" must encompass a suite of technologies linked by a network of institutions, financial systems and regulations, along with public outreach activities, that are able to achieve broad public understanding and acceptance. Additional work is necessary in the following areas.

Regulatory Issues

For CO_2 storage to flourish, a predictable, science-based regulatory regime needs to be in place. Fortunately, regulations governing the injection of acid gases with a CO_2 component and other industrial applications are already in place. A complementary regulatory framework for long term storage applications with respect to safety and reliability may be required.

The experience from current provincial regulations on issues such as emergency planning and protection, health and safety, and drilling and well completion standards, as well as the fact the oil has been kept in the geological structure for many years should prove very helpful to future CO_2 storage regulatory efforts.

Finally, a transparent registry system should be created, with well-defined measurement protocols and verification requirements, to ensure proper accounting for greenhouse gas reductions created by geological storage and recognition of offset credits.

Public outreach

Geological Storage of CO_2 is increasingly recognized as a pragmatic way to address CO_2 emissions. As Julio Friedmann and Thomas Homer-Dixon wrote in Foreign Affairs, "the technology may be the only realistic way to satisfy the world's gargantuan energy needs while responsibly mitigating their side effects."[2] An effective public outreach and consultation process could be helpful to ensure public understanding and acceptance of geological storage as a viable means of CO_2 sequestration. The technology needs to be communicated to the public in the context of GHG mitigation options, with clear explanations regarding why it is safe and viable over the long-term.

Current Status—Final Phase

The initial technical research package was approved by the sponsors in November 2006 along with a first year budget of $2.9 million (Canadian). Research agreements are currently being reviewed, and the research providers will launch research as soon as the agreements are finalized.

Conclusion

It is EnCana's hope that the experience at Weyburn will enable the start-up of a significant number of commercial-scale EOR-based CO_2 geological storage projects, a win-win scenario for the economy and the environment. These projects would provide substantial environmental benefits by enabling the geological storage of significant quantities of CO_2 that would otherwise be emitted to the atmosphere. Ramping up development of CO_2-based EOR projects would also increase oil recovery and hence improve energy security. Conventional methods in North America only recover approximately 30% of oil in place, leaving a tremendous resource in the ground for EOR.

Although EnCana's activities have focused on EOR-based operations and not on other storage alternatives such as deep saline aquifers or coal bed methane, many of the operating practices so developed would be applicable to these other storage alternatives. Furthermore, the operating practices developed for Weyburn's geological environment would also be transferable to other sites with different geological characteristics. EOR projects currently represent the storage alternative that is the closest to being economic and with the right policy and regulatory framework, market signals and economic conditions, a number of projects could realistically be initiated.

Finally, Weyburn, particularly the IEA Project, demonstrates the power of collaboration and partnerships between governments, researchers and industry to unlock value through technology. The research was valuable to EnCana as it helped the company to better understand its oil field and to innovate (e.g. CO_2 monitoring by four-dimensional seismic survey). It provided the opportunity for a Canadian research centre to develop expertise and potentially become the world leader in CO_2 geological storage monitoring and assessment. Finally, it has enabled government to advance their innovation, technology and sustainability agendas.

References

1. Wilson M. and Monea M., IEA GHG Weyburn CO_2 monitoring & storage project—Summary report 2000-2004, 7th International Conference on Greenhouse Gas Control Technologies, Vancouver, Canada, Sept. 5-9, 2004.
2. Friedmann S. J. and Homer-Dixon T., Out of the Energy Box, Foreign Affairs, November/December 2004, pp 72-83.

Response to questions submitted for the record by Judy Fairburn

Question 1: In your testimony, you report that you inject 6,600 tons of carbon dioxide per day, allowing you to produce over 30,000 bbls/day as opposed to the 13,000 bbls/day that would be produced in the absence of the injection. That works out to 17,000 bbls/day due to the injection, or about 2.5 barrels for every ton of carbon dioxide. Given that a barrel of oil produces roughly 20 gallons of gasoline, and each gallon of gasoline produces roughly 20 pounds of carbon dioxide, it appears that just from the gasoline component of the newly recovered oil, approximately 1.000 pounds of carbon dioxide are being generated. This doesn't include jet fuel, diesel, kerosene, or other fractions from the barrel. So, it is fair to say that the sequestration of one ton of carbon dioxide for EOR generates at least a half-ton of additional carbon dioxide that would otherwise not be generated?

Answer:

The carbon dioxide (CO_2) being used for EOR in Weyburn will ultimately be stored, but would otherwise have been emitted to the atmosphere. Regardless of the product's end use, CO_2 sequestration is an important means to help address the GHG challenge. Oil production is driven by consumer demand and at Weyburn we are able to meet a portion of this demand by producing oil in a less carbon intensive manner. Another consideration is that, through the coal gasification process, Dakota Gasification Company is converting coal to synthetic natural gas. When used as fuel, natural gas produces a little over Vi the CO_2 emissions versus burning coal to produce the same amount of energy. In effect, DGC de-carbonizes coal and Weyburn closes the loop by disposing of the CO_2 that is a by-product of this process.

Question 2: How applicable is your Weyburn experience to other potential sequestration sites? Is it only good for oil fields, or are we learning things that will be important for any potential reservoir?

Answer:

Weyburn experience applies most directly to mature oil fields undergoing enhanced oil recovery using CO_2 but the technology we have developed is easily extended to other geological storage applications. However, each potential site will be unique and so must be rigorously screened to ensure suitability. Research at Weyburn has created a foundation of understanding for potential future projects.

Question 3: Do the monitoring technologies that you're working on work equally well in different reservoir types?

Answer:

Experience to date indicates that many of the techniques applied for oil recovery management are equally applicable to geological storage of CO_2,. Examples would include geophysical methods such as: repeated three-dimensional seismic that allow for analysis of changes in CO_2 migration pathways over time; and petrophysical measurements from well logging tools. Such monitoring can be very expensive, so a simpler method such as soil gas sampling is very useful. This method can detect C02 that may have escaped from the reservoir and migrated to surface. Overall, each potential storage site will be unique, and the monitoring techniques applicable wilt thus vary according.

Question 4: In your testimony, you mention that carbon dioxide movement in the reservoir was predicted, monitored and verified. How good were the predictions? Do we need to do more work in improving these predictions?

Answer:

In a general sense, results have agreed with our predictions in terms of oil production response to COi injection. However, as is typical with any oil recovery scheme, these predictions were not perfect and we revise our forecasts periodically to account for observed data and an ever-improving understanding of the underground geology. This is common industry practice and the complexity of underground oil and gas reservoirs suggests that it is very unlikely that we will ever have perfect predictive capability. In terms of the efficacy of CO_2 storage, Phase 1 of the IEA Weyburn GHG Storage and Monitoring Project determined that 99.8% of the CO_2 would be safely stored underground in Weyburn for at least 5000 years, with a 95% confidence interval range of 0.005% to 1.3% of initial COS in place. This is an extremely high retention rate; nevertheless, we are continuously looking for opportunities to improve. IEA Project first phase results suggested there were no insurmountable technical barriers to Carbon Storage, but identified some areas for refinement which are to be addressed in the Final Phase.

Question 5: How much money and time do you believe is still needed to develop the cost-effective protocols that you're working on?

Answer:

The final phase of the IEA Weyburn GHG Storage and Monitoring Project will help to inform and influence the development of:

- Best practices manual for CO_2 storage associated with EOR:
  - firm protocols for site selection
  - most effective underground monitoring methods
  - most effective reservoir techniques for maximizing storage capacity & oil recovery,
  - most cost effective & credible risk assessment methods & risk mitigation techniques to ensure integrity of the storage medium
- Clear workable regulations for COZ storage—building from existing regulations.
- An effective public policy and consultation process.

Current estimates are that this final phase will cost $18-20 million ($, Canadian) and take three years from commencement of the research.

Question 6: Does the Canadian government attempt to answer the "pollutant versus commodity" question for carbon dioxide sequestration?

Answer:

EnCana's understanding is that the Canadian government have not addressed this issue.

Question 7: Will your "final phase" include any work on the non-technical next steps—the regulatory and public outreach areas?

Answer:

As indicated in the answer to question 5, there wilt be work on the regulatory and public outreach areas. It is important to have clear workable regulations for CO_2 storage—building from existing regulations, and an effective public policy and consultation process.

Question 8: Of the $40 million that has been spent on the International Energy Agency project, how much was paid for by private entities and how much from the public sector? Do you know what the Department of Energy's contribution to that was?

Answer:

Of the $40 million that was spent during Phase 1 of the IEA project, approximately $26 million (65%) came from private industry, including EnCana, and $14 million (35%) was provided by the government sector.

Of this $14 million, the U.S. Department of Energy contributed $5.4 million, with the remaining balance of government funding, approximately $8.6 mm, coming from Canadian institutions.

All figures are in Canadian Dollars.

Mr. COSTA. Thank you very much, Ms. Fairburn. I am sure there will be questions, and thank you for staying within the five-minute time allotted. Our next witness is Mr. Howard Herzog, Principal Research Engineer for the Laboratory for Energy and Environment from the Massachusetts Institute of Technology, a well respected institution.

STATEMENT OF HOWARD HERZOG, PRINCIPAL RESEARCH ENGINEER, LABORATORY FOR ENERGY AND THE ENVIRONMENT, MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Mr. HERZOG. Thank you. Thank you, Mr. Chairman and members of the committee. Thank you for the opportunity to appear here before you today to speak about carbon dioxide geological sequestration. I have been involved with carbon dioxide capture and sequestration for over 18 years. I was coordinating lead author on the intergovernmental panel on climate change special report on carbon dioxide capture and storage and a coauthor of the just released MIT study on the future of coal. I am also a U.S. delegate to the Carbon Sequestration Leadership Forum.

Just two weeks ago in the April 16 edition of Newsweek, there was a quote on climate change that caught my attention. It went like this. “If we cannot get a handle on the coal problem, nothing else matters.” Similar sentiments motivated my colleagues and I to undertake our “Future of Coal Study.” In that study, we conclude that CO_2 capture and sequestration is the critical enabling technology that will reduce CO_2 emissions significantly while also allowing coal to meet the world’s pressing energy needs.

We conclude that carbon sequestration is a critical component of the portfolio of climate change mitigation options but we also recognize that carbon sequestration is not a silver bullet. All components of a carbon sequestration are in commercial operation today. There are several power plants in the U.S. that have a slip stream process to produce carbon dioxide to sell to the commercial markets. For instance, carbonation of beverages.

There exists over 2,000 miles of CO_2 pipeline primarily in the western U.S. We inject tens of millions of tons of CO_2 into the ground each year for enhanced oil recoveries at over 80 sites in the United States, and finally the monitoring tools used in the oil and gas exploration are directly applicable to geologic sequestration operations.

The challenge ahead is to integrate these components and operate them at scale. This challenge should not be underestimated. It will take considerable effort and investment. The MIT coal study concludes that it is scientifically feasible to store large quantities of CO_2 into geologic formations. However, it is urgent to undertake a number of large scale experimental projects in reservoirs that are instrumented, monitored and analyzed to verify the large scale implementation of sequestration.

None of the current sequestration projects worldwide meet all of these criteria. These projects are offshoots of commercial projects with the science coming as an afterthought. We need sequestration demonstrations designed with scientific data collection as the primary goal to enable us to move to the large scale deployment phase.

The MIT coal study makes five recommendations for geological sequestration. First, the DOE should launch a program to develop and deploy large scale sequestration demonstration projects. The program should consist of a minimum of three projects that will represent the range of U.S. geology. Second, the U.S. Geological Survey and the Department of Energy should embark on a three-year bottom up analysis of U.S. geological storage capacity assessments.

Three, the DOE should accelerate its research program for carbon sequestration, science and technology. Four, a regulatory capacity needs to be built. And five, the government needs to assume the liability for the sequestered CO_2 once injection operations cease and the site is closed.

Because of the long lead times associated with developing energy technologies, there is some urgency to start moving the sequestrations demonstrations forward as quickly as possible. If we start on a well funded and well constructed demonstration phase today, within 10 years we could then start commercial deployment. In other words, we need to start planting seeds immediately because of the long lead time required to bear the first fruit.

Unfortunately, the situation today regarding proposed sequestration demonstration projects in the U.S. are that they are underfunded; they do not meet all the criteria I outlined above. Instead the proposed projects are being driven to inject CO_2 into the ground as soon as possible. We do not need to demonstrate that we can inject CO_2 into the ground. We are already doing that. Instead we need demonstrations with full monitoring, integrated where possible, to lay the groundwork for large scale deployment.

In summary, I would like to end with the central message of the MIT coal study. The demonstration of technical, economic and institutional features of carbon capture and sequestration at commercial scale coal combustion and conversion plants will: One, give policymakers and the public confidence that a practical carbon mitigation control option exists; two, shorten the deployment time and reduce the costs for carbon capture and sequestration should a carbon emission policy be adopted; and three, maintain opportunities for the lowest cost and most widely available energy forum to be used to meet the world's pressing energy needs in an environmentally acceptable manner. Thank you, and I look forward to your questions during the question period.

[The prepared statement of Mr. Herzog follows:]

Statement of Howard Herzog, Principal Research Engineer, Massachusetts Institute of Technology Laboratory for Energy and the Environment

Mr. Chairman and members of the committee, thank you for the opportunity to appear before you today to discuss Carbon Dioxide (CO_2) geological sequestration. I have been involved with CO_2 capture and sequestration (CCS) for over 18 years. I started my first research project in CCS in 1989. In 1992-93, under Department of Energy (DOE) funding, I led a 2-year effort that produced the first comprehensive research needs assessment in the field (see DOE/ER-30194). More recently, I was a coordinating lead author on the Intergovernmental Panel on Climate Change (IPCC) Special Report on Carbon Dioxide Capture and Storage (see www.ipcc.ch), as well as one of 13 co-authors on the just released MIT report on The Future of Coal (see www.mit.edu/coal). I am also a U.S. delegate to the Technical Group of the Carbon Sequestration Leadership Forum (see www.cslforum.org).

Just two weeks ago in the April 16 issue of Newsweek, this quote referring to climate change caught my attention: "If we cannot get a handle on the coal problem, nothing else matters." Similar sentiments motivated me and my colleagues at MIT to undertake our "Future of Coal Study". In that study, "we conclude that CO_2 capture and sequestration (CCS) is the critical enabling technology that would reduce CO_2 emissions significantly while also allowing coal to meet the world's pressing energy needs." While we conclude that CCS is a critical component of a portfolio of climate change mitigation options, we also recognize that CCS is not a silver bullet.

CCS has four major technical components in its life-cycle. First there is the capture of CO_2 at a large industrial source, such as a coal-fired power plant. By capture, it is meant isolating the CO_2 in relatively pure form (>90% by vol and typically >99%) and at high pressure (typically in the 1500-2500 psia range). Secondly, the CO_2 is transported from the capture site to the sequestration site, primarily by pipeline. Note that in many cases, the CO_2 capture site may be sitting on top of a sequestration site, so transport could be very minimal. Thirdly, the CO_2 is injected into the geological reservoir (usually at depths greater than 800 m). Finally, the injected CO_2 is monitored in the subsurface via a variety of techniques.

The cost of a CCS system has been estimated to add about 25% to the delivered price of electricity to the consumer. This price assumes that CCS systems are mature and operating at scale. Costs to first movers will be more. The majority of the costs are associated with the capture of CO_2. Over time, it is expected that costs will decrease as technological advances occur.

All components of a CCS system are in commercial operation today. There are several power plants in the U.S. that capture CO_2 from a slip stream to sell into the commercial markets, such as carbonation of beverages. There exists over 2000 miles of CO_2 pipelines in the western US. We inject tens of millions of tons of CO_2 each year for Enhanced Oil Recovery at over 80 sites in the US. Finally, the monitoring tools used in oil and gas exploration are directly applicable to CCS operations.

What are lacking today are the demonstration of CCS as an integrated system and the demonstration of sequestration at scale in a variety of relevant geologies. The issue of scale is a critical point and the task ahead should not be underestimated. It will take considerable effort and investment. It should be noted that the world's current large sequestration projects operating today are all offshoots of commercial projects, with the science coming as an afterthought. We need sequestration demonstrations designed with scientific data collection as a primary goal to enable us to move on to the large-scale deployment phase.

For geological sequestration, the MIT Coal Study finds:

Current evidence indicates that it is scientifically feasible to store large quantities of CO_2 in saline aquifers. In order to address outstanding technical issues that need to be resolved to confirm CCS as a major mitigation option, and to establish public confidence that large scale sequestration is practical and safe, it is urgent to undertake a number of large scale (on the order of 1 million tonnes/year injection) experimental projects in reservoirs that are instrumented, monitored, and analyzed to verify the practical reliability and implementation of sequestration. None of the current sequestration projects worldwide meets all of these criteria.

The MIT Coal study makes five specific recommendations for sequestration:

1. The DOE should launch a program to develop and deploy large-scale sequestration demonstration projects. The program should consist of a minimum of three projects that would represent the range of U.S. geology.
2. The U.S. Geological Survey and the DOE should embark on a 3 year "bottom-up" analysis of U.S. geological storage capacity assessments.
3. The DOE should accelerate its research program for CCS Science & Technology.
4. A regulatory capacity covering the injection of CO_2, accounting and crediting as part of a climate regime, and site closure and monitoring needs to be built.
5. The government needs to assume liability for the sequestered CO_2 once injection operations cease and the site is closed.

There is some urgency to start moving the sequestration demonstrations forward as quickly as possible. The urgency is related to the long lead times associated with developing energy technology. If we started on a well-funded and well-constructed demonstration phase today, within ten years we could then start deployment with commercial CCS plants going on-line. In other words, we need to start planting seeds immediately because of the long lead time required to bear the first fruit.

Unfortunately, the situation today regarding sequestration demonstration projects are that they are underfunded and do not meet the criteria I outlined above. Instead, the proposed projects are being driven to inject CO_2 into the ground as soon as possible. We do not need to demonstrate we can inject CO_2 into the ground—we are already doing that. Instead, we need demonstrations with full monitoring, integrated where possible, to lay the groundwork for large-scale deployment.

In summary, I would like to end with the central message of the MIT Coal Study: The demonstration of technical, economic, and institutional features of carbon capture and sequestration at commercial scale coal combustion and conversion plants, will (1) give policymakers and the public confidence that a practical carbon mitigation control option exists, (2) shorten the deployment time and reduce the cost for carbon capture and sequestration should a carbon emission control policy be adopted, and (3) maintain opportunities for the lowest cost and most widely available energy form to be used to meet the world's pressing energy needs in an environmentally acceptable manner.

For more details on these topics, please see the MIT Coal Study at www.mit.edu/coal. Chapter 4 deals with the topic of geological sequestration. Below are the introduction and recommendations of that chapter.

Introduction:

Carbon sequestration is the long term isolation of carbon dioxide from the atmosphere through physical, chemical, biological, or engineered processes. The largest potential reservoirs for storing carbon are the deep oceans and geological reservoirs in the earth's upper crust. This chapter focuses on geological sequestration because it appears to be the most promising large-scale approach for the 2050 timeframe. It does not discuss ocean or terrestrial sequestration.

In order to achieve substantial GHG reductions, geological storage needs to be deployed at a large scale. For example, 1 Gt C/yr (3.6 Gt CO_2/yr) abatement, requires carbon capture and storage (CCS) from 600 large pulverized coal plants (1000 MW each) or 3600 injection projects at the scale of Statoil's Sleipner project. At present, global carbon emissions from coal approximate 2.5 Gt C. However, given reasonable economic and demand growth projections in a business-as-usual context, global coal emissions could account for 9 Gt C by 2050. These volumes highlight the need to develop rapidly an understanding of typical crustal response to such large projects, and the magnitude of the effort prompts certain concerns regarding implementation, efficiency, and risk of the enterprise.

The key questions of subsurface engineering and surface safety associated with carbon sequestration are:

Subsurface issues:

- Is there enough capacity to store CO_2 where needed?
- Do we understand storage mechanisms well enough?
- Could we establish a process to certify injection sites with our current level of understanding?
- Once injected, can we monitor and verify the movement of subsurface CO_2?

Near surface issues:

- How might the siting of new coal plants be influenced by the distribution of storage sites?
- What is the probability of CO_2 escaping from injection sites? What are the attendant risks? Can we detect leakage if it occurs?
- Will surface leakage negate or reduce the benefits of CCS?

Importantly, there do not appear to be unresolvable open technical issues underlying these questions. Of equal importance, the hurdles to answering these technical questions well appear manageable and surmountable. As such, it appears that geological carbon sequestration is likely to be safe, effective, and competitive with many other options on an economic basis. This chapter explains the technical basis for these statements, and makes recommendations about ways of achieving early resolution of these broad concerns.

Recommendations:

Our overall judgment is that the prospect for geological CO_2 sequestration is excellent. We base this judgment on 30 years of injection experience and the ability of the earth's crust to trap CO_2. That said, there remain substantial open issues about large-scale deployment of carbon sequestration. Our recommendations aim to address the largest and most important of these issues. Our recommendations call for action by the U.S. government; however, many of these recommendations are appropriate for OECD and developing nations who anticipate the use CCS.

1. The U.S. Geological Survey and the DOE, and should embark of a 3 year "bottom-up" analysis of U.S. geological storage capacity assessments. This effort might be modeled after the GEODISC effort in Australia.
2. The DOE should launch a program to develop and deploy large-scale sequestration demonstration projects. The program should consist of a minimum of three projects that would represent the range of U.S. geology and industrial emissions with the following characteristics:

- Injection of the order of 1 million tons CO_2/year for a minimum of 5 years.
- Intensive site characterization with forward simulation, and baseline monitoring
- Monitoring MMV arrays to measure the full complement of relevant parameters. The data from this monitoring should be fully integrated and analyzed.

3. The DOE should accelerate its research program for CCS S&T. The program should begin by developing simulation platforms capable of rendering coupled models for hydrodynamic, geological, geochemical, and geomechanical processes. The geomechanical response to CO_2 injection and determination or risk probability-density functions should also be addressed.
4. A regulatory capacity covering the injection of CO_2, accounting and crediting as part of a climate regime, and site closure and monitoring needs to be built. Two possible paths should be considered—evolution from the existing EPA UIC program or a separate program that covers all the regulatory aspects of CO_2 sequestration.
5. The government needs to assume liability for the sequestered CO_2 once injection operations cease and the site is closed. The transfer of liability would be contingent on the site meeting a set of regulatory criteria (see recommendation 4 above) and the operators paying into an insurance pool to cover potential damages from any future CO_2 leakage.

Mr. COSTA. Thank you very much, Mr. Herzog. Two witnesses in a row under five minutes. We have a streak going here. Our next witness, Mr. Vello Kuuskraa, did I pronounce that name correctly? Kuuskraa. Thank you very much, Mr. Kuuskraa. You are President of Advanced Resources, and we look forward to your testimony.

STATEMENT OF VELLO KUUSKRAA, PRESIDENT, ADVANCED RESOURCES

Mr. KUUSKRAA. Good afternoon. In addition to being President of Advanced Resources, I also serve on the board of directors of Southwestern Energy which is an oil and gas and utility company, and we began to address many of these questions. I am very pleased to address this joint subcommittee. My topic is how to productively begin to use and reuse our industrial and power plant CO_2 emissions for increasing domestic oil recovery.

Our nation's oil basins are mature and declined. In the past 20 years, domestic oil production has dropped by three million barrels a day while consumption has continued to increase. As a result, imports now provide over 60 percent of the oil we use with serious implications for our domestic energy security.

However, we still have nearly 400 billion barrels of oil left behind. This is because of our current production methods recover only about one-third of the original oil in place from domestic oil fields. Accelerated application of CO_2 enhanced oil recovery and particularly what I call next generation technology would enable industry to recover a much larger portion of this left behind oil.

As already noted, CO_2 enhanced oil recovery is already underway, though to a limited extent, in west Texas and New Mexico, along the gulf coast of Louisiana and Mississippi, and in the Rockies. However, many barriers still stand in the way. One of the most significant of these barriers is the lack of sufficient, affordable, and what I call EOR ready CO_2. At the same time, we emit to the atmosphere significant volumes of CO_2 from our industrial and electric power plants.

Capturing and productively using a portion of these emissions in domestic oil fields would have two important benefits. First, it would enable industry to recover over 50 billion barrels of additional domestic oil, enough for two to three million barrels a day of the oil production. This is equal to all of the oil we currently import from the Middle East. With next generation technology, these oil volumes would be appreciably higher.

Second, it would provide a secure geological setting for storing 8 to 12 billion tons of industrial and power plant CO_2. This is enough storage capacity for all of the CO_2 emissions from 80 to 120 large 500 megawatt coal-fired power plants. Next generation technology would also increase the capacity of our reservoirs to store the CO_2.

The above information on domestic oil recovery and productive use of CO_2 is available in a series of 10 basin studies and other reports prepared by our company and the Department of Energy in response to previous Congressional budget language. In summary, three Congressional actions would be of great benefit in my view. First, to provide incentives for capturing and productively using industrial and power plant CO_2 emissions for enhanced oil recovery, such as a tax credit of $15 per metric ton. This would enable and encourage power plant operators to engage the oil industry as a value-added customer for their CO_2.

Second, establish a new research and technology institute for building next generation CO_2 EOR technology. This would greatly expand the size of the market for CO_2 for the power sector as well as further increased domestic oil production. Third, support a large number, 30 or so, of commercial sized demonstrations of CO_2 capture and storage. This would help drive down the costs of CO_2 capture and build confidence in CO_2 storage.

Expansion of efforts such as those in Senate Bill 962 would be an important step in this direction. Thank you very much.

[The prepared statement of Mr. Kuuskraa follows:]

Statement of Vello A. Kuuskraa, President, Advanced Resources International

Good Afternoon. I am pleased to address the House Subcommittee on Energy and Resources on the topic of productivity using industrial and power plant CO_2 emissions for increasing domestic oil production.

Our nation's oil basins are mature and in decline. In the past 20 years, domestic oil production has dropped by 3 million barrels per day while demand for oil has continued to grow. As a result, imports now provide over 60% of the oil we use, with serious implications for energy security.

However, we still have nearly 400 billion barrels of oil left behind or "stranded", Figure 1. This is because our existing primary and secondary oil recovery methods recover only about one-third of the original oil in-place from domestic oil fields, Figure 1. Accelerated application of CO_2-enhanced oil recovery (CO_2-EOR) technology, particularly "next generation" CO_2-EOR technology, would enable industry to recover a large portion of this left behind (stranded) domestic oil.

CO_2-enhanced oil recovery is underway (to a limited extent) in the Permian Basin of West Texas and New Mexico, along the Gulf Coast in Louisiana and Mississippi and in the Rockies in Colorado, Utah and Wyoming, Figure 2. However many barriers stand in the way. One of the most significant of these barriers is the lack of sufficient, affordable "EOR-ready" supplies of CO_2.

At the same time, the nation emits to the atmosphere significant volumes of CO_2 from its industrial and electric power plants. Capturing and productively using a portion of these large CO_2 emissions in domestic oil fields would have two important benefits:

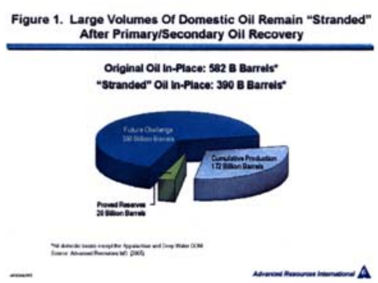
- It would enable industry to recover 40 billion barrels of additional domestic oil, enough to support two to three million barrels per day of domestic oil production, equal to all of the oil we currently import from the Middle East. With "next generation" CO_2-EOR technology, these oil volumes would be appreciably higher.

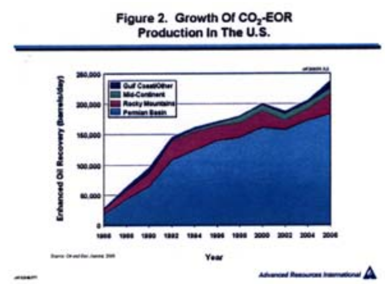
- It would provide a safe, secure geological setting for storing 8 to12 billion tons of industrial and power plant CO_2. This would provide productive use and eventual storage of all of the CO_2 emissions from 80 to 120 large (500 MW) coal-fired power plants for the next 35 years.

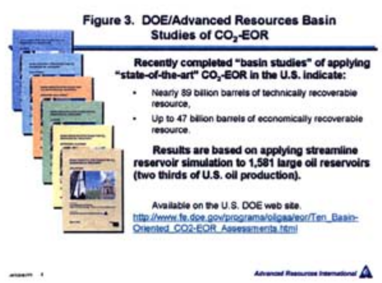
The information on the potential for domestic oil recovery and productive use of CO_2 is based on a series of ten "basin studies" prepared by our company and the Department of Energy in response to previous Congressional Budget language, Figure 3. Three Congressional actions would greatly help realize these important and complementary objectives:

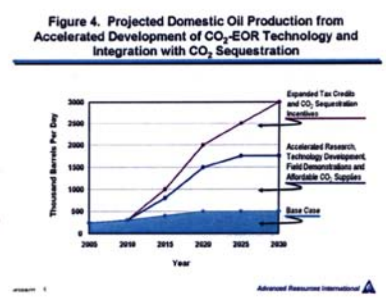
1. First, provide incentives for capturing and using industrial and power plant emissions for CO_2-EOR, such as a tax-credit of $15 per metric ton. This would encourage industrial and power plant operators to engage the oil industry as a "value-added" market for CO_2.
2. Second, establish a new research and technology institute for building "next generation" CO_2-EOR technology. This would greatly expand the size of the market for CO_2 emissions for the power and other coal-using sectors.
3. Third, support a large number of commercial-size demonstrations of CO_2 capture and storage. This would enable the costs of CO_2 capture to be reduced significantly, further expanding the market for productive use of CO_2 and would help build confidence in CO_2 storage.

I urge you to support this three-part initiative, a "win-win" situation for U.S. industry and consumers, Figure 4.









Response to questions submitted for the record by Vello Kuuskraa

1. Could you provide additional detail about what you mean by "next generation" enhanced oil recovery technology, in addition to what you testified at the hearing? Are there specific technologies that are being developed for this next-generation EOR, and could you describe them?

"Next generation" CO_2-EOR is the integrated application of a series of scientifically established but not yet proven (in field applications) oil recovery technologies. These technologies would enable the CO_2-EOR process to become much more efficient and predictable. These technologies include:

- Advanced well drilling designs (e.g., maximum reservoir contact wells) and CO_2 injection designs (e.g., gravity stable CO_2-EOR) that would enable the injection

CO_2 to contact much more of the “left behind”, residual oil in the reservoir (Figure 1 illustrates one such “next generation” CO_2 injection design);

- New CO_2 mobility control and miscibility enhancement materials and processes;
- Much larger CO_2 injection volumes, combined with more efficient use of the injected CO_2; and
- A series of real-time information and feedback systems (e.g., permanent downhole seismic arrays and “smart wells”) that would enable the CO_2-EOR operator to “steer and control,” not just operate, the CO_2-flood.

The two key benefits of “next generation” CO_2-EOR technology—doubling oil recovery shown efficiency and nearly tripling the CO_2 storage capacity of domestic oil fields—are shown on Figure 2. This figure also provides the web site for the report on “next generation” CO_2-EOR technology prepared by my firm, Advanced Resources International, for the U.S. Department of Energy.

Figure 1. Integrating CO2-EOR and CO2 Storage

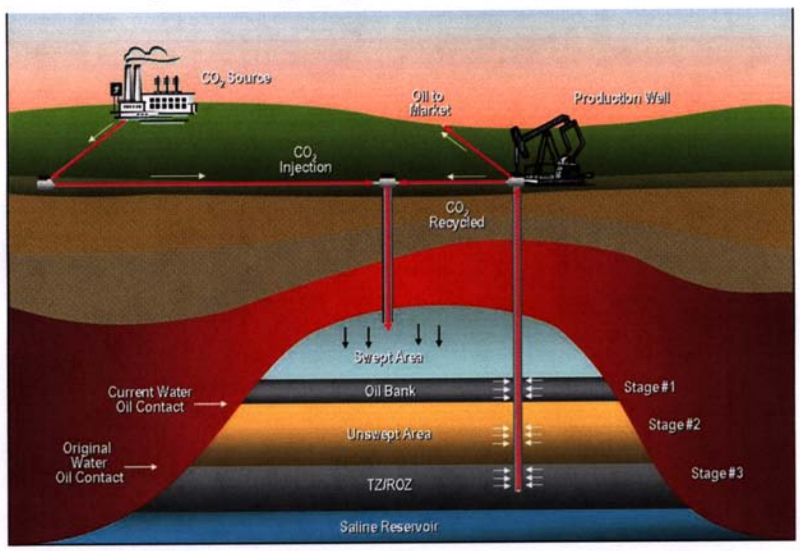


Figure 2. DOE/Advanced Resources Basin Studies of CO2-EOR

Ten “basin studies” of applying “state-of-the-art” CO_2-EOR in the U.S. indicate:

- Nearly 89 billion barrels of technically recoverable resource,
- Up to 47 billion barrels of economically recoverable resource.

Available on the U.S. DOE web site.
http://www.fe.doe.gov/programs/oilgas/eor/Ten_Basin-Oriented_CO2-EOR_Assessments.html

“Next Generation” CO_2-EOR study indicates:

- Oil recovery would be nearly doubled.
- CO_2 storage capacity could increase three fold.

Available on the U.S. DOE web site.
http://www.fe.doe.gov/programs/oilgas/eor/Game_Changer_Oil_Recovery_Efficiency.html

One of my top priority recommendations is that Congress establish a new research and technology institute for CO_2-EOR technology (as set forth in my testimony):

> *"Second, establish a new research and technology institute for building 'next generation' CO_2*-EOR technology. This would greatly expand the size of the market for CO_2 emissions for the power sector, as well as further increase domestic oil production."

A complementary goal for the institute would be to integrate "next generation" technology with CO_2 sequestration.

Such an institute is essential because a serious market imperfection exists in the enhanced oil recovery R&D market place•, precluding higher oil prices (on their own) from assuring the timely development and use of "next generation" EOR technology.

As the major oil companies have exited onshore domestic oil production, this sector has increasingly become dominated by a host of smaller independent producers. None of these independent producers control a large enough portion of the onshore oil resource to justify incurring, on their own, the high costs of developing this "next generation" know-how and technology. (Historically, in this sector, patents have not been able to sufficiently protect a company's investment in new technology.)

As important, our domestic oil fields are mature, with many of these fields near abandonment. As such, time is of the essence because, once abandoned, re-entering these fields with CO_2-EOR becomes much more costly, if not prohibitive.

One specific way to establish this institute would be for Congress to add "Integrated CO_2-EOR and CO_2 Storage Technology" to Sec. 999 of the Energy Policy Act (EPAct) of 2005, and authorize and appropriate $100,000,000 per year of funding to this activity for years 2007 through 2016. These funds would be from Federal royalties, rents and bonuses derived from Federal onshore and offshore oil and gas leases issued under the OCS Land Act and the Mineral Leasing Act.

In Subtitle J of EPAct, Sec. 999H(e) Authorization of Appropriations provides room for an additional $100,000,000 to be appropriated to carry out this section for each of the Fiscal Years 2007 through 2016.

Given that a non-profit organization called RPSEA (Research Partnership to Secure Energy for America) has already been formed and authorized by the Secretary of Energy to carry out two technology topics set forth in Sec. 999—ultra deepwater and unconventional natural gas—adding CO_2-EOR/CO_2 sequestration (which is already noted in Sec. 999(a) (other petroleum resources, sequestration of carbon) could be relatively straightforward and be quick to get started.

2. Do you have any estimates of what the costs would be for a 15 dollar per metric ton tax credit for carbon capture and sequestration for EOR?

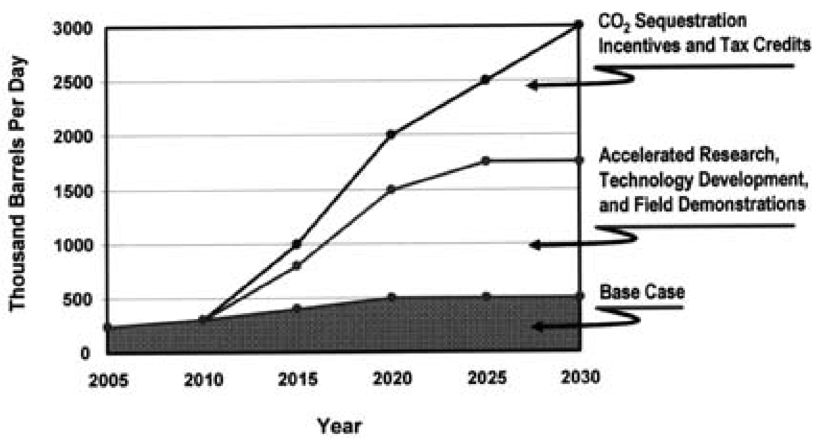
My estimate is that the costs of the $15 per metric ton of CO_2 tax credit for productively using industrial and power plant CO_2 for EOR would be $80 million for the next five years and about $800 million for the next ten years. This estimate is based on the following data and assumptions:

- Oil production volumes are from Figure 3 of my testimony. Half of the incremental oil volumes attributed to the CO_2 Sequestration and Tax Credits wedge of oil production (on Figure 3) would result from the $15 per metric ton of CO_2 tax credit. The other half of the incremental oil would be due to proposed revisions to existing Sec. 43 EOR tax credits to provide a floor oil price for CO_2-EOR to mitigate price risk (as discussed in previous House testimony.)
- The volumes of oil production in the Base Case (on Figure 3) are assumed not to be eligible for tax credits. Since no Federal or state programs currently exist for Accelerated Research, Technology Development and Field Demonstration (see Figure 3) these oil volumes are also not included.
- Finally, based on our work in the ten "basin studies", we use a factor of 0.25 metric tons of purchased CO_2 (about 5 Mcf) to produce one barrel of incremental oil.

Figure 3. Projected Domestic Oil Production from Accelerated Development of CO_2-EOR Technology and Integration with CO_2 Sequestration

---

The recently issued CBO Paper entitled "Evaluating the Role of Prices and R&D in Reducing Carbon Dioxide Emissions" (September 2006), recognizes and further elaborates on this market imperfection.



The benefits of providing this incentive are significant (assuming an oil price of $50 per barrel): (1) additional domestic oil production of 215 million barrels (reaching 160,000 barrels per day) in 10 years; (2) improvement in the trade balance of nearly $11 billion; (3) additional state oil severance tax revenues of about $600 million and additional state and Federal royalty revenues of about $700 million. (These revenues could be used to fund the new "research and development" institute for building "next generation" CO_2-EOR technology.); and, (4) a significant number of new high value, high paying domestic jobs.

3. Do you believe that such a tax credit should be specific for EOR? Or should it be for any capture and storage of carbon dioxide? Since the recovered oil has value, should any tax credit be scaled to reflect the higher costs for non-EOR storage?

Please note that I limited my testimony to the topic of productively using industrial and power plant CO_2 emissions for CO_2-EOR. Clearly, capturing and non-EOR storage of CO_2 (in settings such as deep saline formations) is more costly. Under today's technology, the cost of CO_2 capture and storage from a coal-fired electric power plant is $35 to $40 per metric ton of CO_2, with CO_2 capture being the dominant cost.

At this time, the most productive step in my view is to initiate a series of actions that could cut the cost of CO_2 capture by half, as set forth in my testimony:

> *Third, support a large number, 30 or so, of commercial-size demonstrations of CO_2* capture and storage. This would help drive down the costs of CO_2 capture and build confidence in CO_2 storage. Expansion of efforts, such as those in Senate Bill 962, would be an important step in this direction.

To gain the full scope of benefits, this demonstration program would need to be underlain by a robust and growing program of research and development.

While implementing this recommendation would cost on the order of $25 to $30 billion ($2.5 billion per year for the next 12 years), if successful, it would save the domestic industry and consumers about $200 billion should full-scale implementation of CO_2 capture and storage be required for the 250 or so new coal-fired power plants (with 1,000 MW of capacity) expected to be installed by 2050.

4. In Ms. Fairburn's testimony, she reports that EnCana injects 6,600 tons of carbon dioxide per day, allowing them to produce over 30,000 bbls day as opposed to the 13,000 bbls day that would be produced in the absence of the injection. That works out to 17,000 bbls day due to the injection, or about 2.5 barrels for every ton of carbon dioxide. Given that a barrel of oil produces roughly 20 gallons of gasoline, and each gallon of gasoline produces roughly 20 pounds of carbon dioxide, it appears that just from the gasoline component of the newly recovered oil, approximately 1,000 pounds of carbon dioxide are being generated. This doesn't include jet fuel, diesel, kerosene, or other fractions from the barrel. So, given that the sequestration of one ton of carbon dioxide for EOR generates at least a half-ton of additional carbon dioxide that would otherwise not be generated, should we scale incentives for EOR to reflect the total lifecycle climate impact of the technology?

Most likely, the same volume of gasoline (or diesel) will be consumed by the domestic transportation sector, whether that gasoline (or diesel) is produced domestically with CO_2-EOR, is imported as crude oil or product, or is produced by coal to liquids.

The benefit of obtaining this transportation fuel from domestic use of CO_2-EOR is that, as set forth in the above example, as much (or more) CO_2 is put into the ground (and sequestered) as is contained in the produced oil. As such, the oil produced by CO_2-EOR would be carbon neutral or "green oil". However, should this oil be imported, it would not be carbon neutral, and if produced by coal-to-liquids, it would be even more carbon intensive.

Given these choices and the value of energy security, the incentives for CO_2-EOR should not be scaled back. Rather, they could be further strengthened to give more preference to producing domestic "green oil", particularly with "next generation" CO_2-EOR technology.

Mr. COSTA. Thank you very much, Mr. Kuuskraa, and you too have stayed within the five-minute rule. So we have a real streak going here, and thank you for your succinct testimony as well. It will encourage some questions. Our next witness, Dr. William Schlesinger, who is the Dean of the Nicholas School from Duke University, otherwise known as Chairman Rahall's alma mater, is that correct?

Mr. RAHALL. That is correct.

Mr. COSTA. That is correct. I knew there was a reason we had a good Duke Dean here.

STATEMENT OF WILLIAM SCHLESINGER, DEAN OF THE NICHOLAS SCHOOL, DUKE UNIVERSITY

Mr. SCHLESINGER. Well I am glad to be here. I have spent the last 30 years or so studying various aspects of the carbon cycle of the planet, particularly forests and soils in both forests and agricultural situations, and today, of course, we are here to talk about carbon sequestration, and I think the thing that everybody needs to realize is that trees do a remarkable service for us. Like all plants, every year all the time, they take carbon dioxide out of the atmosphere in photosynthesis and fix it into tissues such as wood which is close to 50 percent carbon by weight, and that is one form of carbon sequestration that has gone on for long periods of time.

Now, of course, not all plant parts live forever. Some of them are leaves and roots and bark and parts that fall off, fall to the ground, and when they hit the ground, they are subject to the action of bacteria and fungi and some portion of that, usually a large fraction, decomposes and puts the carbon dioxide or the carbon in those tissues back to the atmosphere as carbon dioxide.

But a small amount typically can escape decomposition and store carbon in the soil, and that is another form of carbon sequestration. So we can look to the land surface and say that trees and wood in trees and soil carbon, humus as we might call it in a garden, might be good places to store carbon. I also want to mention that a lot of this pertains to some of the questions we had at the end of the previous session here.

The uptake of carbon by trees and the release of carbon in decomposition that is part of the natural carbon cycle, and the same occurs on the surface of the ocean. The ocean takes up carbon. The ocean gives off carbon. These are huge amounts of carbon. But they have been balanced through geologic time. And it really was not until the industrial revolution came on strong and humans began to dig into the crust of the earth for coal and oil and natural gas and burn it, bring it to the surface and burn it, that we had an emission of carbon dioxide in the atmosphere that had no natural balance.

And what we are talking about here today with carbon sequestration is to try to produce some process by which we can get carbon dioxide out of the atmosphere to balance what we are mining out of the surface. And so it is the perturbation of the carbon cycle not these large natural backgrounds that really makes the difference.

I want to talk about sequestration today in two units. When we talk about an individual forest or individual soil, we will use grams of carbon per square meter per year, and for a little comparison, a graphite pencil lead in a new pencil has about a gram of carbon in it. So when I talk about a gram of carbon per square meter per year storage in soils or wood, think of each gram as being equivalent of a pencil.

When we talk about the whole country, I prefer to use the word teragrams, Tg, grams of carbon. That is a million metric tons of carbon, and right now the U.S. emits about 1,600 Tg of carbon to the atmosphere every year in our burning of fossil fuels, and so when we think about carbon sequestration in trees and soils, we need to compare it to the emission of as much as 1,600 Tg of carbon to the atmosphere. That is our basis of comparison.

Now there is no doubt that young and growing forests take up carbon. We can see they get bigger from one year to the next, and a lot of that increase in size is in wood, and the wood is 50 percent carbon, and a landscape that is a mix of old and young trees typically takes up about 300 grams of carbon per square meter per year. That is a good kind of round number.

If you envision planting young forests to take up 10 percent of the nation's carbon dioxide emissions at that rate—sort of take the typical rate—you would need an area roughly the size of the State of Texas. That gives you an indication of the magnitude of the carbon that we need to deal with—a reduction of 10 percent of our emissions by planting new forest where forest does not currently exist in an area the size of the State of Texas.

Now why do I stress young and often planted forests? Eventually a forest matures, and at that time which we call steady state, there is really no further net uptake of carbon. Growth matches death at that point. Now sure there are still some trees growing in an old forest but others are dying. So if you look at an acre, there is no net increase in carbon. And so it is really only in young forests that we can expect a substantial increase in carbon sequestration, in other words removal of carbon dioxide from the atmosphere.

We heard several comments earlier about the temptation to cut down old mature forests in which we would not expect much carbon sequestration to be going on and replace them with young forests, and I want to stress today I think that would be a huge mistake. When an old forest is cut, much of the carbon that it contains and that it has accumulated over many years is released to the atmosphere, and the net carbon sequestration that would count and make a difference in reducing atmospheric carbon dioxide levels will be the difference between the uptake in planted forests versus the release from a cut down forest, and so when we look at forests, we want to think about the value of the storage in old growth forests as they stand before us.

It is really only the planting of forests where forests do not currently exist, either reforestation or afforestation, that will produce a net uptake of carbon. I can see the red light was on. My previous colleagues quit early. I better stop at this point.

[The prepared statement of Mr. Schlesinger follows:]

Statement of William H. Schlesinger, Dean of the Nicholas School of the Environment and Earth Sciences, Duke University

Good afternoon. I am William Schlesinger, currently Dean of the Nicholas School of the Environment and Earth Sciences at Duke University. (N.B. in late May, I will become President of the Institute of Ecosystem Studies in Millbrook, N.Y.) I have spent the past 30 years conducting scientific investigations of the global carbon cycle, especially on the carbon content of trees and soils and how they may affect the content of carbon dioxide (CO_2) in Earth's atmosphere.

We are here today to talk about carbon sequestration. Trees, like all plants, take carbon dioxide from the atmosphere in the process of photosynthesis, and they store some of what they take up in wood, which is about 50% carbon by weight. Carbon storage in trees is one form of carbon sequestration.

Some of the carbon that trees take up is allocated to leaves, small branches and fine roots that do not live for long. When these plant parts die and fall to the ground, they decompose, returning carbon dioxide to the atmosphere. If any of these materials escapes decomposition, it accumulates in the soil as soil organic matter or humus. That storage is another form of carbon sequestration.

Today, I will refer to carbon sequestration using units of grams of carbon-per-square-meter-per-year ($gC/m^2/yr$) for individual forests or soils. For comparison, a graphite pencil lead contains about 1 gram of carbon. In contrast, when we talk about the annual rate of storage of carbon in trees and soils for the entire United States, we will use units of teragrams (TgC/yr). This is equivalent to a million metric tons.

Each year the U.S. emits more than 1600 TgC to the atmosphere as carbon dioxide by burning coal, oil and natural gas. This is a huge mass. For perspective, a long train of coal—100 rail cars of 100 tons each, carries 1/100th of a teragram of carbon, which is converted to carbon dioxide and added to the atmosphere when it is burned.

The potential for carbon sequestration in forests and agricultural soils must be measured against our nation's annual emissions of 1600 TgC/yr.

Young growing forests can accumulate more than 500 gC/m^2yr,disturbed sites stores much less (Clark et al. 2004). In the southeastern U.S., where young pine plantations cover large areas of the coastal plain, average carbon accumulation is 100 $g/m^2/yr$ (Binford et al. 2006). To accumulate 10% of the nation's emissions of carbon dioxide in wood, it would take an area of planted forests about the size of the state of Texas. No small order.

Why do I refer to young, planted forests? Because eventually all forests mature to what is known as a steady-state, where growth matches death, and there is no further sequestration of carbon. Even then, some trees in the forest are growing, but others are dying and the total biomass per acre does not show an increase in carbon content. Only in young forests can we expect significant carbon sequestration.

It is tempting to suggest that we should cut down such old, mature forests that no longer provide carbon sequestration and replace them with young forests that do so. This would be a mistake. When an old forest is cut, much of the carbon that it contains is released back to the atmosphere as CO_2. Net sequestration is thus the difference between carbon stored in the planted forest minus the carbon released from the previous forest, and the value is often neutral, or even negative. Nearly twenty years ago, Mark Harmon and his colleagues (1990) showed that timber harvest results in a net release of carbon dioxide to the atmosphere. Long-lived timber products—houses, furniture, coffins—do not store large amounts of carbon—about 6 TgC/yr for the U.S. (Woodbury et al. 2007). (Remember our emissions are closer to 1600 TgC/yr). Old growth forests retain large stores of carbon, and we should make every effort to retain them.

This means that if we wish to store more carbon in forests—that is carbon sequestration—we need to do so by planting forests in areas that were previously harvested (reforestation) or by encouraging successful forest growth in areas that have never contained forests (afforestation). We can expect those forests to accumulate carbon dioxide from the atmosphere for a number of decades, perhaps even at rates somewhat higher than today's growth rates due to rising concentrations of carbon dioxide in the atmosphere (DeLucia et al. 1999). We would need to allow those forests to grow to maturity, and to maintain them as mature forests or use them as a substitute for fossil fuels if we are to see any benefit from the carbon they have sequestered.

In forests, there is also carbon beneath our feet. A typical forest soil contains about 10,000 gC/m^2, but it accumulates new carbon at a rate of only about 2.5 $gC/m^2/yr$ (Schlesinger 1990). When forests are cut and replanted immediately, there is little loss of soil carbon, but where forests have been converted to agricultural fields for significant periods of time, there are often large losses of soil organic matter, which contributes carbon dioxide to the atmosphere. Replanting forests on those areas can be expected to restore soil carbon and offer another form of carbon sequestration. Typically the rates of carbon storage in soils abandoned from agriculture are 30 to 40 $gC/m^2/yr$ (Post and Kwon 2000)—less than 1/10 of the rate of carbon storage in wood. Nevertheless, as native vegetation has returned to lands enrolled in the Conservation Reserve Program (CRP), it has undoubtedly resulted in some carbon sequestration in soils during the past few decades.

In recent years, rather outlandish claims have been made for the potential for better management of agricultural lands to result in significant carbon sequestration in soils (Lal 2004). These should be examined carefully. In many cases, irrigation and a greater use of nitrogen fertilizer result in additional carbon dioxide emissions to the atmosphere (Schlesinger 2000). Conversion of cultivated lands to no-till agricultural practice offers rather limited benefits in terms of carbon storage (Baker et al. 2007), and these can be erased by a single act of cultivation at a later time (Six et al. 2004). West and Post (2002) found average rates of carbon sequestration were 57 $gC/m^2/yr$ with conversion to no-till, but Kern and Johnson (1993) estimated that the conversion of all U.S. farmland to no-till would store only 1% of U.S. carbon emissions in soils. Only the abandonment of agriculture in favor of planted or natural regeneration of forest is likely to produced significant carbon sequestration (Jackson and Schlesinger 2004).

So, my take-home message today is not an optimistic one. Growing forests store carbon in wood and soil, but we should not sacrifice old-growth forest to increase the nation's carbon sequestration, and carbon sequestration in forests is not likely to offer much overall benefit to the problem of global climate change.

If credit is given to those who choose not to cut existing forests, an increasing global demand for forest products will simply shift deforestation to other areas. Frequent audits of carbon sequestration projects will be needed to determine current carbon uptake, insurance will be necessary to protect past carbon sequestration from destruction by fire or windstorms, and payments will be necessary if the forest is eventually cut. All these efforts will be costly to administer, diminishing the value of the rather modest carbon credits expected from forestry (Schlesinger 2006).

Abandoning agricultural lands might offer some soil carbon sequestration, but large-scale agricultural abandonment seems unlikely at a time when there is so much enthusiasm for biofuels to power the nation's future energy needs. For me, the only realistic way for the United States to contribute meaningfully to reduced concentrations of carbon dioxide in the atmosphere will be to curtail emissions, from a combination of conservation, efficiency and non-fossil sources of energy production.

Thank you.

References

Baker, J.M., T.E. Ochsner, R.T. Venterea, and T.J. Griffis. 2007. Tillage and soil carbon sequestration—What do we really know? Agriculture, Ecosystems and Environment 118: 1-5.
Binford, M.W., H.L. Gholz, G. Starr, and T.A. Martin. 2006. Regional carbon dynamics in the southeastern U.S. coastal plain: Balancing land cover type, timber harvesting, fire, and environmental variation. Journal of Geophysical Research 111:doi:10.1020/2005 JD006820.
Clark, K.L., H.L. Gholz, and M.S. Castro. 2004. Carbon dynamics along a chronosequence of slash pine plantations in north Florida. Ecological Applications 14: 1154-1171.
DeLucia, E.H. J.G. Hamilton, S.L. Naidu, R.B. Thomas, J.A. Andrews, A. Finzi, M. Lavine, R. Matamala, J.E. Mohan, G.R. Hendrey, and W.H. Schlesinger. 1999. Net primary production of a forest ecosystem with experimental CO_2 enrichment. Science 284: 1177-1179.
Harmon, M.E., W.K. Ferrell, and J.F. Franklin. 1990. Effects on carbon storage of conversion of old-growth forests to young forests. Science 247: 699-702.
Jackson, R.B. and W. H. Schlesinger. 2004. Curbing the U.S. carbon deficit. Proceedings of the National Academy of Sciences 101:15827-15829 (Perspective).
Kern, J.S. and M.G. Johnson. 1993. Conservation tillage impacts on natural soil and atmospheric carbon levels. Soil Science Society of America Journal 57: 200-210.
Lal, R. 2004. Soil carbon sequestration impacts on global climate change and food security. Science 304: 1623-1627.
Post, W.M. and Kwon. 2000. Soil carbon sequestration and land-use change: processes and potential. Global Change Biology 6: 317-326.
Schlesinger, W.H. 1990. Evidence from chronosequence studies for a low carbon-storage potential of soils. Nature 348: 232-234.
Schlesinger, W.H. 2000. Carbon sequestration in soils: Some cautions amidst optimism. Agriculture, Ecosystems and Environment 82: 121-127.
Schlesinger, W.H. 2006. Carbon trading. Science 314: 1217
Six, J., S.M. Ogle, F. J. Breidt, R.T. Conant, A.R. Mosier, and K. Paustian. 2004. The potential to mitigate global warming with no-tillage management is only realized when practiced in the long term. Global Change Biology 10: 155-160.
West, T.O. and W.M. Post. 2002. Soil organic carbon sequestration rates by tillage and crop rotation: A global analysis. Soil Science Society of America Journal 66: 1930-1946.
Woodbury, P.B., J.E. Smith and L.S. Heath. 2007. Carbon sequestration in the U.S. forest sector from 1990 to 2010. Forest Ecology and Management 241: 14-27.

Response to questions submitted for the record by William H. Schlesinger

I am writing to respond to your letter of 7 May, asking three questions arising from the 1 May 2007 hearing on carbon sequestration by the Subcommittee. These are:

"Do you believe that converting a field to no-till agriculture would be a bad offset in a carbon regulatory scheme?"

In brief: not a bad offset, but probably not a significant offset.

Generally, one can assume that raising the level soil organic matter offers a number of benefits, so it is good to encourage land management practices that increase soil carbon accumulation. West and Post (2002) report that carbon sequestration averages 0.57 tonsC/ha/yr in soils when farm fields are converted from conventional to no-tillage agriculture. Note that something on the order of 35% of U.S. farmlands are already under no-till management (Uri 1999), where credit should not be granted for carbon accumulations that are not incremental to current practice. In some cases conversion to no-till simply slows the loss of soil carbon, so it should not get any credit at all (Huggins et al. 2007).

Baker et al. (2007) question whether high rates of soil carbon accumulation in no-till fields are real; most studies reporting high C sequestration in no-till have considered only the gain in the surface layers whilst the lower layers often lose carbon. Policy makers must also insist on permanence of the incremental carbon storage in soils. Several studies have suggested that a single subsequent tillage can release most of the carbon stored by several years of no-till management (VandenBygaart and Kay 2006)

Unless the value of offsets is extremely high ($100/ton), it is unlikely that farmers will convert much new acreage to no-till based on the value of the carbon credits alone. The small amount of carbon that will be accumulated and the cost of doing so do not speak strongly for the potential for no-till agriculture to contribute much to the nation's carbon emissions problem. There are a number of problems with the auditing and validation of such carbon credits that are outlined in an editorial I recently published in Science, which is attached here as an appendix.

"In your testimony, you mention using forests as substitutes for fossil fuels. Do you have any estimates of how much energy we could get out of forests while still being environmentally sound? Could you elaborate on your thoughts on this matter?"

At Princeton University, Robert Williams (1994) has conducted a number of analyses indicating that biomass could provide a significant fraction (perhaps 20%, p. 217) of the nation's energy without major environmental degradation. The most obvious potential stems from substituting biomass for coal in power plants, but trees could also provide liquid fuels in the form of cellulosic ethanol when the technology for the efficient conversion of wood to ethanol is improved. Trees for both uses would need to be grown in fast-growing plantations, but I would not recommend a policy of removing native old-growth forests to establish these plantations. They could certainly be established on otherwise barren or degraded lands.

It will be important to investigate the net energy return from managed plantations. In one recent study by Markewitz (2006), the net carbon gain in soil organic matter during 25-year rotations was about equivalent to the carbon released in fossil fuels used during silviculture operations. Nevertheless, whenever we substitute biomass for fossil fuels, we lessen human impact on the global carbon cycle.

"Are there management methods that can be used to increase carbon uptake in mature forests?"

In brief: this will be difficult.

With a few noteworthy exceptions, mature forests tend to show low rates of carbon accumulation, much less than in younger forests (e.g., Clark et al. 2004, Law et al. 2003, Zhou et al. 2006). Management to maintain uptake in older stands could focus on carbon accumulation in soils, riparian sediments, and downstream wetlands (Jandl et al. 2007). Even careful, selective harvest of large trees from old-growth forests is not likely to result in a significant carbon sink in forest products, given that the overall U.S. sink for carbon in forest products is currently only 0.006 PgC/yr, or <1% of our emissions (Woodbury et al. 2007).

I hope this material is useful. Do not hesitate to contact me if you need any further information. Do note that next week my address will change to:

William H. Schlesinger
President, The Institute of Ecosystem Studies
Millbrook, N.Y. 12545
Office phone: 845-677-5343
Email:schlesingerw@ecostudies.org

References

Baker, J.M., T.E. Ochsner, R. T. Venterea, and T. J. Griffis. 2007. Tillage and carbon sequestration—what do we really know? Agriculture, Ecosystems and Environment 118: 1-5.

Clark, K.L., H.L. Gholz, and M.S. Castro. 2004. Carbon dynamics along a chronosequence of slash pine plantations in north Florida. Ecological Applications 14: 1154-1171.

Huggins, D.R., R.R. Allmaras, C.E. Clapp, J.A. Lamb, and G.W. Randall. 2007. Corn-soybean sequences and tillage effects on soil carbon dynamics and storage. Soil Science Society of America Journal 71: 145-154.

Jandl, R., M. Lindner, L. Vesterdal, B. Bauwens, R. Baritz, F. Hagedorn, D.W. Johnson, K. Minkkinen, and K.A. Byrne. 2007. How strongly can forest management influence soil carbon sequestration. Geoderma 137: 253-268.

Law, B.E., O.J. Sun, J. Campbell, S. Van Tuyl, and P.E. Thornton. 2003. Changes in carbon storage and fluxes in a chronosequence of ponderosa pine. Global Change Biology 9: 510-524.

Markewitz, D. 2006. Fossil fuel carbon emissions from silviculture: Impacts on net carbon sequestration in forests. Forest Ecology and Management 236: 153-161.

Uri, N.D. 1999. Factors Affecting the Use of Conservation Tillage in the United States. Water, Air and Soil Pollution 116: 621-38.

VandenBygaart, A.J. and B.D. Kay. 2004. Persistence of soil organic carbon after plowing a long-term no-till field in southern Ontario, Canada 68: 1394-1402.

West, T.O. and W.M. Post. 2002. Soil organic carbon sequestration rates by tillage and crop rotation: a global data analysis. Soil Science Society of America Journal 66: 1930-1946.

Williams, R. 1994. Roles for biomass energy in sustainable development. Pp. 199-225. In R. Socolow, C. Andrews, F. Berkhout and V. Thomas. (Eds.). Industrial Ecology and Global Change. Cambridge University Press.

Woodbury, P.B., J.E. Smith, and L.S. Heath. 2007. Carbon sequestration in the U.S. forest sector from 1990 to 2010. Forest Ecology and Management 241: 14-27.

Zhou, G., S. Liu, Z. Li, D. Zhang, X. Tang, C. Zhou, J. Yan, and J. Mo. 2006. Old-growth forests can accumulate carbon in soils. Science 314: 1417.

EDITORIAL

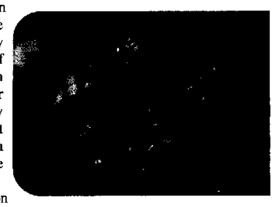
William H. Schlesinger is dean of the Nicholas School of the Environment and Earth Sciences, Duke University, Durham, NC.

Carbon Trading

ENTHUSIASM IS SPREADING FOR CAP-AND-TRADE SYSTEMS TO REGULATE THE AMOUNT of CO_2 emitted to Earth's atmosphere. When the U.S. Environmental Protection Agency set a limit on SO_2 emissions from obvious point sources and allowed those who emit less than their quota to trade excess allowances, regional acid deposition was dramatically reduced. Can the world do the same for CO_2?

Fundamental differences in the biogeochemistry of SO_2 and CO_2 suggest that establishing a comprehensive, market-based cap-and-trade system for CO_2 will be difficult. For SO_2, anthropogenic point sources (largely from coal-fired power plants), which are relatively easy to control, dominate emissions to the atmosphere. Natural sources, such as volcanic emanations, are comparatively small, so reductions of the anthropogenic component can potentially have a great impact, and chemical reactions ensure a short lifetime of SO_2 in the atmosphere. CO_2, in contrast, comes from many distributed sources, some sensitive to climate, others sensitive to human disturbance such as cutting forests. It is thus impossible to control all of the potential sources.

Human-derived emissions from fossil fuel combustion are one of the smaller components of the atmospheric flux of CO_2, which is dominated by exchange between forests and the oceans. During most of the past 10,000 years, the uptake and loss of CO_2 from forests and the oceans must have been closely balanced, because atmospheric CO_2 shows little variation until the start of the Industrial Revolution. CO_2 from coal, oil, and natural gas combustion now comes from many segments of society, including electric power generation, industry, home heating, and transportation. Unbalanced by equivalent anthropogenic sinks for carbon, fossil fuel emissions account for the vast majority of the rise of CO_2 in Earth's atmosphere. Caps on emissions, like those instituted for SO_2, will be difficult to institute if the burden of reducing CO_2 is to be borne equally by all emitters.



Because land plants take up CO_2 in photosynthesis and store the carbon iu biomass, forests and soils seem to be attractive venues to store CO_2. Market-based schemes propose substantial payments and credits to those who achieve net carbon storage in forestry and agriculture, but these projected gains are often small and dispersed over large areas. We will need to net any such carbon uptake against what might have occurred without climate-policy intervention. Conversely, will Canada and Russia be billed for incremental CO_2 releases, as cold northern soils experience warming that stems from the use of fossil fuels worldwide?

If credit is given to those who choose not to cut existing forests, the increasing total demand for forest products will shift deforestation to other areas. Frequent audits will be needed to determine current carbon uptake, insurance will be necessary to protect past carbon credits from destruction by fire or windstorms, and payments will be necessary if the forest is cut. All these efforts will be costly to administer, diminishing the value of the rather modest carbon credits expected from forestry and agriculture.

Many environmental economists recognize that a tax or fee on CO_2 emission from fossil fuel sources is the most efficient system to reduce emissions and spread the burden equitably across all sources: iudustrial and personal. A tax on emissions of fossil fuel carbon could replace the equivalent revenue from income taxes, so the total tax bill of consumers would be unchanged. A higher tax on gasoline would preserve the personal right to drive a larger car or drive long distances, but it will also motivate decisions to do otherwise. A tax on emissions from coal-fired power plants, manifest in monthly electric bills, will motivate the use of alternative energies and energy-use efficiencies at home and in industry.

The biogeochemistry of carbon suggests that both emissions taxes and cap-and-trade programs will work best if restricted to sources of fossil fuel carbon. Other net sources and sinks of carbon in its global biogeochemical cycle are simply too numerous and usually too small to include in an efficient trading system. Simple, fair, and effective must be the hallmarks of policies that will wean us from the carbon-rich diet of the Industrial Revolution, and we must begin soon if we are to have any hope of stabilizing our climate.

– William H. Schlesinger

Mr. COSTA. Well we broke a streak but I guess coming from Duke University, sharing the alma mater of our Chair, that is OK. If you wanted to complete, we did not want to get you at mid thought.

Mr. SCHLESINGER. Most of the rest of what I was going to say is in the printed statement, and we can deal with it in the question period.

Mr. COSTA. Very good. All right. Our next witness, Mr. George Kelly, who is Treasurer I guess of the National Mitigation Banking Association, is that correct?

Mr. KELLY. Yes, sir.

Mr. COSTA. Mr. Kelly.

STATEMENT OF GEORGE KELLY, TREASURER, NATIONAL MITIGATION BANKING ASSOCIATION

Mr. KELLY. Mr. Chairman and members of the committee, it is a great pleasure to be here this afternoon to testify on behalf of the National Mitigation Banking Association. My testimony really relates to forest sequestration, and that from a perspective of a market participant. Before I give you an example of some of the activities we are working on, I wanted to give you a little bit of background about the Association and Mitigation Banking because I think there are some lessons to be learned from that particular industry.

The Association represents commercial businesses that are restoring and protection wetland stream habitat through what is called conservation and mitigation banks. Now they have been operating banks since 1990. My company, Environmental Bank and Exchange, formed in 1997, is a member of the Association. We have restored over 6,000 acres of wetlands, over 34 miles of stream and hundreds of acres of critical habitat using these market-based approaches.

Now mitigation banking is a market-based approach that provides advanced consolidated mitigation to basically compensate for these unavoidable impacts. In terms of the mitigation banker role, typically we restore and enhance and preserve a degraded system in advance of the impacts, and then sell those credits in the marketplace to those we are impacting.

Now the National Academy of Sciences, the Society for Wetland Scientists have basically said this is one of the preferred approaches to mitigation, and as a result there has been a significant proliferation of banks. In 1992, there were 46 banks. Now in 2005, there are over 450 banks. So why this proliferation? For one, there was a clear regulatory driver for mitigation. In addition, Congress stepped in and actually created a preference for mitigation banking for Federally funded roads when there were impacts to those roads, and actually created that preference for mitigation banking.

There have been issues with our industry including the issue of payment for fees, the concept of in lieu fees where you are paying for mitigation which often understates the real cost of mitigation. So why am I going through all this litany on mitigation banking? Because I think there are tremendous lessons to learned in the carbon marketplace.

So the four points that I would like to raise with respect to that is: One, the marketplace is working because there has been a clear regulatory driver. In the case of wetlands and stream, it has been the Clean Water Act or in the case of species banking, it is the Endangered Species Act. In addition, there has been a consistent application of standards to all impactors, and that in essence also might be applicable to the carbon context.

Moreover, there is an opportunity for the private market to play a role in restoring these resources through the concept of offsite mitigation, and finally, as I addressed in the last point is that really we are now resolving some of the issues of letting the market decide the pricing in terms of what the mitigation should actually cost.

So what about the carbon marketplace? Right now we have a voluntary marketplace that is very fragmented. It lacks standards. The pricing is extremely variable. In addition, there are some regulatory standards at the state level. We have had the Global Warming Solution Act in California which is a statewide emissions cap which does contemplate a market-based approach. Those regulations are anticipated in 2011.

Moreover, we have the regional greenhouse gas initiative which is basically 10 northeastern and Mid-Atlantic states. Now in that instance that only applies to power plants and is a cap on power plants. Interestingly enough from the forestry perspective, 3.3 percent of the emission reductions can be met through carbon offsets, and that is an important element.

We understand that there are a number of bills being considered here in Congress, one of which would allow up to 30 percent of offsets. The question here is what percentage of offsets would ultimately dictate what kind of forestry projects might be available. So with respect to forestry mitigation or sequestration, there are four techniques: Afforestation, reforestation, avoided deforestation and forestry conservation practices.

I thought it might be helpful for the committee to hear a recent example of an initiative we recently participated in where there were five utilities under the RGGI regime seeking to buy 7.5 million tons of carbon dioxide. Now under RGGI there are six types of offsets allowed including afforestation. The RGGI standards are very, very strict though and only allowing afforestation on properties that have been in a non-forested condition for 10 years. In addition, there must be a permanent easement. The trees must be planted. Sustainable forestry practices would then apply. Monitoring and verification would be done over five-year periods, and then there is a 60-year accounting for the carbon.

I think the points raised in this initiative is one, there are buyers in the marketplace in RGGI because there is a mandatory cap that is looming. Second, the standards are very strict, and we will have a result of having increased price per unit because it is limited to afforestation, does not allow avoided deforestation or forestry conservation practices, and it has a 60-year accounting period.

I think that one of the biggest points—and I will close with this—is as we as investors in these forest sequestration projects look at these, we need to be able to recoup our funds within a 5 to 10-year period, and the concept of for credit sale is a very important facet. With that I see my red light. I am sorry to have gone over. Thank you very much.

[The prepared statement of Mr. Kelly follows:]

Statemnet of George W. Kelly, National Mitigation Banking Association.

Good Afternoon. My name is George W. Kelly and it is my pleasure to be present today to address the issue of terrestrial carbon sequestration. I am here as a member of the Board of the National Mitigation Banking Association. The focus of my testimony will be on the use of forestry-based sequestration from the perspective of an entrepreneur in the natural resource credit business.

National Mitigation Banking Association and Mitigation Banking

As a matter of background, the National Mitigation Banking Association ("Association") represents commercial businesses committed to the restoration and preservation of our nation's wetlands and natural habitat through the use of mitigation and conservation banks. The Association's members have established and operated mitigation banks throughout the United States since the early 1990s.

Environmental Banc & Exchange ("EBX") has been a member of the Association since 2003. Founded in 1997, EBX is one of America's leading full-service providers of ecosystem mitigation and offsets. It has completed over 35 mitigation banks and client specific projects nationwide, restored 34 miles of stream, restored over 6,000 acres of wetlands and rehabilitated hundreds of acres of forest and other critical habitats. EBX has demonstrated a particular expertise with the restoration of bottomland hardwood systems.

Mitigation banking is a market-based industry which involves creation of sites of advanced, consolidated mitigation for the express purpose of compensating for the adverse impacts on wetlands or streams authorized by a permit under Section 404 of the Clean Water Act ("CWA"), 33 U.S.C. § 1344, or other similar laws. Mitigation bankers are in the business of restoring, enhancing and sometimes creating wetlands, in advance, to sell as compensatory mitigation when mitigation cannot be achieved at the development site. A mitigation bank typically utilizes a medium to large degraded wetland site, and improves the ecological characteristics of the site through restoration and enhancement efforts, or through wetlands creation. The units of restored, enhanced or created wetlands are expressed as "credits," which mitigation bankers sell to developers or other Section 404 permittees to offset the "debits" that will result from permitted filling at the project development site.

Since the seminal report, Protecting America's Wetlands: An Action Agenda, the Final Report of the National Wetlands Policy Forum (The Conservation Foundation, 1988), mitigation banking has been recognized as most appropriate for CWA compensatory mitigation. Indeed, after a comprehensive two-year study, the National Academy of Sciences affirmed that mitigation banking offers advantages over traditional mitigation approaches. National Research Council, Compensating For Wetland Losses Under the Clean Water Act (National Academy Press 2001). The Society of Wetland Scientists also expressed support for mitigation banking in its Wetland Mitigation Banking, Position Paper, February 2004.

In the last 15 years, mitigation banks have proliferated across the country. The Environmental Protection Agency estimates that mitigation banking has grown from 46 banks in 1992, to 219 banks by the end of 2001, to an estimated more than 450 in 2005. According to Corps of Engineers data, as of 2000, there were between 370 and 400 mitigation banks nationwide, in more than 35 states. The Environmental Protection Agency has recognized that "entrepreneurial providers of bank credits have emerged as a nationally-organized industry contributing hundreds of millions of dollars annually to the domestic product." With respect to wetland restoration in general, the Fish and Wildlife Service estimated that more than $139 million would be spent in 25 states and one territory by the end of Fiscal Year 2004 to restore or protect more than 167,000 acres of wetlands.

There are approved wetland and stream mitigation banks in at least 42 States, based on 2004 data:

Alabama	Florida	Kentucky	Mississippi	Ohio	Texas
Alaska	Georgia	Louisiana	Missouri	Oklahoma	Utah
Arizona	Idaho	Maine	Montana	Oregon	Virginia
Arkansas	Illinois	Maryland	Nevada	Pennsylvania	Washington
California	Indiana	Massachusetts	New Jersey	South Carolina	West Virginia
Colorado	Iowa	Michigan	New York	South Dakota	Wisconsin
Delaware	Kansas	Minnesota	North Carolina	Tennessee	Wyoming

It is important to note that the mitigation banking marketplace is entirely driven by rules and regulations under the Clean Water Act and the Endangered Species Act. Those who want to impact wetlands, streams or protected species are required to obtain permits and compensate for the impacts; the basic standard is to provide a "no net loss" in functions and area. Without strict rules and enforcement of the rules, there is no market for mitigation credits. Because mitigation banks are heavily regulated and have a proven track record of success, Congress has provided a preference for mitigation banking where there are impacts from federally-funded road projects. The preference ensures a certain allocation of the marketplace to mitigation banking.

Notwithstanding the positive rules, the mitigation banking marketplace has also suffered from the growth of in-lieu fee projects, under which mitigation requirements may be met through payment of fees. The fees are often set by rule, or in other methods that fail to capture the real cost of mitigation because the actual plan for mitigation (how to spend the money) is developed after the fees are collected. Such programs undermine investment in effective mitigation. Recognizing the importance of a level playing field among mitigation providers, Congress recently enacted a law that requires that the Army Corps promulgate regulations that promote equivalent standards for all forms of mitigation. This was also intended to address the variability in regional approaches that can undermine the marketplace for mitigation credits.

We believe that any policy relating to the carbon market should take into account the lessons learned in the wetland mitigation marketplace, including: (1) establishment of clear regulatory drivers; for wetlands and streams, the driver is the very strict requirement to obtain a permit and the mitigation requirement for impacts; (2) consistent application of the rules and inclusiveness for all or most sources of emissions; for wetlands and streams, very few impacters are exempt from the regulatory system; (3) authorization for private markets in offsets; for wetlands and streams, this means authorization for off-site mitigation; and (4) let the market decide the price of the credits; for wetlands and streams, mitigation fees set by statute or rule (in-lieu fees) impede the credit market and often fail to meet the offset goals.

Carbon

Carbon markets can be separated into two major categories: the regulatory (or compliance) and voluntary markets. Currently, in the US, in light of the lack of national standards, there exists a patchwork of both voluntary and regional regulatory markets. Unlike the regulated market, the voluntary market does not rely on legally mandated reductions to generate demand. Often, the voluntary market participants are motivated by positive public relations and the potential to position themselves as early movers in a marketplace. At the consumer level, participants are trying to reduce their carbon footprint through acquisition of carbon offsets. Currently, there exists the Chicago Climate Exchange whose 52 members have voluntarily committed to reduce their emissions. Also, there exist some three dozen companies offering voluntary carbon offsets. The voluntary market suffers from fragmentation, lack of standards and pricing variability.

From a regulatory perspective, the states and regions are serving as the laboratory for the carbon marketplace. California and the Northeastern states have taken the lead. California enacted in 2006 the Global Warming Solution Act, which contemplates a market-based approach to achieve a statewide emissions cap. Regulations are being formulated and must be in place by 2011. Also, California announced that it would participate in the recently publicized Western Regional Climate Action Initiative with Washington, Oregon and New Mexico. In the Northeast, some 10 states in the Northeast and the Mid-Atlantic have committed to enter into the Regional Greenhouse Gas Initiative, otherwise known as RGGI. RGGI only applies to power plants in those 10 states and imposes a cap on the total emissions, which in turn is allocated among the states. The states have the discretion to allocate to the power plants. The goal is to meet these standards by 2009. RGGI also allows carbon offsets to cover 3.3% of a facility's carbon emissions, and that percentage will rise to 5% if the price of CO_2 goes beyond $7/ton.

Carbon offset trading will need a regulatory system with features similar to wetland mitigation banking, if there is to be a viable market in such credits. As noted with respect to the wetland and stream mitigation marketplace, without a clear legal driver mandating carbon reductions, the market will remain fragmented. In addition, policies need to be in place that allow for flexible mechanisms, such as cap-and-trade, which in turn allows for emitters to identify the most cost-effective options in reducing their carbon emissions. All or most emitters must be included in the regulatory system. The system must require actual offset projects, rather than establish regulatory fees or allow in-lieu fee programs. If all players must meet meaningful limits, the price will be set by the marketplace at the cost effective level. Both the California Act and RGGI provide for such market-based approaches. In this fashion, emitters can decide whether to internally reduce emissions, or purchase either carbon offsets or allowances from another facility.

Carbon offsets from natural resource restoration projects will involve issues of restoration science and land management very familiar to wetland mitigation bankers. Habitat restoration, primarily forestry projects fall under the category of carbon offsets projects. To develop a market for carbon from habitat restoration/forestry, the regulatory system for greenhouse gas reduction needs to authorize a significant percentage of reductions to be met through offsets. It is our current understanding that there are a number of bills pending before Congress, some of which would authorize up to 30% of the carbon reductions to be met through offsets. The offset policy is key to determining the extent that habitat restoration and forestry projects would participate in greenhouse gas emission control. As we mentioned, RGGI allows 3.3% of a facility's emissions to be met by offsets.

Forestry Projects

Forestry projects include afforestation (planting tress on area with no previous cover), reforestation, agroforestry, forest conservation and avoided deforestation. Forestry projects not only sequester carbon, they provide numerous co-benefits such as biological diversity, erosion reduction, enhanced water quality and enhanced recreational opportunities. Forestry projects also are tangible and provide a strong symbol of permanent conservation. They provide natural infrastructure for the planet. Absent incentives for restoration and protection, our forest resources continue to be lost and degraded. Areas needing re-vegetation or reforestation often cannot attract investments, and payments for the storage of carbon may help reduce the conversion of these systems to other so-called "highest and best use" alternatives.

As we explore the role of forest carbon sequestration, I thought it would be helpful for illustration to review a recent Request for Proposal to purchase 7.5m tons of CO_2 credits issued by the Climate Trust in February, 2007. The Request was initiated by the fact that there are 5 participants who are electric utilities under RGGI that will be subject to regulated standards in 2009. As noted, RGGI allows for six types of carbon offset projects, including afforestation. Afforestation under RGGI means the site had to have been in a non-forested state for 10 years or more. To obtain credit under RGGI for afforestation, the site must be replanted; it is subject to strict monitoring and verification protocols (every 5 years); it must be subject to a permanent easement and sustainable forest management practices; and credits may be generated over a 60-year period, even though other programs allow for a 100-year period. If the site is used for other regulatory purposes, such as wetland or "tree save" mitigation, it is not eligible for use for carbon offsets. Also, the project must start only after carbon funding is available to demonstrate "additionality." "Additionality" means that the project will add the function of carbon sequestration beyond the level attained without the project.

RGGI standards provide an example of forestry more strict than other offset forestry programs. RGGI does not allow avoided deforestation or forest conservation practices to get carbon credit. Also, the 60-year accounting period tends to make the unit price of a credit more expensive than a 100-year accounting period because there are fewer tons of CO_2 sequestered over the shorter period, yet the unit costs to produce the credit (i.e., grading, tree planting, monitoring) remain the same. Also, for those submitting a proposal to provide carbon offsets, it is imperative that the initial capital costs of a forestry project be recouped in the early stages, otherwise these projects would never be considered commercially reasonable. Accordingly, the concept of forward credit sale, where payments are made for credits before carbon is actually sequestered, is important in forestry projects. Such forward crediting should only be allowed if there exist adequate safeguards, such as reserves, insurance and monitoring and verification protocols. Prices may be discounted to account for time value of money and the risk of non-delivery. In this fashion, project developers could get early financing for up-front project costs, without waiting 60 to 100 years.

While many wetland and stream mitigation projects can meet performance standards quickly, the mitigation banking industry has experience with slow growth vegetation as well. The mitigation banking marketplace similarly uses the concept of forward selling for wetland mitigation projects involving slow growth trees. For example, it typically takes some 80 years for newly restored bottomland hardwood systems to reach maturity. Nevertheless, mitigation bankers are given credit over 5 to 10 year period, which covers the time while the project is graded, planted and closely monitored for early vegetation success. This monitoring period serves as a proxy for demonstrating whether these newly restored systems are on a trajectory to achieve success. There are also other protections, such as financial assurances and staggered release of credits, to provide additional safeguards to ensure performance.

This provides a balance between ecology and economics. Without the ability to recoup an investment in a reasonable period, there would be very few investors in this significant restoration program.

Conclusion

While there are a number of bills pending in Congress addressing carbon and offset credits, the Association has not take a position on any particular bill. Therefore I am not going to comment on any specific bills.

However, I have been pleased to share with you our experience that certain features are important to creation of environmental credit markets. There need to be consistent standards applied nationwide, and these standards should be predictable in their application. There also should be built-in flexible market mechanisms with an allocation for carbon offset projects. For forestry projects, the concepts of forward selling should be considered, so long as there are adequate safeguards to ensure permanence of the trees. Insurance products supported by the U.S. Government, such as those proposed under the 2007 Farm Bill would be helpful. Moreover, as the mitigation banking marketplace has taught us, having systems that set fee caps or allow fees to be paid in lieu of actual carbon reductions would undermine investment and likely produce inadequate results for carbon reduction.

Thank you for the opportunity to present this information to your joint committees. I would be happy to answer your questions.

Mr. COSTA. That is OK. Anyhow, we have our last witness but certainly not the least, and we will move on to questioning by members of the committee. Mr. Michael Goergen, is that correct?

Mr. GOERGEN. Goergen, but that is fine.

Mr. COSTA. Goergen. OK. I am sorry. Executive Vice President and CEO of the Society of American Foresters.

STATEMENT OF MICHAEL GOERGEN, EXECUTIVE VICE PRESIDENT AND CEO, SOCIETY OF AMERICAN FORESTERS

Mr. GOERGEN. Thank you very much, Mr. Chairman, members of the committee. I am thrilled to be here today in front of you talking about what I see as really some very important issues that are related to forests and carbon and our ability to do something about the challenges that face us today.

Mr. COSTA. Well we are thrilled to have you here.

Mr. GOERGEN. Thank you. The Society represents 15,000 members who are forest managers, consultants, academics, and researchers. We promote sustainable forest management for balance and diverse values. SAF members are working on these challenges in a variety of different settings, through their research units, through companies that they are working with in some of the mitigation banking concepts that we have been hearing about already this morning.

There are a number of factors that really mandate a prominent role for forests in any comprehensive solution that addresses climate change. Forests globally, above ground and in the soil, store 50 percent more carbon than is actually in the atmosphere. Forests in the United States sequester approximately 200 to 280 million tons of carbon per year, offsetting 10 to 20 percent of our country's emissions from fossil fuels.

In addition, forest biomass could be used to generate energy and can provide as much as 30 percent of the nation's renewable energy supply. Given today's improved technologies, analysis has shown that for every bone dry ton of biomass used to generate power, there is a net reduction of approximately one ton of greenhouse gases. So forests are not the solution to the carbon question but they are certainly an important part of a broad set of strategies and recognizing this introduces a number of policy implications for forests and forest management. I would like to review a few key points today.

The first is that forests are storing carbon right now. What can we do to make sure that forests stay forested so that there is not pressure to convert forests to other uses that would reduce the amount of carbon being stored? The second is, that we need to find new markets for people who own forests. Remember 57 percent of our nation's forests are held by private, small landowners.

They need markets. We need a carbon market that actually makes sense for them, that is easy to participate in, and the rules are not so onerous that they can participate in a relatively economical way. We also need to look at biomass energy and biofuels as certainly a potential for forests and forest products.

The second point I would like to make is that this renewable resource that we have really could do something about our energy independence needs, and as I mentioned before we could generate 30 percent of our renewable energy needs from forests and forest products. Another important policy implication concerns wildfire and forest health. Our Federal lands alone—there are approximately 100 million acres of forests—are at unnaturally high risk of catastrophic fire.

A wildfire on these lands can emit up to 100 tons of greenhouse gases, aerosols and particulates per acre. So it is incredibly important to increase management activities on these lands, mostly in the form of thinnings for treating hazardous fuels and reducing the threat from uncontrolled fires. In order to help develop renewable energy from biomass obtained from forest treatments, one particular issue that we would need to take a look at is the Section 45 production tax credit for wind and geothermal energy. That is twice the rate right now that it is for biomass energy. That is something Congress could take a look at that could really provide some incentives for investment in forest biomass energy.

If you take a look at life cycle analysis for forest products, there are really some opportunities here. Substitutes—steel, concrete—they actually can consume 250 percent more energy than using the same type of building materials from forests. There is a tremendous opportunity that we have right in front of us today to use more forest products to sequester more carbon and reduce the total greenhouse gas emissions.

Finally, I would like to sum up by saying that hopefully we can get away from the old "us versus them" rhetoric and really focus on the positive dialogue that is now being generated amongst conservation groups, forest industry, scientists, government agencies, and others on the essential role of forest and forest management in accomplishing carbon sequestration and mitigating global warming. Forests are the only form of sequestering and offsetting carbon that also provide many other benefits that we all count on such as clean water, wildlife habitat, biological diversity, wood products and aesthetics, all necessary for the successful functioning of our society. We cannot afford to miss this important opportunity. Thank you.

[The prepared statement of Mr. Goergen follows:]

Statement of Michael Goergen, Executive Vice President and CEO, Society of American Foresters

Chairmen Costa and Grijalva, Ranking Members Pearce and Bishop, and Members of the Committee on Natural Resources, I am Michael Goergen, Executive Vice President and CEO of the Society of American Foresters (SAF). The Society has 15,000 members who are forest managers, consultants, academics, and researchers and promotes sustainable forest management for balanced and diverse values.

Many SAF members are working on climate change issues through their respective universities, agencies, organizations or companies and have already begun to inform the dialogue concerning the essential role of forests and forest management in offsetting greenhouse gas emissions (GHG).

They, and others, have uncovered a number of factors that mandate a prominent role for forests in any comprehensive solution addressing climate change. Forests globally, above ground and in the soil, store fifty percent more carbon than is in the atmosphere. Forests in the United States sequester approximately from 200 to 280 million tons of carbon per year, offsetting 10 to 20 percent of our country's emissions from fossil fuels. In addition, forest biomass can be used to generate energy and could provide as much as 30 percent of the nation's renewable energy supply. Given today's improved technologies, analyses have shown that for every bone dry ton of biomass used to generate power, there is a net reduction of approximately one ton of greenhouse gasses. At worst, energy derived from woody biomass is carbon neutral. This is also the case for biomass converted into biofuels such as cellulosic ethanol or biodiesel, which are decidedly better alternatives than corn, which when converted into bioethanol is a net GHG emitter.

So forests are not the solution to controlling GHG, but they are certainly an important part of a broad set of strategies. Recognizing this introduces a number of policy implications for forests and forest management. I'll review a few of those today.

First and foremost, it will be critical to stabilize the nation's forestland base, reducing forest loss from conversion to other land uses. Fortunately, the total number of forested acres in the U.S. has remained relatively stable for nearly one hundred years; however, we are starting to see an increase in the loss of forestland to development, now occurring at a rate of 1 million acres per year. Since 57 percent of our forests are owned privately, and most of those are in the hands of small, non-industrial, family landowners, economics plays a large role in decisions to convert forestland. The development of carbon markets, that provide income to landowners for sequestering carbon, could have a major affect on reducing forest conversion. Matt Smith and Steven Ruddell, both members of SAF, have recently published articles in SAF publications on carbon markets. They are very informative and are attached to my testimony. I respectfully request that they be submitted for the record. In summary of their findings: most carbon markets do not currently recognize carbon from managed forests, those that do, such as the California Climate Action Registry, are currently establishing rules and standards for participation. As these protocols are implemented and the markets mature, it is likely that they will provide a significant investment and cash flow opportunity for owners of sustainably managed forests.

Another important forest policy implication concerns wildfire and forest health. As this Committee is well aware, catastrophic wildfires are on the increase in this country for a variety of reasons but largely as a result of the increase of hazardous woody debris in our forests, a direct result of overstocking and insect-caused mortality, together with increased human development in the wildland-urban interface. On our federal lands alone there are approximately 180 million acres at an unnaturally high risk of catastrophic fire. A wildfire on these lands can emit up to 100 tons of greenhouse gasses, aerosols and particulates per acre. One study of the 2002 Hayman Fire in Colorado found that more GHGs were emitted from that event than from all the automobiles in the state that year. So it is incredibly important to increase management activities on these lands, mostly in the form of thinnings, for treating hazardous fuels and reducing the threat from uncontrolled wildfire. This, of course, was the purpose behind passage of the Healthy Forests Restoration Act of 2003. Even though the amount of funding and the number of acres treated has quadrupled in recent years, the amount of work being done is still inadequate—a major constraint being available funding. As stated above, new markets in the form of woody biomass for renewable energy and biofuels could provide significant revenues that could help pay for or reduce the costs of fuels treatments.

In order to help develop renewable energy from the biomass obtained from forest treatments, one issue, in particular, must be addressed. Currently the Section 45 Production Tax Credit (PTC) for wind and geothermal energy is twice the rate available for biomass energy investments. If investment in a broad array of renewable energy is to be encouraged, Congress must provide a level playing field for all renewable energy sources, including forest biomass. Fortunately, Representatives Meeks and Herger have introduced H.R. 1924 to provide tax parity for renewables. I encourage your support for this legislation.

Finally concerning wildfire, given the huge amount of forestland with unnatural accumulations of hazardous fuels, even if we greatly increase the number of acres treated, we will still continue to see some large landscape scale fires for decades to come. Since young, growing forests sequester carbon in significant amounts, it is important to insure prompt assessment of needed remediation measures and rapid regeneration through planting following many of these fires, in order to establish a new forest as quickly as possible. This not only helps sequester carbon, it also insures prompt restoration of watersheds and water quality, wildlife and fisheries habitats, and public recreational opportunities. Another significant forest policy consideration concerns the use of wood products. The dais in front of you is a form of sequestered carbon. Though wood products do not provide permanent sequestration, it is well documented that they do store carbon for long periods of time. For example, consider that many towns in the original thirteen colonies still preserve and feature as tourist attractions wood frame homes that were built during the earliest days of our settlement as a nation. Many are older than three hundred years. In addition, life cycle assessments of various building materials show that using wood framing for construction and housing consumes up to 250 percent less energy in its manufacture and installation than alternatives such as aluminum, steel, concrete or plastic. Besides being obtained from a renewable resource, the use of wood products over other construction alternatives substantially allows us to reduce our carbon footprint. When it comes to climate change, wood products obtained from sustainably managed forests are a very wise preference, particularly when combined with effective recycling.

On the other hand, wood obtained from international sources has diverse implications. The world is currently experiencing a net loss of about 45 million acres of forestland per year. Most of this is from conversion to cropland, but some is the result of inappropriate or illegal logging and unsustainable forest practices in developing countries. There is much that could be said on the many issues related to international forest management, but for the sake of time today, I'll just say that aid to foreign countries in the form of education and technology should be an important priority, and technical assistance for reforestation and forest management could pay major dividends in helping manage carbon internationally. Ultimately, however, it is probably most important that we continue to improve upon forest practices in our own country where we can have the most effect on insuring sustainable management, energy independence and in providing the many goods and services that come from healthy, well-managed, and diverse forests.

Implementing appropriate forest practices and applying the best available science is probably more important now than ever, given the increases in atmospheric temperature that we are witnessing. Forests will be affected by this trend in various ways—affecting forest insects, disease, wildfire, tree species composition, and a host of other variables. Forests have changed with climate through the millennia and will continue to do so, but as we rely on forests for many values and amenities, we recognize that well managed and functioning forests are the most resilient to drought, insects, disease, invasive species, and changing temperatures.

For example, a cool wet climatic phase coupled with the effects of human fire suppression and other land management practices has led to a forest condition across the Inland Northwest (Montana, Idaho, eastern Washington and Eastern Oregon) that is characterized by homogeneous dense forests comprised largely of shade tolerant and fire intolerant conifers. Scientific analysis of past climatic events indicates that historical warm dry phases resulted in severe large landscape wildfires. Forests historically survived these warm dry periods because they consisted of patchy mosaics of different ages and species distributions. All of the best science with regard to future climates indicates that we are in a warm dry phase, exacerbated by greenhouse gases creating a climatic shift of a magnitude that significantly exceeds the warm dry phases that occurred over the past several thousand years. Given these conditions, current and extensive ecological research indicates that active forest management that converts homogenous forest landscapes into patchy mosaics of age classes and species will increase the resilience of these forests. It must also be stressed that forests across the Inland Northwest must be managed for future climatic conditions and that a policy of restoring forests to a condition that reflects the climate of 200 years ago may not be facilitating the survival of these forests for future conditions. Since we have the ability to predict the future climatic conditions with some degree of accuracy we also have the ability to moderate the effects of predicted global warming on our forests.

Forestry has been the source of much debate in this country for a number of years, particularly in relation to management of our national forests and other federal lands, and though that tension has lessened as science and forest practices have continued to improve and as groups and individuals are learning to work together to find common ground, there still exist unfortunate lingering effects from those old battles. Almost everyone in the forestry community supports some protections for old growth, roadless areas and wilderness, but we also recognize the importance and value of maintaining a full array and diversity of forest types, age classes and management regimes. Hopefully, the old "us verses them" rhetoric will not obscure the positive dialogue that is now being generated among conservation groups, forest industry, scientists, government agencies and others on the essential role of forests and forest management in accomplishing carbon sequestration and mitigating global warming. Forests are the only form of sequestering and offsetting carbon that also provide many other benefits such as clean water, wildlife habitat, biodiversity, wood products and aesthetics—all necessary for the successful functioning of society. We cannot afford to miss or neglect this important opportunity.

[The article by Matt Smith submitted for the record by Mr. Goergen follows:]

Carbon Market May Offer Opportunities for Forest Landowners
By Matt Smith, CF

The greenhouse affect, global warming, biofuels, alternative or "green" energy, carbon neutrality, emissions reduction, carbon sequestration—these are just some of the terms that have become increasingly prevalent in the media today. The global initiative to reduce the effects of fossil fuel consumption, combined with the controversial issue of dependence on sources of foreign oil, has developed into what could be considered a renaissance when it comes to environmental policy and responsible environmental practices. It certainly appears that the time has arrived for real progress on the issue of global warming and its effect on our society.

So, what does this all mean for forestry? There are four main methods by which a greenhouse gas-emitting entity can reduce its emissions to comply with an emissions cap. These are the reduction of point emissions, reduction of the entity's' carbon "footprint" by using alternative fuels or energy sources, the purchase of offset credits from another entity that has reduced its emissions below the cap, or the purchase of offset credits from sequestration projects (projects that fix carbon in some way). Forests are just one type of sequestration project considered an offset in many registries and markets today.

Although the four primary types of forestry offset projects—afforestation, reforestation, managed forests, and forest conservation—are all important aspects of forest carbon sequestration, the primary focus of this article is sustainably managed forests, which are somewhat controversial in the world of carbon sequestration.

A Test Case for Sustainably Managed Forests

Sustainably managed forests are believed to have the greatest potential for sequestering carbon in the United States. Forests that are managed for some mix of objectives and benefits, such as recreation, biodiversity, wood products, esthetics, or water quality, benefit society most by providing all of these benefits along with clean air and reduced greenhouse gas buildup in the atmosphere. This suite of environmental services is matched by no other type of offset.

So, what is the income potential of participation by managed forests in carbon markets? To find out, we decided to test the actual performance of a managed forest, a 9,000+ acre privately owned parcel of high-quality hardwood forest in the northeastern US, which we'll call the "K tract." At the date of the analysis, the tract was comprised of a mix of age classes distributed in even-aged stands across the property.

Although there are a variety of market opportunities available for carbon offset credits at this time, our analysis is based on the only open market available in the United States—the Chicago Climate Exchange (CCX). CCX is the world's first and North America's only voluntary, legally binding, rules-based greenhouse gas emission reduction and trading system. It started in 2003 with 13 members and now has approximately 250, including companies such as Rolls Royce, Dow, DuPont, Ford, IBM, International Paper,MeadWestvaco, and Stora Enso NA; municipalities such as the state of New Mexico and the cities of Boulder, Colorado; Chicago, Illinois; Portland, Oregon; and Berkeley and Oakland, California, as well as several others.

Our test was built to answer one primary question: "How would the K tract have performed as a forestry offset project from 2001 to 2006 had the landowner entered the CCX without changing his or her management plan?" Our test involved the establishment of baseline carbon stocks from existing forest inventory, modeling growth using the CCX-approved NE TWIGS growth model, and removing harvest volumes annually, all under the CCX rule set. Other edits included adjustments for other activities such as forest road construction. It should be noted that during the analysis period, total harvest levels equated to roughly 40 percent of overall growth (a key factor in the calculation of net volumes of carbon).

To start the analysis, it was necessary to establish our project's baseline carbon stocks for the beginning of 2001. To accomplish this, we converted per species volume estimates from a 2001 forest inventory to its carbon dioxide equivalent. The result was overall estimates of carbon stocks that averaged 28 metric tons of carbon dioxide equivalent ($MtCO_2e$) per forested acre. Using this baseline data and the actual harvest levels, along with estimates of growth from the NE TWIGS growth model, net sequestration for the K tract was calculated for each year. The results revealed that our managed forest sequestered an average of about 14,850 $MtCO_2e$ annually, or about 1.69 $MtCO_2e$ per forested acre per year.

After calculating the sequestration levels for our forest, we then calculated the estimates of income through the sale of the resulting carbon "credits" on the CCX platform. At the time of the project carbon credits sold for values between $.95 and $3.70 per $MtCO_2e$. Using these historical prices for carbon, our project yielded gross income of $135,738.00 for the period.

The cost side of our analysis breaks the various costs for the project into two categories, start-up costs and participation costs. Start-up costs can include forest inventory costs, costs of third-party certification of sustainability (such as SFI or FSC), and lastly, project preparation costs. Participation costs include fees associated with aggregation, trading, reporting, and verification. These costs are incurred after the project is approved and are dependent on the scope of the project and the amount of carbon generated for trading or banking. For the K tract the total costs for participation for the 6-year period equated to $91,779.53

The end result of our economic analysis for the K tract revealed net revenue from the sale of carbon credits of $43,959, or about $.83 per forested acre per year. These results are summarized in Table 1 (see below).

Although $.83 per forested acre per year is a positive economic outcome, it is hardly worth getting excited about. Thus, landowners faced with the choice of whether or not to enter this ecosystem market will not be likely to do so at this level of financial incentive.

Carbon in Harvested Wood Products

As we consider the outcome of this historical analysis and look to the future for managed forests in carbon markets, it is important to keep an eye on policy and rule setting developments that are on the horizon. From a broad perspective, as we think about accounting for sequestered carbon from our forests it's easy to understand that growth and harvest are the key factors influencing our net carbon stocks. Growth represents our sequestration and harvest equates to our "emission." The problem with this train of thought is that the harvesting of trees does not fully release the associated carbon stocks into the atmosphere. Wood is made into products, which then have a lifespan of their own and they continue to sequester carbon that can be accounted for and that is not emitted at the time of harvest.

If we implement the Department of Energy's 100-year depreciation model method for harvested wood products in use on the K tract, the resulting net revenue increases from $.83 per forested acre per year to $1.14 per forested acre per year—a 37 percent increase in net revenue. While this income level is still not very significant, you can see the effect of this policy development on the project's economic performance.

The Current Market Result

When we completed the K tract analysis in August 2006, the sale price of one $MtCO_2e$ on the CCX platform was $4.35. This is significantly more than the $.95 to $3.70 per $MtCO_2e$ used in the historic K tract economic analysis.

If we take the sequestration estimates from our K tract analysis and apply the current price of carbon for each year in the period, our net income estimates rise to nearly $4.70 per forested acre per year. If we then add in the ability to take credit for harvested wood products in use, our net revenue rises to $5.92 per forested acre per year, for total revenue of more than $310,000 for the 6-year period. As these results suggest, market conditions and policy developments are creating income opportunity for forest landowners that could be significant over time. It is at these levels of net revenue that we believe forest landowners will be interested in making the commitments and investments required to participate in carbon markets.

Summary

The results of the K tract analysis reveal several important and interesting aspects about sustainably managed forests and rapidly developing carbon markets. While the historical economic results weren't very impressive, the K tract test model did produce a positive financial result. The result is even more encouraging when you consider the current price of carbon, which could result in revenue streams similar to those currently generated through recreational leases on forestland.

By interviewing representatives from carbon markets and registries, and reading through volumes of carbon market rules and policies, it becomes evident that this business is in its infancy and is changing rapidly. Rule sets are quickly developing in response to new policies and other influences. The various viewpoints on additionality, assuredness, andpermanence, combined with outside political pressures, will make the acceptance of offset credits from managed forests inconsistent at best. As a result, experts expect that a federal greenhouse gas program will be created in the coming years. To ensure that this program benefits the forestry community, the profession should prepare to act. In sum, the potential for managed forests in this new ecosystem market is significant, and rising prices for carbon credits are creating a significant opportunity for some forest landowners. Better yet, no other form of carbon offset can produce a volume of carbon credits to mitigate climate change with all of the other positive ancillary benefits that managed forests provide. Clean water, biodiversity, esthetics, wood products, and recreation are just a few of the valuable cobenefits from forests that are not associated with other types of sequestration projects.

Smith is director of land management for "Forecon Inc. For more information, contact him at Forecon Inc., 1890 East Main Street, Falconer, NY 14733; (716) 664-5602, ext 313; smitty@foreconinc.com.

[NOTE: Additional information submitted for the record has been retained in the Committee's official files.]

Response to questions submitted for the record by Michael Goergen

Your submitted testimony notes that current carbon sequestration in our nation's forests is about 200-280 million tons per year. Do you know how this compares to our country's historical forest sequestration ability or its future forest sequestration potential?

There are no quantitative data on how much carbon was stored in pre-European forests. Because these forests had a higher proportion of old growth the total amount of carbon stored in historical forests would have been greater than it is today. However, because historical forests were older, the rate of carbon sequestration per year and net carbon uptake was most likely much less than in today's forests that have a higher proportion of young trees.

The future of carbon sequestration by U.S. forests is largely dependent on ensuring that existing forest land remains in forest and not converted to other land uses. This is particularly important given that more than half the U.S. forest land base is managed by some 11 million small, non-industrial or family owners who are under increasing pressure to sell to developers. Another factor is the need to provide incentives for forest owners to manage sustainably.

You also talk about creating incentives for forest landowners by giving them access to carbon markets. I imagine that providing such an incentive would involve some sort of commitment from the landowner to manage their land in a particular carbon neutral way. In practice, how long would the individual landowner have to commit to certain management practices to serve as a verifiable carbon sink? Would the timeframe vary by forest type?

Tree growth is carbon neutral in that the amount of carbon taken up in photosynthesis is balanced by the amount returned to the atmosphere when that tree or harvested wood is ultimately decomposed or burned. In the process of management, there are carbon costs from the use of machinery and fuel for transportation. However, wood products from forest management are renewable and when used for building or construction have a far lower carbon cost than using alternatives such as steel, aluminum, concrete or plastic which are not renewable and use substantially greater amounts of energy for manufacture. (Dr. Lippke at the University of Washington has shown that it takes 250-280% more fossil fuel energy to create the steel or concrete product compared to the equivalent wood product. In addition, it has been shown that 1 bone dry ton of woody biomass used for power generation provides a net reduction of 1 ton of green house gas emissions and a direct offset for coal or natural gas-fired powerplants: Dr. Gregg Morris, Future Resources Association.)

The time frame does not depend on forest type directly, but the market for carbon sequestration is more attractive for those forest types or growing conditions that are more productive, sequester carbon at a higher rate, and store more carbon.

The amount of time required for a forestry project to serve as a verifiable carbon sink depends on the particular protocol or set of rules being used and these vary both nationally and internationally. The simplest case is when land is reforested that has not had trees growing on it for some time (1990 is often used as the datum). A project of this kind can immediately qualify as a carbon sink (or carbon offset) if the trees are not intended for harvest or if canopy cover is maintained above a prescribed level. Existing forests can qualify if management is undertaken that is verifiably oriented to carbon storage and is additional to "business as usual". The requirement that the forest used for carbon storage is "permanent" varies among protocols and sometimes is for a rotation of perhaps several decades or 100 years, or it may be required that the forest be placed under a conservation easement. Because of differing requirements among regions of the country in addressing issues of additionality, base line condition, and permanence there is need for establishing a common basis under which forestry carbon projects are managed.

In the U.S., EPA's focus has been on annually determining nationwide carbon emissions and sinks; not carbon marketing. Hence, there has been no regulatory effort that would require methodology for baseline characterization and management scenarios for carbon absorption and release over time. Fortunately, there is a substantial body of knowledge that has addressed this issue. Again, Dr. Bruce Lippke has been a leader in this regard. In addition, Richard Birdsey, Kenneth Skog, Linda Heath, and other U.S. Forest Service researchers have spent years producing life cycle analysis information, publishing results by geographic area and species.

By landowners describing their management plans (commercial thinnings at certain ages and final regeneration), the carbon absorption rate from growth, decreases in carbon at harvest, then accelerated growth afterwards, can be graphed. In addition, determination of the disposition of the harvested carbon is readily available. Some of the carbon will be stored long-term in wood products, some used for pulp and paper, and the remainder may be used as woody biomass feedstock for electric power generation. Eventual decomposition and the associated rates and corresponding CO_2 release rates are well documented for post-harvest activities. Carbon costs from the use of machinery and fuel for transportation can also be calculated.

Once the graph of a landowner's management strategy is completed, an annual "net sequestration rate" can be determined along with the corresponding annual amount of carbon for marketing purposes.

Concerning the markets themselves, forest landowners in the U.S. wishing to access carbon markets to trade carbon offsets have only one option—the Chicago Climate Exchange. The CCX has established "market periods" where landowners can access the CCX trading platform through bodies called Aggregators, using the rules set by the CCX. Landowners, under CCX rules, must maintain their forests as carbon stocks through the current market period for the years 2006-2010. The CCX is a voluntary cap-and-trade program driven by its members. The length of the current market period was based, in part, on the uncertain direction and timing of federal mandatory climate change regulation. Future market periods can be established that provide for longer commitments, ensuring longer term climate change mitigation.

The other option available to some forest landowners is marketing carbon stock on the retail or direct sale market. There are about 35 offset providers/buyers in the U.S. retail market, who are providing/buying offsets from a variety of projects, including alternative energy, landfill methane, soil conservation, and forestry projects. Since there are no U.S. standards under which the retail market qualifies, quantifies, verifies, and sells offsets, the requirements for how long landowners must commit to maintaining their forests as carbon stocks varies.

The proliferation of "Registries" in the U.S. (for example the California Climate Action Registry, Regional Greenhouse Gas program, Chicago Climate Exchange, and multistate The Climate Registry) is also a result of the current uncertain regulatory environment. These Registries set their own rules regarding the type of forest offset project, e.g. forestation and managed forests, which can participate as offsets within the Registry. In many cases the Registries sell credits into the retail market based on the certainty and quality of the credits provided by these Registries. Buyers can reduce their risk of buying forestry offsets by knowing the rigor of the rules behind the quantification, verification, and registration of a Registries offsets. Again, the forestry rules that these Registries use are quite different.

The rules set by offset providers/buyers and Registries address, to varying degrees, the key UNFCCC carbon principles of additionality, permanence, and leakage for forest offset projects. These rules are not wholly appropriate for forest offset projects, creating barriers for promoting sustainable forest practices and creating the incentives required to help keep forests as forests.

For either case, trading on the CCX or selling in the retail market, the economics of forests participating is largely based on the size of the ownership, favoring larger acreages, and the productivity of the site. Since most non-industrial, private ownerships are less than 100 acres, comprising nearly 60% of the forests in the east, the current market rules and structures are barriers for these landowners.

Maybe the most significant long term barrier for forestlands to participate in carbon markets is that managed forests—and the harvested wood products that provide long-term storage of carbon—are not fully recognized in the U.S. Registries or retail market.

So the creation of incentives must address setting rules in any federal cap-and-trade program that allows all forest projects, including sustainably managed forests, to fully participate as offsets. We can implement mechanisms that provide cost effective access to trading platforms or retail markets for the non-industrial private forests, ensuring that this important group of landowners can gain additional revenues that will help maintain family forests as forests.

Mr. COSTA. Thank you. Now moving to the question stage here. Mr. Herzog, do you have an opinion on enhanced oil recovery or enhanced coal bed methane recovery as a method for carbon sequestration?

Mr. HERZOG. Yes. I think enhanced oil recovery is in the near-term sort of a first step. I think in the long-term the amount of storage capacity and enhanced oil recovery is limited compared to say the vast amount you have in the saline aquifers. So for the longer term, the saline aquifers would be more important, but I think in the shorter term because of the economic benefit that Vello talked about enhanced oil recovery would be important.

In terms of the coal bed methane or coal beds in general, I do not think that is as far along advanced in terms of our understanding and what its potential is. So I think there is a lot of work to be done to understand that, and I do not think those are ready for the real large scale demonstrations of, say, a million tons with demonstrations.

Mr. COSTA. All right. Are you familiar with H.R. 1267?

Mr. HERZOG. Is that the one——

Mr. COSTA. Mark Gordon. Congressman Gordon's measure that would direct the USGS to do a national assessment of carbon storage.

Mr. HERZOG. I am not intimately familiar but I am somewhat familiar.

Mr. COSTA. Does it get at the recommendation from your study do you think?

Mr. HERZOG. Yes. I think basically it does. I think the one comment I would have is in our study we recommend a collaboration between USGS and DOE, and I think the——

Mr. COSTA. Do you think DOE is moving quickly enough?

Mr. HERZOG. In terms of doing the assessment?

Mr. COSTA. Right.

Mr. HERZOG. I think what is limiting DOE right now is their budget.

Mr. COSTA. So you think they ought to be moving faster. You said current projects are not meeting the criteria outlined in your testimony because we already know how to inject carbon dioxide into the ground, but do we know how to do so at rates that would be needed for the kind of large-scale commercial developments that we are talking about if we are going to try to reach the goals we are setting?

Mr. HERZOG. Yes. I think, as you point out, it is a scale issue. A lot of the demonstrations show that when you inject a lot in the ground, the pressure response really pushes back on you, and we are not really seeing those in a lot of the injection ones. We need to understand that for the longer term.

Mr. COSTA. That is back to the permeability issue that I was talking about earlier with the seal?

Mr. HERZOG. That is correct. Permeability is how well it flows in there, and what you want to do is——

Mr. COSTA. Still have the seal.

Mr. HERZOG. What?

Mr. COSTA. You still have a seal.

Mr. HERZOG. And still have the seal. Right. What happened is you put it in. The pressure will rise but you have to keep that pressure below the seal. So it is called injectivity. How much can you really get in, and that feeds back on how much real capacity you have.

Mr. COSTA. All right. Mr. Vello Kuuskraa, can you describe in more detail what you mean? You kept making references to the next generation of enhanced oil recovery technology. We have done some of that in the Kern County area in my district but what do you mean by next generation?

Mr. KUUSKRAA. This would be a step forward in terms of the efficiencies. Today's CO_2 enhanced oil recovery might recover let us say 10 to 15 percent of the oil in place. Some of the very best ones. The type of technology we are talking about and I think Ms. Fairburn at EnCana and the practice they are using comes as close to it, and possibly what Exxon is doing comes as close to it, as the models we are thinking about which would push the recovery to 20 to 25 percent, basically doubling what the——

Mr. COSTA. So that next generation, how far away? It sounds like it is taking place now.

Mr. KUUSKRAA. Well, pieces are——

Mr. COSTA. Not in the next generation.

Mr. KUUSKRAA. Pieces of it are. There are a number of things that we would need to bring together. Particularly, the way I like to describe it is, basically, put some headlights and a steering wheel on the CO_2 process, not just push it down the hill, which is mostly what is being done today without being too critical.

Mr. COSTA. You talk about 40 billion barrels of oil using conventional techniques. Where did you get that number?

Mr. KUUSKRAA. That comes from the studies that I reference. The studies were done in response to Congressional language to look at how use of CO_2 could be productively used to develop more of our domestic oil reserves. There is a series of 10 reports. They cover essentially all of the U.S. except the Appalachians, unfortunately, and the deep water offshore.

Mr. COSTA. All right. I have some other questions with regards to the issue of the carbon tax credit issue but I will submit them for you to respond later on. Mr. Schlesinger, quickly before my time expires, you talked about the National Academy of Sciences and the report on no-till policies on agricultural areas. But it seems like an awfully small amount that would be said. We are talking about 4 and then we talk about 1 percent. Which of these figures is most accurate?

Mr. SCHLESINGER. Those figures are the percent of current emissions of carbon dioxide from the U.S. that could potentially be sequestered in agricultural soils. Generally speaking the estimates have ranged from 1 to 4 percent at best. So the——

Mr. COSTA. Seems minuscule. I do not know.

Mr. SCHLESINGER. What is that?

Mr. COSTA. Seems minuscule.

Mr. SCHLESINGER. It is very small.

Mr. COSTA. In the bigger picture.

Mr. SCHLESINGER. Yes. Everybody likes soil and organic matter, but it is not going to make a huge difference to atmospheric carbon dioxide levels.

Mr. COSTA. My time has expired but not for the gentleman from New Mexico who is next in line.

Mr. PEARCE. Thank you, Mr. Chairman.

Mr. COSTA. You are at the plate.

Mr. PEARCE. Mr. Schlesinger, in answer to Mr. Brown and Mr. Shuster you had mentioned that it is the perturbation that is the problem. What was the perturbation that occurred to create those seashells 25 miles inland? In other words, that is quite a long distance. So there had to be some disturbance that caused enough warming to create a rise in the sea level.

Mr. SCHLESINGER. Both that and the coastline itself has been in some kind of up and down movement as well. Deposits like that undoubtedly date back into the Pleistocene where we went through glacial and interglacial epics.

Mr. PEARCE. But what caused the melting? I mean you had to have a change in the earth's temperature.

Mr. SCHLESINGER. In the position of the earth and the tilt of the earth relative to the sun—what are known as Milankovitch cycles—that play out over hundreds of thousands of years. For the last 8,000 to 10,000 years carbon dioxide—and that includes all of organized human society—language, cities, culture, money, all of that, agriculture—carbon dioxide levels and temperature have been remarkably stable.

Mr. PEARCE. New Mexico is at 3,600 MSL, mean sea level, and we have great indicators of inland oceans there. So you do not have the seashore moving up and down causing that. I used to hunt arrowheads all over in New Mexico, and you would just find seashells laying out there everywhere, and the great indications are that the sea existed there. So there have been some previous perturbations.

Mr. Kuuskraa, you had mentioned that it is a fairly expensive process. At what dollar value of oil does the reinjection of CO_2 become economic?

Mr. KUUSKRAA. There is no single number even today.

Mr. PEARCE. Just approximately.

Mr. KUUSKRAA. Sure. You would need a price of somewhere between $30 and $40 for the very best fields, and you would need prices of $50 to $70 for the more average or let us say typical fields, and then the remnants—and there are many of those—you really need just new technology to make it efficient enough to bring those on.

Mr. PEARCE. Ms. Fairburn, you had also testified about this. You testified about your project, and I have seen projects very similar, and am appreciative of them. If you were to take a look at all oil fields in the U.S.—and I am just asking you because you are probably the best here today to make a guess and I understand it is going to be a guess—what percent of those oil fields open would be potential candidates for the reinjection like you are doing in large scale there in Canada?

Ms. FAIRBURN. While I could answer the question, I know Vello is an expert in this.

Mr. PEARCE. You bet. Why don't you take a stab at it, and we are going to give him a second shot at it, but I want him to know he is second fiddle on this deal to you. No. I am just joking.

Ms. FAIRBURN. From what we are aware of, the State of Texas is probably where the best opportunities are, and California offers some good candidates as well. So generally in that area. A little bit in Appalachia and we focused a lot in Canada in terms of where the potential is there.

Mr. PEARCE. Would you just go to any one of your fields and put it in? Is it a thing you have to be cautious with? That is what I am trying to get a broader understanding of.

Ms. FAIRBURN. Very good. Take Weyburn as an example. It took years of technical analysis—now granted, the technology has evolved since then—to make sure that the geology was appropriate plus negotiations with an adequate CO_2 supplier. You need to have a CO_2 supply that is quite pure, and the supply in North Dakota was a good fit for us. It was only 200 miles away, and because it comes from the gasification it was quite pure, and a lot of discussions have to go on with all the landowners in the area, the property rights owners underground, to pull that all together. So that is what is required. So each project is unique.

Mr. PEARCE. OK. Mr. Kuuskraa, not on that. We are in the short rows here but how big a cost is the transportation? In other words, how close does your CO_2 have to be to be economically viable to reinject? And I think both of you—in fact, Mr. Chairman, this is a super panel—I think if we took both panels and us as policymakers and sat around for a couple of days I think we probably could reach a balance, but go ahead.

Mr. KUUSKRAA. It depends on the volume of CO_2. With big pipelines, you can bring it down like currently takes place in Permian Basin. With a smaller volume, like at Weyburn, you can pipeline it about 200, 300 miles. So it is a volume type of issue. The costs are not outlandish. CO_2 once you compress it works somewhat like a fluid, and so it is cheaper to transport. Packs together very well.

Transportation costs might be on the order of let us say 50 cents an mcf, which would be what? About $8 a ton or so of CO_2. About half of our U.S. oil fields would be amenable to CO_2. We have looked at all the large ones in the country. Not all of those are economic but a large portion are.

Mr. PEARCE. Thank you, Mr. Chairman.

Mr. GRIJALVA. [Presiding.] Thank you, sir. Dr. Schlesinger, let me thank you for being here. In your testimony you state that we should not sacrifice old growth forests to increase the nation's carbon sequestration. Could you elaborate on the point about the net release of carbon dioxide into the atmosphere when an old forest is cut?

Mr. SCHLESINGER. When you cut an existing old growth forest, not only is a lot of the material left in the slash that decomposes so it used to hold carbon and now it is returning carbon dioxide to the atmosphere, but very typically the product stream out of that forest enters into products, wood and paper and things, that have relatively limited lifetimes. Houses are probably the longest. Pizza boxes and things like that probably relatively short lifetimes, and those are either burned or decompose and return carbon dioxide to the atmosphere.

So the sequestration needs to balance the loss of carbon that used to be stored in an old growth forest against the uptake with what you replant there, and typically that comes out to be a wash or even negative. There is a disadvantage to carbon sequestration by cutting old growth.

Mr. GRIJALVA. Yes. Let me just talk a little bit with you about your testimony regarding reforestation and the role that can play in the carbon sequestration process. Last Congress at a hearing on reforestation we heard testimony from Dr. Jerry Franklin that emphasized the importance of structurally complex, gradual reforestation for ecological diversity. That is the point he was making. Could you address reforestation objectives from a forest health perspective, and why we need to avoid the pitfalls of plantation style reforestation?

Mr. SCHLESINGER. Right. Plantations are vulnerable to lots of things, particularly fire and insect attack. If you have a species, a single species plantation that is subjected to either insects or other kind of pathogen, it could wipe the whole project out.

So that a healthy forest—and Jerry Franklin is certainly one of the nation's premiere people to testify on that—is one that has trees of a variety of species, at a variety of ages, an under story and an over story that has the biological diversity that essentially becomes a self-protection for it. It will harbor certain kinds of predatory insects and birds that will keep down populations of things that might wipe out a much less diverse forest. And typically if you look at carbon sequestration rates, they are not terribly different between the plantation and the mixed diversity, mixed age forest.

Mr. GRIJALVA. Thank you. Mr. Goergen, did I say that correctly?

Mr. GOERGEN. It is Goergen, but that is fine.

Mr. GRIJALVA. Goergen. Thank you, sir. A recent hearing that we had on the impacts of climate change on public lands we heard testimony from Dr. Anthony Westerling who said that most of the increase in forest wildfire is due to climate change and earlier springs. You state in your testimony, if I am not mistaken, that the wildfires are largely the result of an increase of hazardous fuels in our forest. Do you agree with Dr. Westerling's published study that climate change increases wildfire activity in our forests out west or not?

Mr. GOERGEN. There definitely is an impact from climate change on fire severity. There is no doubt about that but it is a combination of things. It is not so easy to say that there is one factor that is causing the problems that we have with forest health throughout the western U.S. and on a lot of the national forest lands. There are multiple factors, and if the climate is changing at the rate that the models seem to predict, what we need to do is be prepared for the future, and that is going to require management of forests to make sure that we can reduce the risk of that catastrophic fire.

Mr. GRIJALVA. Right.

Mr. GOERGEN. And make sure that those systems are functioning within the range that that new climate is going to be, and so, for example, the Hayman Fire in Colorado in 2002, that fire actually released as much carbon as all the cars in that state that year. So we have to be careful with what we can accomplish by reducing the risk of catastrophic fire on national forest lands.

Mr. GRIJALVA. But nevertheless climate change being a factor in that wildfire activity?

Mr. GOERGEN. Absolutely. There is a link between all of these factors, and as we plan for the future, we really need to look at managing for what that future climate is going to be, not based on 200, 400 years ago when the climate was significantly different than it will be in the future.

Mr. GRIJALVA. I do not have any questions. Mr. Sarbanes, do you have any questions, sir?

Mr. SARBANES. Thank you, Mr. Chairman. A number of you—and I am forgetting which because it is a large panel, I appreciate your testimony—talked about the importance of demonstration projects with respect to geological sequestration I guess was where we focused that, and we have also heard about how the amount of time it takes to judge the risks and benefits of this is pretty extended.

So I wondered if you could speak to exactly how a demonstration project would work. What are the things that you would be looking at, and when would you be looking at them? In other words, how quickly could we kind of get back an assessment off of these demonstration projects? And for those dealing with the terrestrial sequestration, is there a similar opportunity to do demonstration projects in that area? I would imagine it might be a little more difficult to do but maybe you could speak to that as well.

Mr. HERZOG. I will start by taking a quick crack. In the MIT study, we look at these projects as 8 to 10-year type of timeframe. Two to three years upfront to do the planning and get ready for the injection, an injection period of four to five years, and then two to three years afterwards of post injection monitoring and analysis of all the data. So you are looking at about 8 to 10 years.

What you really want to do is really instrument this well, both methods such as seismic but also methods such as monitoring wells to take samples. So you really want to monitor this well and that, of course, takes some time up front in that first two to three years to set up also.

Mr. SARBANES. And are there a number of alternative methods that you would be testing the different methods with these demonstration projects? Is that how you envision it, a sort of a bundle of demonstration projects work?

Mr. HERZOG. Well what we are looking at—I think the biggest difference between—we say we should maybe do three to five in the United States, maybe 10 worldwide. You want to look at different geologies because not every saline aquifer is the same. Some are high permeability. Some are low permeability. Some are carbonate reservoirs. Some are silicate reservoirs. So you want to sort of have a representative geology, and we should pick here in the U.S. the geologies which are our biggest resources to look at.

Mr. SARBANES. Right. OK. And what about in the terrestrial sequestration area?

Mr. KELLY. Congressman Sarbanes, in terms of demonstration projects, I would say there has been a history over the last seven years of a number of large scale reforestation projects in the Louisiana, Mississippi delta that has already taken place, and a lot of these projects were done by utilities. A group called UtiliTree which was kind of a mutual fund of utilities actually trying to plant and reforest trees to sequester carbon.

The bigger issue is what standards are these projects going to be held to, and as a result, that dictates different results, and so in the voluntary market people are planting trees left and right but there is not real strict standards. In the regulatory marketplace you have heard a description under the RGGI context where there are very strict standards. And so that really is the issue that dictates the type of projects that are out there but there has been a host of them.

Mr. SARBANES. Thank you.

Mr. GRIJALVA. Thank you. Mr. Inslee?

Mr. INSLEE. I am going to try this out. I thank you. Through our discussion of global climate change we repeatedly hear references that 96 or 97 percent of the CO_2 going in the atmosphere is natural. It is part of the natural cycle. We are only responsible for the 3 or 4 percent. It is the Alfred E. Neuman theory of chemophysics that we should not worry then. What me worry?

And I have been trying to think of the right metaphor. I want to try one out on some of you that it is like our diet. We have kind of a balance. I weigh about 200 pounds. There is a kind of a balance to what I take in and what I burn up. It is pretty much in balance, at least in a good month anyway. It is pretty much balanced.

But if I eat an extra doughnut a day, just a doughnut, I think I would probably gain at least four pounds a year. Just one doughnut a day. And then the next year I would gain another four pounds, and then the next year another four pounds, and then in 20 years I would weigh 280 pounds. Just one doughnut a day, and I would only be increasing my caloric intake by 3 to 4 percent, but I would weigh 280 pounds.

Now is that at least a rough metaphor for why our 3 or 4 percent increase in the rate of CO_2 going in the atmosphere is something we should worry about and not adopt the Alfred E. Neuman approach?

Mr. SCHLESINGER. I will take that one. I had not thought of the doughnut analogy but I think it is not bad and, of course, when we talk about carbon sequestration that is the equivalent of saying, OK, are you going to spend an extra hour on a treadmill somewhere to balance that doughnut? We are all in the business and for 150-or-so years we have been in the business of putting carbon dioxide from the earth's crust into the atmosphere. Until carbon sequestration began to be in vogue and talked about, we hadn't really talked about doing something the equivalent of the treadmill that would get it out of the atmosphere. So I like that analogy.

Mr. INSLEE. I will go with both of them. We will use both of them. Dr. Herzog, you talked about I think you said three potential sites for actually doing a program. How does that compare to the FutureGen project now?

Mr. HERZOG. I think the FutureGen project can be considered one of the demonstrations. It will eventually choose a single site. It is about the right size. I think hopefully they will have the monitoring equipment that will be sufficient to learn from it. So that could be considered one of the three to five that we would recommend.

Mr. INSLEE. Yes. Ms. Fairburn?

Ms. FAIRBURN. I would like to make it clear that our project that we have been doing since 2000 is a very excellent example of carbon capture and storage with coal gasification in North Dakota. Extensive monitoring has been going on in 2000 to 2004 as reported in the IA report. So I think you have one excellent example of a demonstration at commercial scale already performed.

Mr. INSLEE. Dr. Herzog, I am asking you to look in a crystal ball a little bit but can you give me your seat-of-the-pants estimate of the number of coal facilities today that you think 20 years from now there is at least approaching a probability that we will have technology if we become aggressive about it? If we become aggressive about it. Roughly could you give us any parameters—what are the number of coal sites today where we have a coal-fired plant where we are using CGCC or some technology where sequestration is likely to be an option? Any estimate at all? Ten percent of the existing plants? Fifty? Eighty? Just kind of any sense of that at all?

Mr. HERZOG. How many years from today?

Mr. INSLEE. Say 20 years from now.

Mr. HERZOG. Well I will say the number is less than 10 percent, and part of it is until we get the economic incentive out there, it is a problem.

Mr. INSLEE. Yes. Let me rephrase my question. Assuming we have a cap and trade system which creates a real economic incentive for sequestration, makes it economically competitive, assuming the Federal government gets active and really makes a major league investment like the Apollo project, if we really make this a high priority, what is sort of in the realm of the feasible?

Mr. HERZOG. You know retrofits are going to be difficult. So I think where you will see this coming in is a lot with new builds and building it directly because that is going to be less expensive than the retrofits. I think eventually as you see capital stock turnover, which may happen over decades, then I think you start seeing the——

Mr. INSLEE. So maybe let me ask this. Of the plants that you would see going in, of the new plants, kind of what rough percentage or fraction could you think making sequestration possible?

Mr. HERZOG. Depending on the policy, it could be close to 100 percent of the new plants.

Mr. INSLEE. Thank you. I have one more question I wanted to ask quickly, Mr. Goergen. Dr. Schlesinger basically said that there is a net disadvantage for taking out old growth forests and replanting with fast growing. There is a net disadvantage from a CO_2 perspective. Do you agree with that?

Mr. GOERGEN. I do not know anyone that is credibly talking about cutting down old growth for carbon storage. I do not think that that is even a realistic option for most folks. If you look at the carbon balance of it, I am not sure if it is a negative. It is probably a wash.

Mr. INSLEE. OK. There are some people because they were in my office last week. Thank you.

Mr. GOERGEN. I said credibly, Mr. Inslee.

Mr. GRIJALVA. Mr. Pearce.

Mr. PEARCE. Thank you, Mr. Chairman. Mr. Schlesinger, you had mentioned that we have had 8,000 or 10,000 years of stable temperatures, but when I look at the chart from U.N. intergovernmental panel on climate change they show a swing of about 20 degrees over the last 1,000 years. In other words, the medieval period is about 10 degrees warmer, and a little ice age about eight and a half degrees cooler. Does that fall within your definition of stable temps for the last 10,000 years or do you disagree with intergovernmental?

Mr. SCHLESINGER. I would have said that the numbers you had were too high by a factor of 10. Yes.

Mr. PEARCE. So you think the U.N. has——

Mr. SCHLESINGER. Well——

Mr. PEARCE. These are degrees Celsius by the way. You can have staff carry it out there and let him look. If you say that we have a net carbon loss when we cut a tree, now we just recently did some work on my house over here on Sixth Southeast and it was built 100 years ago. Those two-by-fours that were put into place, do they just bleed out their carbon all of a sudden? If the wood is not decayed, does it lose its carbon?

Mr. SCHLESINGER. No. As long as the house is standing there and the two-by-fours are there, that is a sink for carbon.

Mr. PEARCE. So we would have an incentive to go ahead and use the tree. If we cut the trees down, then we do not contribute back to the carbon. So we use them as forest products like Mr. Goergen says we can really reverse that net loss trend. Mr. Herzog, you had mentioned kind of the strenuous liability that we need to be very careful with this reinjection. That there are definite problems.

You had mentioned the government liability. In other words, I contemplate that also because again you see it up close, and you see the volatility, and that is something that we work with but that is something you want to be careful with. Do you have any idea what the liability might be nationwide for this sort of large scale reinjection?

Mr. HERZOG. Yes. I actually think it could be fairly minimal because I think if the sites are well chosen and before the companies turn the sites over to the government there is some very strict guidelines on best practices, I think the chance of leakage is fairly small and, as it says in the literature, as time goes on, the CO_2 in the ground gets immobilized. The pressure goes down. The CO_2 loses its buoyancy through absorption in both the soil and the water so the chances of leakage goes down. But the companies, especially the utility companies I speak with, just do not want to take on that risk.

Mr. PEARCE. Mr. Kuuskraa, if we contemplate the use of these carbons to reinject in oil fields, now up near Clayton, New Mexico—the Bravo Dome—is where we take our carbon from and take it down to Denver City, Texas. So about 400 miles I guess, 300 miles something like that. At what level do we have to get the cost of the CO_2 when we are talking about sequestering but you have to economically get it down to where it is as cheap as that we are getting out of the Bravo Dome and the transportation cost, and I would like your input and Ms. Fairburn's input. I mean help us. I understand the prospect but I do not know nationwide the economics of it.

Mr. KUUSKRAA. Sure. Let me take a stab at this. There is no true market for CO_2 because of certain limitations but it is probably on the order of $20 a ton give or take your distance from the source.

Mr. PEARCE. OK. Ms. Fairburn?

Ms. FAIRBURN. I concur with the $20 a ton number, and as information a lot of the cost of CO_2 would be much greater than, maybe $50, $80 from power plant CO_2 to get it pure enough. So that is one of the huge challenges out there right now.

Mr. PEARCE. OK. Mr. Kelly, you talked about mitigation. There have been articles about fraud in mitigation. Are those articles factual? In other words, people are either cooking the books or claiming stuff that cannot be claimed? Are those factual articles or do you think there is no fraud in those mitigation projects?

Mr. KELLY. I am not quite sure of the articles you are referring to but I will say mitigation banking is the most heavily regulated industry of all forms of mitigation. We are subject to an entitlement process that sometimes takes three years with over 12 agencies participating. We then get our credits released over a five-year timeframe.

Mr. PEARCE. So you think the articles are not correct?

Mr. KELLY. I think there are probably some factual misrepresentations and some taken out of context.

Mr. PEARCE. Mr. Schlesinger, I will give you the last time to respond to that one chart there if you want to as my time elapses. You can take the rest. Thank you.

Mr. SCHLESINGER. Right. So this chart is not a chart that shows the change in temperature over the last 1,000 years or so but the absolute temperatures, and the changes are less than a degree from today. Less than a degree colder during the cold periods and about a degree warmer during the warm periods. So there——

Mr. PEARCE. That median line, there is a median line running through the chart that says that is the 20th century average temperature.

Mr. SCHLESINGER. Right.

Mr. PEARCE. And it goes 10 degrees warmer during the medieval period.

Mr. SCHLESINGER. No. But the 20th degree average temperature is at 9.3 degrees. So when you see it go up to 10, that is a .7 degree change. That is relatively small.

Mr. PEARCE. So the scale on the chart is——

Mr. SCHLESINGER. It is the absolute scale not the change.

Mr. PEARCE. Why is that line not just flat there showing that it is about the same? Point seven tenths of a degree is a very narrow parameter. But my time has elapsed, Mr. Chairman. You can answer that in writing if you would like but there are people who say that it was tremendously warmer in the middle ages than now, and it was tremendously colder at other times. They say that is the reason that we have seashells at 3,600 feet elevation in New Mexico. Thank you, Mr. Chairman.

Mr. GRIJALVA. Thank you, Mr. Pearce. Let me thank the witnesses for your very valuable testimony. The members of the Subcommittee may have some additional questions. We are going to keep the record of this hearing open for 10 days, with the expectation of getting your responses if questions are directed to you. There is no further business before the Subcommittee, and again thank you to the members of the Subcommittee and our witnesses, and with that the meeting stands adjourned.

[Whereupon, at 4:40 p.m., the Subcommittee was adjourned.]

○