CLIMATE CHANGE TECHNOLOGY RESEARCH: DO WE NEED A "MANHATTAN PROJECT" FOR THE ENVIRONMENT?

HEARING

BEFORE THE

COMMITTEE ON GOVERNMENT REFORM

HOUSE OF REPRESENTATIVES

ONE HUNDRED NINTH CONGRESS

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COMMITTEE ON GOVERNMENT REFORM

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THURSDAY, SEPTEMBER 21, 2006

HOUSE OF REPRESENTATIVES,
COMMITTEE ON GOVERNMENT REFORM,
Washington, DC.

The subcommittee met, pursuant to notice, at 10:25 a.m., in room 2157, Rayburn House Office Building, Hon. Tom Davis (chairman of the subcommittee) presiding.

Present: Representatives Tom Davis, Shays, LaTourette, Waxman, Lantos, Maloney, Kucinich, Clay, Watson, Van Hollen, Higgins, Norton, Cummings, Platts, and Bilbray.

Staff present: David Marin, staff director; Larry Halloran, deputy staff director; Jennifer Safavian, chief counsel for oversight and investigations; Mindi Walker, professional staff member; A. Brooke Bennett, counsel; Michael Galindo and Benjamin Chance, clerks; Greg Dotson and Alexandra Teitz, minority counsels; Earley Green, minority chief clerk; and Jean Gosa, minority assistant clerk.

Chairman TOM DAVIS. Good morning, and welcome to today's hearing on climate change technology. As we sit here today, the debate over climate change science continues, but this committee, as well as the administration and many others in Government, already have recognized the important facts: that global mean temperature has increased over the past century, and that carbon dioxide in the atmosphere has contributed in some way to this warning.

With that in mind, our committee seeks to move away from debating science to finding solutions. The purpose of today's hearing is to learn about the Federal Government's climate change research and development programs, specifically those dedicated to exploratory or innovative technology. We are also going to discuss the best ways to steer these initiatives.

Right now, the administration spends nearly $3 billion on climate change technology research. Ostensibly, this research falls under the umbrella of the President's climate change technology program. The characterization of the CCTP, however, is misleading, because the CCTP has no budgetary authority. The billions of dollars that fund CCTP actually are dispersed directly to Federal agencies without CCTP approval. In fact, to date the CCTP has only received $1.5 million in program support to supplement the creation of its strategic plan, which outlines the current research and future priorities of the program.

Without direct funding, CCTP does not employ full-time staff, and both Director Stephen Eule and Deputy Director Robert Marlay hold other positions within the Department of Energy. Currently, CCTP employs neither administrative nor analytical staff; it shares personnel with other offices on an as-needed basis.

Additionally, thus far the Federal Government has yet to engage in any exploratory or innovative technology research on climate change. Under the current funding structure, only near and mid-term technology research programs receive R&D dollars. Climate clinicians that lie outside of existing technology, such as geo-engineering and artificial photosynthesis, remain unaddressed.

Although CCTP is capable of commenting on technology-focused projects conducted across 13 Federal agencies under the program, in its current state CCTP simply does not have the authority to allocate funds for climate technology projects, begging the questions: one, how well are we coordinating climate change technology research? And, two, because of the present configuration of Federal climate change technology research, is it necessary to create a central, authorized body to command exploratory research, an ARPA for climate change?

The Defense Advanced Projects Agency, DARPA, was created to turn innovative technology into military capabilities. The agency is highly regarded for its work on the Internet, high-speed microelectronics, stealth and satellite technologies, unmanned vehicles, and new materials, all of which produced not only military advancement but commercial benefits, as well.

Unlike the CCTP, DARPA can segregate itself somewhat from its governing body, the Pentagon, and remain a small and flexible agency capable of quickly exploiting emerging technologies and adapting to immediate military circumstances. Conversely, CCTP remains under the strict direction of the Cabinet-level Committee on Climate Change Science and Technology Integration [CCSTI], reducing the likelihood it will support novel concepts in climate technology research. Given its strict structure and limited authority, would the CCTP be the appropriate body to potentially manage a free-thinking and innovative exploratory technology agency?

To date, the under-funded and administratively barren climate change technology program has yet to sufficiently coordinate and influence the technology research initiatives conducted by the multiple Federal agencies under its charge, let alone manage potential new exploratory technology research programs such as the Climate Change Advanced Research Projects Agency [CCARPA].

It is time to say CCARPA Diem and seize the opportunity to take technology research to the next level by bringing CCTP to the forefront of the U.S. climate change agenda. Or will the full initiative of CCTP prove sufficient to guide climate change technology research into the future? These are the questions that we hope to begin resolving today.

The committee has invited several highly qualified individuals to address these uncertainties. We will hear from Dr. Stephen Eule, the Director of CCTP, on the status of climate change technology in the United States and on his role in overseeing climate change technology and potential budgetary or organizational obstacles to the full implementation of a centralized climate technology program.

We will also hear from the GAO on the ambiguity of the appropriations to agencies with regard to climate change and the need for more clear disclosure of the nature of climate change research and development funding.

Also, we will explore the merits and challenges of creating a Federal climate change exploratory technology program and will hear from experts on DARPA about the applicability of instituting a CCARPA for exploratory technology research and development.

Global climate change is one of the most serious environmental concerns of the 21st century. This committee has taken an important step by discussing how the Federal Government can better arm itself with technology to address this worldwide problem.

I would like to thank all of our witnesses for their invaluable insights in this issue.

[The prepared statement of Chairman Tom Davis follows:]

ONE HUNDRED NINTH CONGRESS

Congress of the United States

House of Representatives

COMMITTEE ON GOVERNMENT REFORM

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Opening Statement of Chairman Tom Davis
Government Reform Committee Hearing
"Climate Change Technology Research:
Do We Need a 'Manhattan Project' for the Environment?"
September 21, 2006

Good morning, and welcome to today's hearing on climate change technology. As we sit here today, the debate over climate change science continues, but this Committee – as well as the Administration and many others in government – already have recognized the important facts: that global mean temperature has increased over the past century, and that carbon dioxide in the atmosphere has contributed in some way to this warming.

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Is it time to say "CCARPA Diem", and seize the opportunity to take technology research to the next level by bringing CCTP to the forefront of the U.S. climate change agenda? Or, will the full initiation of CCTP prove sufficient to guide climate change technology research into the future? These are the questions we hope to begin resolving in today.

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Global climate change is one of the most serious environmental concerns of the 21st Century. This Committee is taking an important step by discussing how the federal government can better arm itself with technology to address this worldwide problem. I would like to thank all of our witnesses for their invaluable insights into this issue.

Chairman TOM DAVIS. I would now like to recognize our distinguished ranking member, Mr. Waxman, for his opening statement.

Mr. WAXMAN. Thank you, Mr. Chairman.

Today's hearing will begin to examine what policies Congress should consider for addressing the major threat of global warming. We will hear from some of the Nation's leading experts on global warming and technology. They will present their views of how we move forward to take carbon out of the world's economy.

I believe almost all of us agree that global warming is occurring and action must be taken to avoid potentially catastrophic impacts to our country and the world. Our position reflects the scientific consensus which only a small cadre of oil-industry-funded propagandists are still denying. But, despite this committee's interest, it would be a serious mistake for anyone watching this hearing to conclude that either the administration or the Republican leadership in Congress is willing to tackle the problem. That is why I would like to take a moment to review the past 6 years.

President Bush and Vice President Cheney came into office determined to radically change the Nation's energy policy, and that is what they did. They crafted their policy with oil companies like Exxon and Mobil and refused to meet with consumer or environmental groups. Their plan bestowed countless favors on oil, coal, and other polluting industries and it abandoned the President's pledge to reduce greenhouse gas emissions. In fact, under the plan they developed, we have wasted precious years and exacerbated global warming.

During the last 6 years there have been many constructive ideas put forward. For example, in July 2002 the Pugh Center on Global Climate Change released a report on designing a climate friendly energy policy. In July 2003, the Energy Future Coalition released an energy plan to fight global warming and address the political and economic security threat posed by our dependence on oil. In January 2004, the Apollo Alliance, a coalition of labor unions, environmental groups, and other public interest groups proposed an energy policy to modernize America's energy infrastructure and fight global warming. In April 2005, the Natural Resources Defense Council released a paper proposing an energy policy that would enhance our national security and reduce air and water pollution while curbing global warming and creating jobs. But these ideas to move us forward fell on deaf ears. The Republican Congress was simply uninterested in learning about the problem, let alone addressing it.

In December 2004, the bipartisan National Commission on Energy Policy released a plan to address the Nation's long-term energy challenges, including oil dependence and global warming. The commission was composed of Republicans and Democrats, industry and environmentalists, and they had figured out a way to come together, yet the chairman of the Energy and Commerce Committee would not even hold a hearing on the plan.

Recently the administration has begun to change its rhetoric on global warming. Unfortunately, it is only the rhetoric that is changing. They are sticking with their policy of denying the urgency of the problem and delaying any real action.

That has to change. We have already lost 6 years. Mr. Chairman, that is why our committee holding these hearings stands out in stark contrast to what the rest of the Congress has been doing.

Today we are going to hear about the administration's 100-year strategic plan. The name is impressive, but inside the covers the plan has no time line for actions, no goals for what we need to achieve. Thinking about technology research and development is very important, but by itself it will do nothing to solve the problem.

Thank you.

[The prepared statement of Hon. Henry A. Waxman follows:]

Statement of
Rep. Henry A. Waxman, Ranking Minority Member
Committee on Government Reform
Hearing on
Climate Change Technology Research: Do we need Manhattan Project for the Environment?

September 21, 2006

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We will hear from some of the nation's leading experts on global warming and technology. They will present their views of how we move forward to take carbon out of the world's economy.

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Chairman TOM DAVIS. Thank you, Mr. Waxman.

Do other Members wish to speak? Mr. Shays.

Mr. SHAYS. Thank you. Mr. Chairman, thank you for holding this hearing.

We are failing to deal with this problem not because of Republicans; we are failing to deal with this problem because there is not a bipartisan effort to move forward on this issue, and it goes back a long ways. It goes back to when President Clinton was President and he negotiated Kyoto and there was a bipartisan resolution in the Senate that passed 100 percent. It said don't leave India and China out of Kyoto. They left India and China out of Kyoto. The treaty was negotiated. It was brought before us and President Clinton never ever submitted it to Congress because he only had five or six supporters in the entire Senate.

It is fascinating to me. I wish this President had submitted it so all the Senators who criticize him now would have been faced with voting for it, because at the time they weren't going to support it.

There is a bipartisan effort to kill what is so logically something we should do: making better use of the energy we have. Minivans, SUVs, and trucks should get the same mileage as cars, but the dean of the House, Mr. Dingell, in a bipartisan effort with other Members who represent the automobile manufacturers, not the oil industry, labor unions who oppose getting minivans, SUVs, and trucks to get the same mileage as cars opposed it. That is our problem.

We can make it a partisan issue and it is great for an election, but it is not the truth. The truth is we need to work together, Republicans and Democrats, to solve what is a huge problem.

I introduced a bill with Maurice Hinchey supported by the League of Conservation Voters—not a very partisan group, I would say. The purpose is to get minivans, SUVs, and trucks to get the same mileage as cars, to take out of the energy bill that I voted against, to take out the dollars and tax write-offs that were going to the fossil fuel industry and put it into alternative fuels.

That bill remains to be supported by Members on both sides of the aisle. It is bipartisan. It would move the agenda forward. But because we have decided that this is a tough election year and we are going to target certain Members, we are going to tell Members on the other side of the aisle they are going to be told by their leadership not to cosponsor legislation supported by any Member who is targeted.

So when we get all of this political garbage that you are going to hear from Members about how this is a partisan issue, when we can get beyond that and we can get the election done with, I hope Nancy Pelosi will, as my own leadership, say that we need to work together instead of the Democrats going further to the left and Republicans going further to the right.

Hopefully we will start to hear Members on both sides of the aisle start to be bipartisan again, talk bipartisan, and stop trying to make such a serious issue a partisan issue when it isn't.

Thank you, Mr. Chairman.

Chairman TOM DAVIS. Thank you very much.

Mr. Lantos.

Mr. LANTOS. Thank you very much, Mr. Chairman. I want to thank you and Ranking Member Waxman for your leadership on this issue.

My approach to this whole subject stems from my possession as the ranking Democrat on the House International Relations Committee and the ramifications of our energy policy or lack of energy policy on our international position. I will have a word or two to say about that later.

I have been disappointed and dismayed by this administration's position on climate change. Despite overwhelming scientific evidence that global warming is taking place, the administration has basically removed itself from the international conversation and worked to stifle Government scientists. This is willful ignorance about the severe challenges and strengths that will be placed on future generations by the results of climate change.

Coupled with an alarming lack of foresight for the national security implications these effects will have on our world, the administration's policies have significantly weakened our efforts toward the solution of this problem.

The science on the issue is incontrovertible and the need to respond is immediate. The actions taken by the President and this Congress thus far have been woefully inadequate. It is my hope that this hearing just might be the straw that breaks the camel's back against the misinformation campaign engineered by some key energy companies which have sown seeds of doubt and have slowed a legitimate debate to occur.

Our Nation's reliance on foreign oil, which is my principal concern, means that we are providing the enemies of freedom with the resources to oppose the United States or even to wage war against us. If you heard last night Chavez at the United Nations in New York you know exactly what I am talking about. But whether it is Chavez, Ahmadinejad of Tehran, Putin in Moscow, or the Wahabis in Saudi Arabia, the amplified voice of these forces of anti-democracy and anti-freedom must be enormously enlarged by virtue of their incredible oil income which they have gained largely as a result of our policies.

The United States is a leader in scientific research and technological discovery and we have witnessed the extraordinary results of what happens when our Nation harnesses this intellectual resource with the Manhattan Project, which made us the first project to harness the energy of the atom, or the Apollo Project that put an American on the moon.

The most abundant source of new energy, Mr. Chairman, is conservation. Although we must provide the impetus for research and development into new technologies, the most immediate and effective means of reducing our reliance on current fuel sources is to be intelligent about cutting back on their use. That is not a matter of creating new technologies but making people more conscious of existing ways to reduce energy waste.

The time has come for America to rise up and face the challenge of relieving itself from its dependency on carbon-based energy and the pollutants that come with it. We need to reach beyond our current energy policy and achieve this goal through a nationwide effort combining both conservation efforts and increases in research and development of alternate energy sources.

Mr. Chairman, while this hearing is ostensibly about American Government policy and the need for a nationwide project to make America a carbon neutral nation, let me speak for a moment on the international relations aspect of this project and the imperative need for us to reach out to the global community on this issue.

We must re-engage the international community in order to seek successful solutions and best practices. The interconnection of international energy policy and the effects on climate change will only continue to increase in the years ahead.

I hope that our President and our Congress can have the vision of a Roosevelt or a Kennedy to see over the horizon. We need to lead the American people to work together to unshackle us from our dependency on foreign energy and to preserve the environment for the sake of those who will inherit this world from us.

Thank you, Mr. Chairman.

Chairman TOM DAVIS. Thank you very much.

Are there other Members who wish to make opening statements? Yes, ma'am, Ms. Watson.

Ms. WATSON. Mr. Chairman, thank you so much for convening today's hearing. I commend your timeliness on the issue pertaining to energy policy.

This hearing explicitly highlights the administration's research and development activities, or lack thereof, on technologies to address global warming and the administration's strategy on addressing global warming. I am haunted by the fact that the year before last, when we attended a conference in Cutter, there was someone from the Department of Commerce that made the idea of global warming into a myth. It was a Dr. Lash. Just recently we got into quite a warm discussion after his remarks, because it said to the world that we were hallucinating if we thought global warming was a real thing. Just recently he ended up in the newspapers as one who killed his 12 year old son and himself. I saw indications of a hot-headed approach there in Cutter.

Energy is essential to the American lifestyle. The United States has only 2 percent of the world's oil reserves, but accounts for 25 percent of the world's energy demand. Of the global supply, we consume 43 percent of motor gasoline, 25 percent of crude petroleum, 25 percent of natural gas, and 26 percent of electricity. Currently, American demand for all these commodities is rising dramatically, while climate change is on the rise, as well.

On the production side of the issue, the generation and delivery of energy is a serious challenge. Procurement of energy is a challenge of engineering, a challenge of planning, and a challenge that evokes the most serious aspects of our foreign policy. Moreover, energy is a key factor in the environmental challenges we face in modern America and in the world. Reliance on fossil fuels causes serious air and water pollution and it is the source of constant pressure to exploit our last precious wildlands.

As the petroleum demand intensifies, Americans will remain exposed to the environmental cost and the harmful public health impacts associated with the dependence on oil. Global warming is occurring at a rapid pace today, and the consensus of the worldwide scientific community is that it will accelerate during the 21st century.

Global warming and our related energy policies also raise national security concerns. One such concern is the prospect of international destabilization caused by the consequences of global warming such as the loss of land area of the loss of water resources.

Mr. Chairman, I have stated in previous hearings, we have a chance to start again to create adequate climate change research and development that can help our world in the future, so I look forward to today's hearing and I look forward to hearing from the witnesses and I think that you are beginning and we are beginning to play a vital role on environmental safety in our world.

Thank you so much.

Chairman TOM DAVIS. Thank you very much.

Mr. Bilbray.

Mr. BILBRAY. Yes, Mr. Chairman. I want to thank you for holding this hearing and want to publicly thank you for letting me participate on this committee for the rest of this session.

Mr. Chairman, you may know but other Members may not know that I had the privilege of serving for 6 years on the State Air Resources Board for the State of California. I was very proud to participate in that agency because California has the distinction of having an agency that has done more to reduce emissions than any agency anywhere else in the world. The Air Resources Board in California is second to none. It has led on many, many issues, as the ranking member will remind us, many times, both in his presentations and his writings.

But one of the reasons why that agency has been so successful in the past and I am sure will be successful in the future, the Air Resources Board in California does not allow partisan bickering to stand between getting to the answer. They don't allow the fact of posturing to be the primary motivation there. I have been very, very pleased to work with Democrats and Republicans in that body. But I have to tell you, since coming to Congress and leaving that body, I have been frustrated with the fact that science gets put on a back burner in Washington all too often for partisan fighting, but at the same time people don't want to look at the fact that the guilt rests on both sides of the political aisle.

I was very frustrated with my first term in Congress here when I saw that the Clinton administration talked a lot about global warming, a lot about this issue on emissions. At the same time, the only policy I saw really being pushed at that time was the decommissioning of zero emission generators such as hydroelectric and nuclear. I saw an obsession with the destruction of zero emission generators without any identifying where the alternative power was going to come from without contributing to the global warming and the emissions issue.

So I am very excited to be able to say that there are opportunities here. I hope that we join together. I have been frustrated with the discussion that global warming and Kyoto are somehow tied together. I do not see how any of us can take care of the global warming without working together, but I also do not see how we are going to justify any global warming policy that exempts the

Third World, and especially China. I see that Kyoto was a non-starter, and we should have been brave enough to be able to recognize that there is a problem out there but the answer that was being proposed was not an answer to the problem.

I hope to be able to take some of the experience I have been able to bring from California and hopefully work with both sides of the aisle to try to address this issue, but I think that we need to stop finding barriers to getting to answers and quit finding excuses just to fight about it.

Thank you very much, Mr. Chairman. I yield back my time.

Chairman TOM DAVIS. Mrs. Maloney.

Mrs. MALONEY. Thank you, Mr. Chairman. I would like permission to place my remarks in the record——

Chairman TOM DAVIS. Without objection, so ordered.

Mrs. MALONEY [continuing]. And just ask to be associated with the comments of Mr. Waxman and Mr. Lantos and Ms. Watson. I think Ranking Member Lantos' statement of the danger this poses in the world community and in our search for peace was very relevant.

Ms. Watson, you talked about how many skeptics are out there that have kept saying that it is not a problem. I appreciate the comment on the other side of the aisle that science too long has been put on the back burner. Scientists have been telling us for a long time that this is one of the gravest challenges that we confront, and there have been many skeptics, such as the one she described from the Commerce Department, that have made light of this very serious challenge.

I would like to place in the record this photograph of the Arctic climate impact assessment of 2004. It shows the extent of the surface ice melting in Greenland between 1992 and 2002. They say one picture is worth a thousand words. It truly shows that we are losing the snow in Greenland, and other photographs of the Antarctic, even Florida, shows a very changing coastline with the multi-meter rises in sea level. This is a very serious problem.

I congratulate former Vice President Al Gore on his book An Inconvenient Truth and the movie The Inconvenient Truth. It was inspiring for me to see a documentary literally have people standing in lines waiting to get in to see it. I think he helped beyond a shadow of a doubt to close the mouths of the skeptics whom I think are just people who don't want to do anything.

I welcome this hearing today on global warming technology and research, but say that there is so much that we could do besides research right now, such as put a cap on CAFE standards, such as: switching from coal and oil to natural gas; increasing efficiency of energy in use and buildings, transportation, and industry; transition to a lower energy intensity mix of economic activities.

There are so many actions that we could take right now to address this, so I urge my colleagues not only to be looking at technology and research but looking at technical possibilities that we can take right now to reduce energy intensity and carbon intensity on our planet. I truly believe it is the most important issue facing us for the future of our country and the health of our planet, so I thank you for this hearing and would like to place in the record these papers.

[The prepared statement of Hon. Carolyn B. Maloney follows:]

Representative Carolyn B. Maloney (NY-14)
"Climate Change Technology Research:
Do we need a 'Manhattan Project' for the Environment?"
2154 RHOB – 10:00 A.M.
September 21, 2006

Thank you Chairman Davis
and Ranking Member Waxman
for holding this important hearing today
on global warming technology research.

In July, this committee held a hearing
examining the science surrounding
global warming.

Finding that global warming
is indeed real and that increasing levels
of carbon dioxide in our atmosphere
are greatly contributing to it,
we can now move forward
to the critical question of how best
to address the problem.

Federal research and development
on technologies to address global warming
is no doubt a critical first step,
and I am eager to hear about progress
on the Administrations strategic plan

for Climate Change Technology Program.

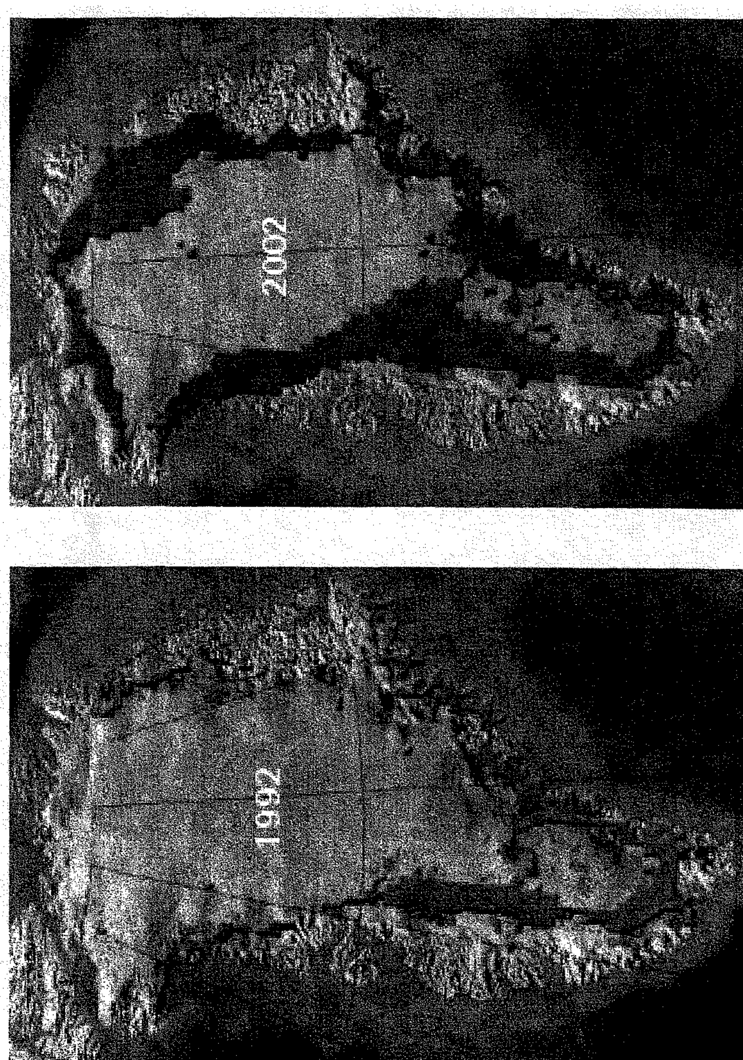
But what I am really hoping to hear
is a set of concrete plans for deploying
these new technologies into the market place,
in both the short and long terms.

As we all know, technology
that is not actually being used
can do nothing to address global warming.

Finally, I look forward to hearing
the witnesses views on the creation
of a new climate technology program
based on the model of the Defense Advanced
Research Projects Agency (DARPA),
which would focus on high-risk research.

If successful, this type of research
may hold the key to dramatic results
in combating global warming.
I thank all our witnesses for being here today,
and I look forward to hearing your testimony.

Extent of summer surface ice melting in Greenland, 1992 and 2002



Arctic Climate Impact Assessment 2004

Chairman TOM DAVIS. Without objection they will be placed in the record. Thank you, Mrs. Maloney.

Mr. Kucinich.

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

The title of this hearing is Climate Change Technology Research: Do we need a Manhattan Project for the Environment? I would respectfully suggest this is kind of an unfortunate title for this particular hearing. The Manhattan Project harnessed the scientific genius of America for a purely destructive purpose, the building of nuclear weapon, under conditions of assorted history of human experimentation and spawned a nuclear industry which drove up utility rates and gave us nuclear waste forever. Nuclear weapons now constitute a threat to the survival of our entire planet, and certainly, as Jonathan Schell pointed out in his book, Fate of the Earth, a threat to the common global environment.

Now, if we are talking about saving the planet, maybe we should come up with an analogy that is not so obviously contradictory. Asking whether we need a Manhattan Project for the environment begs the question don't we already have one. Everything about our energy policies are destabilizing. Oil runs our politics, bringing with it not only the injurious effects of climate change but war, environmental ruin, economic decline, manipulation of prices, oil politics are visiting us right now on the eve of an election. You see the prices dropping at the pump trying to lull the public to sleep about the game that is being played by the oil companies in cooperation with the administration.

Global warming? Until recently, scientists for hire were ready to discount the result of our destructive energy policies and urging administrations to refuse to participate in the Kyoto Climate Change Treaty. I would agree with the colleague that we ought to talk to China, but wouldn't it be good if we had trade agreements that held environmental quality principles as one of the bases for international trade.

Mr. Chairman, I have to submit for the record here a study of the Manhattan Project called the New and Secret World of Human Experimentation. I also have my statement, which calls for new direction with respect to sustainable energy choices like wind, solar, ocean, geothermal, and with a call for investment to match the intention of changing our energy policies. We really ought to change the title of the hearing though.

Thank you.

Chairman TOM DAVIS. Thank you. Maybe we ought to call it a Marshall plan. Do you like that better?

Mr. KUCINICH. You know, yes, like rebuilding after a war. Yes, that is a great idea.

Chairman TOM DAVIS. OK.

Next, Mr. Van Hollen.

Mr. VAN HOLLEN. Thank you, Mr. Chairman, and thank you for holding this hearing, and to Ranking Member Waxman for his leadership on this very important issue.

I agree with statements made by my colleagues really some on both sides of aisle here with respect to the importance of moving forward in a bipartisan manner, but to do that we are going to have to make decisions based on science and based on the facts.

Everyone is entitled to their own opinions, but everyone is not entitled to their own set of facts. Unfortunately, here in political Washington people seem to think that they can make up the facts as well as making up the policy. There is an absolute scientific consensus that global warming is real and that there is an important human contribution to the problem, and so, though we have settled science and settled facts on that question, we continue to have a lack of political leadership on this very important issue.

We continue to have, for example, the chairman of the Environment and Public Works on the Senate side say that the whole global warming issue is the greatest hoax ever perpetuated on the American people. We had a Member of the House on the Science Committee in a hearing yesterday saying that the whole thing was made up, as well. Even the President of the United States, when he talks about this issue as he did in July in People Magazine, sort of said there is an open question with respect to whether or not there was a human component to the global warming question. He said it was a question of debate.

So, until the political leadership in Washington begins to deal with the facts, we are not going to be able to move forward. We can have disagreements with respect to what the best policy is, but we need our political leadership to begin to take responsibility for accepting what the scientific community has told us with respect to this very important issue, and then we need to move forward, and we need to move forward quickly, and we need to stop passing energy legislation that continues to provide big subsidies to the oil and gas industry and channel those funds instead into renewable energy and energy efficiency areas.

So I welcome the comments on both sides of the aisle about the need to move forward on a bipartisan basis on this issue, but, unfortunately, we have on the one hand people who continue to misrepresent the facts with respect to the science, and unfortunately the reality of the situation is the legislation that is passed out of the Congress has not demonstrated that people have come to grips with the reality of the science on this issue.

I hope we will begin to turn that situation around and begin to have policy coming out of here and political leadership that matches the facts with respect to this very important issue.

Thank you, Mr. Chairman.

Chairman TOM DAVIS. Thank you, Mr. Van Hollen.

If there are no more opening statements, we will now proceed to our first panel. We have Dr. Stephen Eule, the Director of Climate Change Technology Program, and Mr. John Stephenson, the director of Government Accountability Office.

Thank you for bearing with us through our markup and opening statements.

[Witnesses sworn.]

Chairman TOM DAVIS. Mr. Eule, we will start with you. Thank you for being with us.

STATEMENTS OF STEPHEN D. EULE, DIRECTOR, CLIMATE CHANGE TECHNOLOGY PROGRAM; AND JOHN B. STEPHENSON, DIRECTOR, GOVERNMENT ACCOUNTABILITY OFFICE

STATEMENT OF STEPHEN D. EULE

Mr. EULE. Thank you, Chairman Davis, Ranking Member Waxman, and members of the committee. Thank you for the opportunity to appear before you today to discuss the climate change technology program and its strategic plan, which was released yesterday.

The administration believes that the most effective way to meet the challenge of climate change is through an agenda that promotes economic growth, provides energy security, reduces pollution, and mitigates greenhouse gases. To meet these goals, the administration has established a comprehensive approach, major elements of which include policies and measures to slow the growth in greenhouse gas emissions, advancing climate change science, accelerating technology development, and promoting international collaboration.

Since fiscal year 2001 the Federal Government has devoted nearly $29 billion to climate change programs. In 2002, President Bush set a goal to reduce the Nation's greenhouse gas intensity—that is, emissions per unit of economic output—by 18 percent by 2012. To this end, the administration has implemented about 60 Federal programs, and recent data suggests we are well on our way toward meeting the President's goal.

While acting to slow the growth of greenhouse gas emissions in the near term, the United States is laying a strong scientific and technological foundation. In 2002, two multi-agency programs were established to coordinate Federal climate science and technology R&D activities, the climate change science program [CCSP], and the climate change technology program [CCTP].

CCSP is an inter-agency planning and coordinating entity charged with investigating natural and human-induced changes in the Earth's global environmental system, monitoring understanding of predicting global change, and providing a sound scientific basis for decisionmaking.

CCTP, which was authorized in the Energy Policy Act of 2005, was formed to coordinate and prioritize the Federal Government's investment in climate-related technology, which was nearly $3 billion in fiscal year 2006, and to further the President's national climate change technology initiative [NCCTI].

Ten R&D agencies participate in CCTP. The program's principal aim is to accelerate the development and lower the cost of advanced technologies that reduce, avoid, or sequester greenhouse gases. CCTP strives for a diversified Federal R&D portfolio that will help reduce technology risk and improve the prospects that such technologies can be adopted in the marketplace.

In August 2005, CCTP issued its vision and framework for strategy and planning, which provided broad guidance for the program, and shortly thereafter released its draft strategic plan for public review. More than 250 comments were received and considered.

This revised strategic plan articulates a vision of the role for advanced technology in addressing climate change, establishes strategic direction, guiding principles, outlines approaches to achieve CCTP's strategic goals, and identifies a series of next steps. The six CCTP goals are: reducing emissions from energy use and infrastructure, reducing emissions from energy supply, capturing and sequestering carbon dioxide, reducing emissions of non-carbon-dioxide greenhouse gases, measuring and monitoring emissions, and bolstering the contributions of basic science.

The strategic plan defines a clear and promising role for advanced technologies for the near, the mid, and the long-term; outlines a processes and establishes criteria for setting priorities, such as those in NCCTI; and provides details of the current climate change technology portfolio, with links to individual technology road maps.

CCTP's portfolio includes realigned activities, as well as new initiatives, such as the President's advanced energy and hydrogen fuel initiatives, carbon sequestration, and future gen.

CCTP agencies also periodically conduct portfolio reviews to assess the ability of these programs to meet CCTP goals and to identify gaps and opportunities. In addition, CCTP uses scenario analyses to assess the potential climate change benefits of different technology mixes over the century on a global scale and across a range of uncertainties. When comparing the costs of achieving different greenhouse gas constraints, the cost savings for the advanced technology cases were 60 percent or more.

The administration believes that well-designed multi-lateral collaborations can leverage resources and quicken technology development. The International Partnership for the Hydrogen Economy, Carbon Sequestration Leadership Forum, Generation Four International Forum, Methane to Markets—all U.S. initiatives—and the ITER Fusion Project provide vehicles for international collaboration to advance these technologies. The new Global Nuclear Energy Partnership seeks to develop a worldwide consensus on approaches to expand safe use of zero emission nuclear power.

Of course, through the Asian Pacific Partnership the United States is working with Australia, China, India, Japan, and South Korea to accelerate the uptake of clean technologies in this rapidly growing region of the world.

The United States has embarked on an ambitious undertaking to advance climate change technologies. CCTP's strategic plan, the first of its kind produced by any government, sets out an overall strategy to guide these efforts and provides a long-term planning context in which the nature of both the challenges and the opportunities for advanced technologies are considered.

I thank you for your kind attention. I will, of course, be delighted to answer any questions you may have.

[The prepared statement of Mr. Eule follows:]

TESTIMONY OF
STEPHEN D. EULE
DIRECTOR, CLIMATE CHANGE TECHNOLOGY PROGRAM
U.S. DEPARTMENT OF ENERGY

BEFORE THE
COMMITTEE ON GOVERNMENT REFORM
U.S. HOUSE OF REPRESENTATIVES

HEARING ON
"CLIMATE CHANGE TECHNOLOGY"

SEPTEMBER 21, 2006

INTRODUCTION

Mr. Chairman and Members of the Committee, thank you for the opportunity to appear before you today and report on the Climate Change Technology Program (CCTP).

I would like to begin my testimony by providing a brief overview of the Administration's approach to climate change, which provides the context in which CCTP operates. I will also discuss the role of CCTP, explain the purpose of the *Strategic Plan*, and discuss how the *Plan* will help the Administration and Congress make decisions about investments in advanced technologies that can have a significant impact on reducing greenhouse gas emissions.

As a party to the United Nations Framework Convention on Climate Change (UNFCCC), the United States shares with many countries its ultimate objective: stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. In February 2002, President Bush reaffirmed the Administration's commitment to this long-term goal of the Framework Convention.

There is a growing recognition that climate change cannot be dealt with effectively in isolation. Rather, it needs to be addressed as part of an integrated agenda that promotes economic growth, provides energy security, reduces pollution, and also mitigates greenhouse gas emissions. In July 2005, the G8 leaders, meeting in Gleneagles, Scotland, agreed to a plan of action that interlinked climate change objectives with these other important considerations.

Meeting these complementary objectives will require a sustained, long-term commitment by all nations over many generations. To this end, the President has established a robust and flexible climate change policy that harnesses the power of markets and technological innovation, maintains economic growth, and encourages global participation.

Major elements of this approach include: (1) implementing near-term policies and measures to slow the growth in greenhouse gas emissions; (2) advancing climate change science; (3) accelerating technology development and commercialization; and (4) promoting international collaboration.

From fiscal years 2001 to the end of 2006, the federal government will have devoted nearly $29 billion to science, technology, international assistance, and incentive programs that support climate change objectives, more than any other nation. The President's fiscal year 2007 budget calls for $6.5 billion for climate-related activities.

NEAR-TERM POLICIES AND MEASURES

In 2002, President Bush set an ambitious but achievable national goal to reduce the greenhouse gas intensity—that is, emissions per unit of economic output—of the U.S. economy by 18 percent by 2012. At the time, the Administration estimated that achieving this commitment would avoid an additional 106 million metric tons of carbon-equivalent emissions in 2012 compared to the Energy Information Administration's *Annual Energy Outlook 2002* business as usual base case projection, and would result in cumulative savings of more than 500 million metric tons of carbon-equivalent emissions over the decade.

To this end, the Administration is now implementing numerous programs—including partnerships, consumer information campaigns, incentives, and mandatory regulations—that are directed at developing and deploying cleaner, more efficient energy technologies, conservation, biological sequestration, geological sequestration and adaptation. For example, the Department of Energy's (DOE) Climate VISION program and the Environmental Protection Agency's (EPA) Climate Leaders and SmartWay Transport Partnership programs work in voluntary partnership with specific commitments by industry to verifiably reduce emissions. The Department of Agriculture (USDA) is using its conservation programs to provide substantial incentives to increase carbon sequestration in soils and trees, and to reduce methane and nitrous oxide emissions, two additional and potent greenhouse gases, from crop and animal agricultural systems. The Department of Transportation (DOT) has implemented a new fuel economy standard for light trucks, including sport utility vehicles, that is projected to result in significant reductions in CO_2 emissions over the life of the affected vehicles. DOT has also submitted an Administration proposal to Congress for authority to reform the setting and calculation of fuel economy standards for passenger automobiles.

In terms of financial incentives, new tax rules on expensing and dividends are helping to promote substantial new capital investment, including purchases of cleaner, more efficient equipment and facilities. The Energy Policy Act of 2005 provides for approximately $1.6 billion in tax credits and incentives in fiscal year 2007 to accelerate the market penetration of clean, efficient technologies. For example, the Act also provides tax credits of up to $3,400 for the most highly fuel efficient vehicles such as hybrids and clean diesel. It also establishes 15 new appliance efficiency mandates and a 7.5 billion gallon renewable fuel requirement by 2012.

We expect these efforts will contribute to meeting the President's 18 percent, 10-year goal, which represents an average annual rate of improvement of about 1.96 percent. Data from the Energy Information Administration (EIA) suggest steady progress. Since 2002, EIA reports annual improvements in greenhouse gas emissions intensity of 1.6 percent and 2.1 percent in 2003 and 2004, respectively. Further, a June 2006 EIA preliminary "flash estimate" estimate of energy-related carbon dioxide emissions—which account for about four fifths of total greenhouse gas emissions—shows an improvement in carbon dioxide emissions intensity of 3.3 percent in 2005. Although we are only a few years into the effort, the Nation appears on track to meet the President's goal.

While acting to slow the growth of greenhouse gas emissions in the near term, the United States is laying a strong scientific and technological foundation to reduce uncertainties, clarify risks and benefits, and develop realistic mitigation options through better integration and management of its climate change related scientific and technological activities. In February 2002, President Bush announced the creation of a cabinet-level Committee on Climate Change Science and Technology Integration, co-chaired by the Secretaries of Commerce and Energy. Two multi-agency programs were established to coordinate Federal activities in climate change scientific research and advance the President's vision under his National Climate Change Technology Initiative (NCCTI). These are the U.S. Climate Change Science Program (CCSP), led by the Department of Commerce, and CCTP, led by DOE.

CLIMATE CHANGE SCIENCE PROGRAM[1]

CCSP is an interagency research planning and coordinating entity charged with investigating natural and human-induced changes in the Earth's global environmental system, monitoring, understanding, and predicting global change, and providing a sound scientific basis for national and international decision-making. CCSP combines the near-term focus of the Administration's Climate Change Research Initiative—including a focus on advancing the understanding of aerosols and carbon sources and sinks and improvements in climate modeling—with the breadth of the long-term research elements of the U.S. Global Change Research Program.

In July 2003, CCSP released its *Strategic Plan* for guiding climate research. The plan is organized around five goals: (1) improving our knowledge of climate history, variability, and change; (2) improving our ability to quantify factors that affect climate; (3) reducing uncertainty in climate projections; (4) improving our understanding of the sensitivity and adaptability of ecosystems and human systems to climate change; and (5) exploring options to manage risks associated with climate variability and change. CCSP is now in the process of implementing its 10-year *Plan*. The President's fiscal year 2007 budget request includes $1.715 billion for the climate change science. The knowledge gained through CCSP will be invaluable in helping CCTP plan for needed technology development.

CLIMATE CHANGE TECHNOLOGY PROGRAM[2]

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[1] See: http://www.climatescience.gov.
[2] See: http://www.climatetechnology.gov.

To address the challenges of energy security, economic development, and climate change, there is need for a visionary, long-term perspective. The International Energy Agency estimates there are about 2 billion people who lack modern energy services. Many countries are focusing efforts on providing power to their citizens. Although projections vary considerably, a tripling of energy demand by 2100 is certainly not unreasonable. When one considers further that energy-related carbon dioxide emissions account for about four fifths of all greenhouse gas emissions, the scale of the challenge becomes apparent. Most anthropogenic greenhouse gases emitted over the course of the 21st century will come from equipment and infrastructure not yet built, a circumstance that poses significant opportunities to reduce or eliminate these emissions.

As we look to the future, providing the energy necessary to power economic growth and development while at the same time reducing greenhouse gas emissions is going to require cost-effective transformational technologies that can fundamentally alter the way we produce and use energy. Given the huge capital investment in existing energy systems, the desired transformation of the global energy system may take many decades. A robust research effort undertaken today can make new, competitive technologies available sooner rather than later and accelerate modernization of capital stock.

Other greenhouse gases from non-energy related sources—methane, nitrous oxides, sulfur hexafluoride, and fluorocarbons, among others—also pose a concern. They have higher warming potentials than carbon dioxide. In aggregate, these gases present a large opportunity to reduce global radiative forcing and, in many cases, the technical strategies to reduce their emissions are straightforward and tractable. Finding ways to mitigate these other greenhouse gases is an important part of CCTP's technology strategy.

The United States is leading the development of many advanced technology options that have the potential to reduce, avoid, or sequester greenhouse gas emissions. CCTP was created in 2002, and subsequently authorized in Title XVI of the Energy Policy Act of 2005, to coordinate and prioritize the Federal Government's investment in climate-related technology and to further the President's National Climate Change Technology Initiative (NCCTI). The fiscal year 2007 Budget includes nearly $3 billion for CCTP-related activities.

CCTP's principal aim is to accelerate the development and reduce the cost of new and advanced technologies with the potential to reduce, avoid, or sequester greenhouse gas emissions. It does this by providing strategic direction for the CCTP-related elements of the overall Federal technology portfolio. It also facilitates the coordinated planning, programming, budgeting, and implementation of the technology development and deployment aspects of U.S. climate change strategy. CCTP also is assessing different technology options and their potential contributions to reducing greenhouse gas emissions over the short, mid, and long term to help inform budget decisions and priorities.

STRATEGIC PLANNING FOR TECHNOLOGY DEVELOPMENT: CCTP conducts its planning under conditions of uncertainty and across a wide range of possible futures. The pace and scope of needed change will be driven partially by future trends in greenhouse gas emissions that are subject to great a deal of ambiguity. The complex relationships among population growth, economic development, energy demand, mix, and intensity, resource availability, technology, and other variables make it impossible to accurately predict future greenhouse gas emissions on a 100-year timescale.

In August 2005, CCTP issued its *Vision and Framework for Strategy and Planning*. This document provides an overall strategy to guide and strengthen our technical efforts to reduce emissions. Shortly thereafter, CCTP released its draft *Strategic Plan* for public review and comment. More than 250 comments were received and addressed. We appreciate the thoughtful comments we received, which have improved the document.

Building on the guidance in the *Vision and Framework*, the *Strategic Plan* released yesterday articulates a vision of the role for advanced technology in addressing climate change, defines a supporting mission for CCTP, establishes strategic direction and guiding principles for Federal R&D agencies to use in formulating research and development portfolio, outlines approaches to attain CCTP's strategic goals, and identifies a series of next steps toward implementation.

CCTP's strategic vision has six complementary goals: (1) reducing emissions from energy use and infrastructure; (2) reducing emissions from energy supply; (3) capturing and sequestering CO_2; (4) reducing emissions of non-CO_2 greenhouse gases; (5) measuring and monitoring emissions; and (6) bolstering the contributions of basic science.

Ten Federal agencies support a broad portfolio of activities within this framework. Participating Federal agencies in CCTP include the Departments of Energy, Agriculture, Commerce, Defense, Health and Human Services, Interior, State, and Transportation, as well as the Environmental Protection Agency, the National Aeronautics and Space Administration, and the National Science Foundation.

The *Strategic Plan* provides a comprehensive, long-term look at the nature of the climate change challenge and its potential solutions. It defines clear and promising roles for advanced technologies by grouping technologies for near-, mid- and long term deployment. Together these technologies will facilitate meeting CCTP goals. It also outlines a process and criteria for setting priorities by organizing and aligning Federal climate change R&D and discusses in detail the current climate change technology portfolio, with links to individual technology roadmaps and goals. CCTP and the participating agencies periodically conduct and support strategic planning exercises to identify gaps and opportunities in climate change technology and realign the portfolio as appropriate.

The *Strategic Plan* also identifies a number of next steps outlining an ambitious agenda for advancing climate change technology development. These include strengthening the Federal R&D portfolio, intensifying basic research support of the applied technology R&D programs, extending international cooperation, and exploring a number of supporting technology policy mechanisms.

Many CCTP activities build on existing work, but the Administration also has expanded and realigned some activities and launched new initiatives in key technology areas to support the CCTP's goals. The President's NCCTI includes 12 discrete activities that could advance technologies to avoid, reduce, or capture and store greenhouse gas emissions on a large scale. The Administration's budget proposal for fiscal year 2007 included $306 million for these NCCTI priorities.

CCTP anticipates that a progression of advanced technologies will be available and enter the marketplace in the near, mid, and long terms. Figure 1 provides a schematic roadmap for the technologies being pursued under CCTP. Readers wishing a fuller explanation of the technology research described below should consult CCTP's *Research and Current Activities* and *Technology Options for the Near and Long Term* reports, both of which are available on the CCTP web page. Short descriptions of each of the NCCTI priorities are also available on the CCTP web page.

FIGURE 1. CCTP ROADMAP FOR CLIMATE CHANGE TECHNOLOGY DEVELOPMENT

	Near-Term	Mid-Term	Long-Term
Goal #1 Energy End-Use & Infrastructure	• Hybrid & Plug-In Hybrid Electric Vehicles • Engineered Urban Designs • High-Performance Integrated Homes • High Efficiency Appliances • High Efficiency Boilers & Combustion Systems • High-Temperature Superconductivity Demonstrations	• Fuel Cell Vehicles and H_2 Fuels • Low Emission Aircraft • Solid-State Lighting • Ultra-Efficient HVACR • "Smart" Buildings • Transformational Technologies for Energy-Intensive Industries • Energy Storage for Load Leveling	• Widespread Use of Engineered Urban Designs & Regional Planning • Energy Managed Communities • Integration of Industrial Heat, Power, Process, and Techniques • Superconducting Transmission and Equipment
Goal #2 Energy Supply	• IGCC Commercialization • Stationary H_2 Fuel Cells • Cost-Competitive Solar PV • Demonstrations of Cellulosic Ethanol • Distributed Electric Generation • Advanced Fission Reactor and Fuel Cycle Technology	• FutureGen Scale-Up • H_2 Co-Production from Coal/Biomass • Low Wind Speed Turbines • Advanced Biorefineries • Community-Scale Solar • Gen IV Nuclear Plants • Fusion Pilot Plant Demonstration	• Zero-Emission Fossil Energy • H_2 & Electric Economy • Widespread Renewable Energy • Bio-Inspired Energy & Fuels • Widespread Nuclear Power • Fusion Power Plants
Goal #3 Capture, Storage & Sequestration	• CSLF & CSRP • Post Combustion Capture • Oxy-Fuel Combustion • Enhanced Hydrocarbon Recovery • Geologic Reservoir Characterization • Soils Conservation • Dilution of Direct Injected CO_2	• Geologic Storage Proven Safe • CO_2 Transport Infrastructure • Soils Uptake & Land Use • Ocean CO_2 Biological Impacts Addressed	• Track Record of Successful CO_2 Storage Experience • Large-Scale Sequestration • Carbon & CO_2 Based Products & Materials • Safe Long-Term Ocean Storage
Goal #4 Other Gases	• Methane to Markets • Precision Agriculture • Advanced Refrigeration Technologies • PM Control Technologies for Vehicles	• Advanced Landfill Gas Utilization • Soil Microbial Processes • Substitutes for SF_6 • Catalysts That Reduce N_2O to Elemental Nitrogen in Diesel Engines	• Integrated Waste Management System with Automated Sorting, Processing & Recycle • Zero-Emission Agriculture • Solid-State Refrigeration/AC Systems
Goal #5 Measure & Monitor	• Low-Cost Sensors and Communications	• Large Scale, Secure Data Storage System • Direct Measurement to Replace Proxies and Estimators	• Fully Operational Integrated MM Systems Architecture (Sensors, Indicators, Data Visualization and Storage, Models)

ENERGY USE AND INFRASTRUCTURE: Improving energy efficiency and reducing greenhouse gas emissions intensity in transportation, buildings, and industrial processes can contribute greatly to overall greenhouse gas emission reductions. In addition, improving the electricity transmission and distribution "grid" infrastructure can reduce greenhouse gas emissions by making power generation more efficient of by providing greater grid access for wind and solar power.

Key research activities include FreedomCAR (Cooperative Automotive Research)[3] program, a cost-shared government-industry partnership that is pursuing fuel cell and other advanced automotive technologies. Advanced heavy-duty vehicles technologies, zero-energy homes and commercial buildings, solid-state lighting, and superconducting wires that virtually eliminate electricity transmission losses are other areas of research that could yield significant emissions reduction.

ENERGY SUPPLY: Fossil fuels, which emit CO_2 when burned, remain the world's energy supply of choice. A transition to a low-carbon energy future would, therefore, require the availability of cost-competitive low- or zero-carbon energy supply options. When combined with alternative energy carriers—such as electricity and hydrogen—these options could offer the prospect of considerable reductions in greenhouse gas emissions.

Renewable energy includes a range of different technologies that can play an important role in reducing greenhouse gas emissions. The United States invests considerable resources in wind, solar photovoltaics, and biomass technologies. We have made much progress in price competitiveness of many of these technologies, but there still is a need to reduce their manufacturing, operating, and maintenance costs. For example, new biotechnology breakthroughs offer the potential for extensive domestic production of cellulosic ethanol by both improving feedstocks and increasing the efficiency of converting lignocellulosic material to ethanol. DOE's Office of Science has awarded up to $250 million over five years (subject to appropriations) for two new bioenergy research centers to advance the science needed to develop new cellulosic conversion technologies, which could decrease greatly the greenhouse gas emissions from liquid transportation fuels.[4]

There will be a continuing need for portable, storable energy carriers for heat, power, and transportation. Hydrogen is an excellent energy carrier, produces no emissions when used in a fuel cell, and can be produced from diverse sources, including renewables, nuclear, and fossil fuels (which in the latter case could be combined with carbon capture). President Bush's $1.2 billion Hydrogen Fuel Initiative[5] is exploring these production options as well as the infrastructure needed to store and deliver hydrogen economically and safely. It is expected that the research being performed under the program will make possible a commercialization decision by industry in 2015 and possible market introduction of hydrogen fuel-cell vehicles by 2020.

The United States has vast reserves of coal, and about half of its electricity is generated from this fuel. Advanced fossil-based power and fuels, therefore, is an area of special interest. The FutureGen[6] project is a 10-year, $1 billion government-industry collaboration—which includes India and the Republic of Korea—to build the world's first near-zero atmospheric emissions coal-fired power plant. This project will incorporate the latest technologies in carbon sequestration, oxygen and hydrogen separation membranes, turbines, fuel cells, and coal-to-

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[3] See: http://www1.eere.energy.gov/vehiclesandfuels/about/partnerships/freedomcar/index.html.
[4] See: http://genomicsgtl.energy.gov/centers/index.shtml
[5] See: http://www.eere.energy.gov/hydrogenandfuelcells/presidents_initiative.html.
[6] See: http://fossil.energy.gov/programs/powersystems/futuregen/index.html.

hydrogen gasification. This research can help coal remain part of a diverse, secure, and environmentally acceptable energy portfolio well into the future.

Concerns over resource availability, energy security, and air quality as well as climate change suggest a larger role for nuclear power as an energy supply choice. The Generation IV Nuclear Energy Systems Initiative[7] is investigating the next-generation reactor and fuel cycle systems that represent a significant leap in economic performance, safety, and proliferation-resistance. While the primary focus for developing a next-generation reactor is on producing electricity in a highly efficient manner, there is also the possibility of coupling a reactor with advanced technology that would allow for the production of hydrogen. These advanced technologies are being developed under the Nuclear Hydrogen Initiative[8] and could possibly enable the production of hydrogen on a scale to meet transportation needs.

Fusion energy[9] is a way to generate power that, if successfully developed, could be used to produce electricity and possibly hydrogen. Fusion has features that make it is an attractive option from both an environmental and safety perspective. However, the technical hurdles of fusion energy are very high, and with a commercialization objective of 2050, its potential impact would be in the second half of the century.

In his 2006 State of the Union Address, President Bush outlined plans for an Advanced Energy Initiative (AEI).[10] AEI aims to accelerate the development of advanced technologies that could change the way American homes, businesses, and automobiles are powered. AEI is designed to take advantage of technologies that with a little push could play a big role in helping to reduce the Nation's use of foreign sources of energy and its pollution and greenhouse gas emissions. AEI includes greater investments in near-zero atmospheric emissions coal-fired plants, solar and wind power, nuclear energy, better battery and fuel cell technologies for pollution-free cars, and cellulosic biorefining technologies for biofuels production.

CARBON SEQUESTRATION: Carbon capture and sequestration is a central element of CCTP's strategy because for the foreseeable future, fossil fuels will continue to be among the world's most reliable and lowest-cost form of energy. A realistic approach, then, is to find ways to "sequester" the CO_2 produced when these fuels—especially coal—are used. The phrase "carbon sequestration" describes a number of technologies and methods to capture, transport, and store CO_2 or remove it from the atmosphere.

Advanced techniques to capture gaseous CO_2 from energy and industrial facilities and store it permanently in geologic formations are under development. The Department of Energy's core Carbon Sequestration Program[11] emphasizes technologies that capture CO_2 from large point sources and store the emissions in geologic formations that potentially could hold vast amounts of CO_2.

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[7] See: http://gen-iv.ne.doe.gov.
[8] See: http://nuclear.gov/hydrogen/hydrogenOV.html.
[9] See: http://www.sc.doe.gov/Program_Offices/fes.htm.
[10] See: http://www.whitehouse.gov/stateoftheunion/2006/energy/index.html.
[11] See: http://fossil.energy.gov/programs/sequestration/index.html.

Terrestrial sequestration—removing CO_2 from the atmosphere and sequestering it in trees, soils, or other organic materials—has proven to be a low-cost means for long-term carbon storage. The Carbon Sequestration in Terrestrial Ecosystems consortium, supported by DOE's Office of Science, provides research on mechanisms that can enhance terrestrial sequestration

In 2003, DOE launched a nationwide network of seven Carbon Sequestration Regional Partnerships[12] that include 40 states, four Canadian Provinces, three Indian Nations, and over 300 organizations. The partnerships' main focus is on determining the best approaches for sequestration in their regions, and they also will examine regulatory and infrastructure needs. Small-scale validation testing of 35 sites involving terrestrial and geologic sequestration technologies began in 2005, and will continue until 2009.

NON-CARBON DIOXIDE GREENHOUSE GASES: A main component of the U.S. strategy is to reduce other greenhouse gases, such as methane, nitrous oxides (N_2O), sulfur hexafluoride (SF_6), and fluorocarbons, among others.

Improvements in methods and technologies to detect and either collect or prevent methane emissions from various sources—such as landfills, coal mines, natural gas pipelines, and oil and gas exploration operations—can prevent this greenhouse gas from escaping to the atmosphere.[13] In agriculture, improved management practices for fertilizer applications and livestock waste can reduce methane and N_2O emissions appreciably.

Hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and SF_6 are all high global warming potential (High GWP) gases. HFCs and PFCs are used as substitutes for ozone-depleting chlorofluorocarbons and are used in or emitted during complex manufacturing processes. Advanced methods to reduce the leakage of, reuse, and recycle these chemicals and lower GWP alternatives are being explored.

Programs aimed at reducing particulate matter have led to significant advances in fuel combustion and emission control technologies to reduce U.S. black carbon aerosol emissions. Reducing emissions of black carbon, soot, and other chemical aerosols can have multiple benefits, including better air quality and public health and reduced radiative forcing.

MEASURING AND MONITORING: To meet future greenhouse gas emissions measurement requirements, a wide array of sensors, measuring platforms, monitoring and inventorying systems, and inference methods are being developed. Many of the baseline measurement, observation, and sensing systems used to advance climate change science are being developed as part of CCSP. CCTP's efforts focus primarily on validating the performance of various climate change technologies, such as in terrestrial and geologic sequestration.

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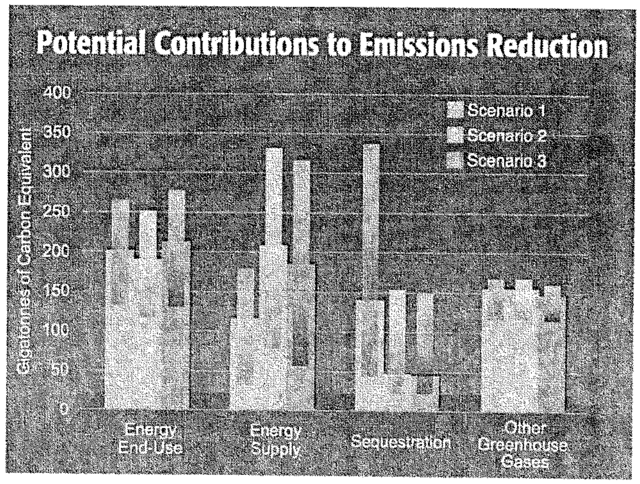
[12] See: http://fossil.energy.gov/programs/sequestration/partnerships/index.html.
[13] Reducing methane emissions may also have a positive benefit in reducing local ozone problems, as methane is an ozone precursor.

BASIC SCIENCE: Basic scientific research is a fundamental element of CCTP. Meeting the dual challenges of addressing climate change and meeting growing world energy demand is likely to require discoveries and innovations that can shape the future in often unexpected ways. The CCTP framework aims to strengthen the basic research enterprise through strategic research that supports ongoing or projected research activities and exploratory research involving innovative concepts.

SCENARIO ANALYSIS: CCTP uses scenario analyses that incorporate various assumptions about the future to clarify the potential role of climate change technologies and to aid in portfolio planning. Scenarios analyses can provide a relative indication of the potential climate change benefits of a particular technology mix compared to others, and it can help determine which classes of technology would most likely provide larger-scale benefits. Figure 2 offers a glimpse of the range of emissions reductions new technologies in energy end use, energy supply, carbon sequestration, and other non-CO_2 greenhouse gases may make possible on a 100-year scale and across a range of uncertainties and constraints.

FIGURE 2: POTENTIAL CONTRIBUTIONS TO EMISSIONS REDUCTIONS



Potential ranges of greenhouse gas emissions reductions to 2100 by category of activity for three technology scenarios characterized by: viable carbon sequestration (Scenario 1); dramatically expanded nuclear and renewable energy (Scenario 2); and novel and advanced technologies (Scenario 3). Note also the consistently large potential reductions in other greenhouse gas emissions under all three scenarios (CCTP 2006).

INTERNATIONAL COLLABORATIONS

The United States believes that well-designed multilateral collaborations focused on achieving practical results can accelerate development and commercialization of new technologies. The U.S. has initiated or joined a number of multilateral technology collaborations in hydrogen, carbon sequestration, nuclear energy, and fusion that address many energy-related concerns (e.g., energy security, climate change, environmental protection).

Asia-Pacific Partnership on Clean Development and Climate[14] **(APP):** Launched formally in January 2006, APP is a multi-stakeholder partnership working to generate practical and innovative projects promoting clean development and the mitigation of greenhouse gases. The six APP partnering nations—Australia, China, India, Japan, South Korea, and the United States—account for about half of the world's economy, energy use, and greenhouse gas emissions. APP is pursuing public-private partnerships to build local capacity, improve efficiency and reduce greenhouse gas emissions, create new investment opportunities, and remove barriers to the introduction of clean energy technologies in the Asia Pacific region. At the ministerial launch, the APP partners created eight task forces in the following areas: (1) cleaner fossil energy; (2) renewable energy and distributed generation; (3) power generation and transmission; (4) steel; (5) aluminum; (6) cement; (7) coal mining; and (8) buildings and appliances. Each Task Force is completing an Action Plan that will serve as blueprint for cooperation and provide a strategic framework for identifying and implementing Partnership activities. The President's fiscal year 2007 budget request includes $52 million to support APP.

INTERNATIONAL PARTNERSHIP FOR THE HYDROGEN ECONOMY (IPHE)[15]**:** In November 2003, representatives from 16 governments gathered in Washington, DC to launch IPHE, a vehicle to coordinate and leverage multinational hydrogen research programs. Moreover, IPHE will develop common recommendations for internationally-recognized standards and safety protocols to speed market penetration of hydrogen technologies. An important aspect of IPHE is maintaining communications with the private sector and other stakeholders to foster public-private collaboration and address the technological, financial, and institutional barriers to hydrogen.

CARBON SEQUESTRATION LEADERSHIP FORUM (CSLF)[16]**:** CSLF is a U.S. initiative that was established at a ministerial meeting held in Washington, DC, in June 2003. CSLF is a multilateral initiative that provides a framework for international collaboration on sequestration technologies. CSLF has as members 22 governments representing both developed and developing countries.

The Forum's main focus is assisting the development of technologies to separate, capture, transport, and store CO_2 safely over the long term, making carbon sequestration technologies broadly available internationally, and addressing wider issues, such as regulation and policy,

[14] See: http://www.asiapacificpartnership.org

[15] See: http://www.iphe.net. IPHE members include the United States, Australia, Brazil, Canada, China, European Commission, France, Germany, Iceland, India, Italy, Japan, New Zealand, Norway, Republic of Korea, Russian Federation, and United Kingdom.

[16] See: http://www.cslforum.org. CSLF members include the United States, Australia, Brazil, Canada, China, Colombia, Denmark, European Commission, France, Germany, Greece, India, Italy, Japan, Korea, Mexico, Netherlands, Norway, Russian Federation, Saudi Arabia, South Africa, and United Kingdom.

relating to carbon capture and storage. To date, 17 international research projects have been endorsed by the Forum, five of which involve the United States.

GENERATION IV INTERNATIONAL FORUM (GIF)[17]: In July 2001, nine other countries and Euratom joined together under U.S. leadership to charter GIF, a multilateral collaboration to fulfill the objective of the Generation IV Nuclear Energy Systems Initiative. GIF's goal is to develop a fourth generation of advanced, economical, and safe nuclear systems that offer enhanced proliferation-resistance and can be adopted commercially by 2030. Six technologies have been selected as the most promising candidates for future designs, some of which could be commercially ready in the 2020 to 2030 timeframe. GIF countries are jointly preparing a collaborative research program to develop and demonstrate the projects.

ITER[18]: In January 2003, President Bush announced that the U.S. was joining the negotiations for the construction and operation of the international fusion experiment called ITER. ITER is a proposed multilateral collaborative project to design and demonstrate a fusion energy production system. If successful, this multi-year, multi-billion dollar project will advance progress toward determining whether fusion technology can produce clean, abundant, commercially available energy by the middle of the century.

GLOBAL NUCLEAR ENERGY PARTNERSHIP (GNEP)[19]: GNEP has two major goals: (1) expand carbon-free nuclear energy to meet growing electricity demand worldwide; and (2) promote non-proliferation objectives through the leasing of nuclear fuel to countries which agree to forgo enrichment and reprocessing. A more fully closed fuel cycle model envisioned by this partnership requires development and deployment of technologies that enable recycling and consumption of long-lived radioactive waste. The GNEP initiative proposes international partnerships and significant cost-sharing to achieve these goals.

Methane to Markets: The Methane to Markets Partnership is another highly practical major element in the series of international technology partnerships advanced by the Administration. Launched in November 2004, the Methane to Markets Partnership focuses on advancing cost effective, near-term methane recovery and use as a clean energy source from coal beds, natural gas facilities, landfills, and agricultural waste management systems. The Partnership will reduce global methane emissions to enhance economic growth, promote energy security, improve the environment, and reduce greenhouse gas emissions. Other benefits include improving mine safety, reducing waste, and improving local air quality.

CLOSING OBSERVATIONS

The United States, in partnership with others, has embarked on an ambitious undertaking to develop new and advanced climate change technologies that have the potential to transform the

[17] See: http://gen-iv.ne.doe.gov/GENIVintl-gif.asp. GIF member countries include the United States, Argentina, Brazil, Canada, France, Japan, Korea, South Africa, Switzerland, and United Kingdom.
[18] See: http://www.iter.org. ITER members include the United States, China, EU, India, Japan, Russian Federation, and Republic of Korea.
[19] See: http://www.gnep.energy.gov.

economic activities that give rise to greenhouse gas emissions. CCTP's *Strategic Plan* sets out an overall strategy to guide and strengthen our technical efforts to reduce emissions, articulates a vision of the role for advanced technology in addressing climate change, and provides a long-term planning context in which the nature of both the challenges and the opportunities for advanced technologies are illuminated and balanced.

Innovations can be expected to change the ways in which the world produces and uses energy, performs industrial processes, grows crops and livestock, manages carbon dioxide, and uses land. In keeping with U.S. climate change strategy, which is consistent with the United Nations' Framework Convention, these technologies could both enable and facilitate a gradual shift toward significantly lower global greenhouse gas emissions. They would also continue to provide the energy-related and other services needed to spur and sustain economic growth.

References

CCTP 2006—U.S. Climate Change Technology Program, *Strategic Plan*, Chapter 3, "Synthesis Assessment of Long-term Climate Change Technology Scenarios," (Washington, DC: CCTP). Available at: www.climatetechnology.gov.

Chairman TOM DAVIS. Thank you very much.
Mr. Stephenson.

STATEMENT OF JOHN B. STEPHENSON

Mr. STEPHENSON. Mr. Chairman, thank you for inviting GAO to testify today on our report issued last year regarding Federal funding for climate research.

As you know, in 1992 the United States ratified the U.N. Framework Convention on Climate Change, which has as its objective the stabilization of greenhouse gas concentrations in the Earth's atmosphere but does not impose specific goals or timetables forlimiting emissions. Since that time, 14 Federal agencies have provided billions of dollars for climate change activities.

OMB, at the direction of Congress, annually reports on expenditures for these activities in four broad categories: one, science, which includes research and monitoring to better understand climate change; two, technology, which is the subject of today's hearing, which includes the research, development, and deployment of technologies to reduce greenhouse gas emissions or increase energy efficiency; three, international assistance, which helps developing countries to address climate change; and, four, tax expenditures which are Federal income tax provisions that grant preferential tax treatment to encourage emission reductions such as renewable energy uses.

The climate change science program, which is a multi-agency coordination body, also reports on the science portion of these expenditures.

In analyzing overall Federal climate change funding, we found that OMB and CCSP reported that climate change budget authority more than doubled from $2.4 billion in 1993 to $5.1 billion in 2004, with almost all of this increase in terms of real or inflation-adjusted terms occurring in technology; however, it was difficult for us to determine if this was real or a definitional increase because of numerous changes in reporting format from year to year without adequate explanation.

We found that in some cases OMB and/or CCSP added new accounts not previously included and expanded the definitions of some accounts to include more activities. For example, $152 million NASA research program to reduce emissions in aircraft was included for the first time in 2003. In addition, we found that over 50 percent of the increase in technology funding between 2002 and 2003 was the result of DOE expanding the definition of two accounts to include over $500 million in nuclear research. OMB explained this difference by stating that the prior administration did not consider nuclear programs to be part of its activities related to climate change, but that the current administration does, as explained in yesterday's released strategic plan on climate change technology.

Also, the merging of direct research, that specifically for climate change, and indirect research, that research primarily for another purpose with residual benefits in climate change, in the 2002 through 2004 reports in our opinion made the reports more confusing and less useful. For example, this merging, in effect, caused carbon sequestration research, a direct activity, and grants to help low-income families weatherize their homes, an indirect activity, appear in the same technology reporting category at the summary level.

In our report, we, among other things, recommended that OMB and CCSP use the same format for presenting data in its annual reports, explain changes in report content or format when they are introduced, and provide and maintain a crosswalk comparing new and old report structures. OMB and CCSP generally agreed with our recommendations and have tried to incorporate them into this year's climate change expenditure reports.

However, OMB told us during the course of our work that the short time line required by Congress for completing that report within 60 days of the budget submission limits its ability to fully analyze data submitted by agencies. As a result, OMB must rely on funding estimates quickly developed by each agency in order to produce the report within a specified time.

It seemed to us that the fact that we don't yet have a clear explanation and understanding of the Federal Government's $5 billion annual investment climate change portfolio and the fact that it is built from the bottom up instead of the top down is very relevant to the purposes of this hearing. We at GAO are strong proponents of setting goals, measuring performance against those goals, and reporting publicly on progress.

We believe that this framework is the cornerstone of good program management and sound investment decisions. Although we have not formally reviewed either the CCSP or the CCTP strategic plans, we believe that as an implementation of these plans move forward there needs to be clearly articulated relationship between the Government's $5 billion investment portfolio and the goals of both programs. In addition, there needs to be a mechanism to ensure that agency investment decisions directly relate to the goals and priorities expressed in the plans.

Mr. Chairman, that concludes the summary of my statement and I will be happy to answer any questions that you or members of the committees may have.

[The prepared statement of Mr. Stephenson follows:]

United States Government Accountability Office

GAO

Testimony

Before the Committee on Government Reform
House of Representatives

For Release on Delivery
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Thursday, September 21, 2006

CLIMATE CHANGE

Greater Clarity and Consistency Are Needed in Reporting Federal Climate Change Funding

Statement of John B. Stephenson, Director
Natural Resources and Environment

GAO
Accountability * Integrity * Reliability

GAO-06-1122T

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Highlights

Highlights of GAO-06-1122T, testimony before the Committee on Government Reform, House of Representatives

Why GAO Did This Study

The Congress has required annual reports on federal climate change spending. The Office of Management and Budget (OMB) reports funding for: technology (to reduce greenhouse gas emissions), science (to better understand the climate), international assistance (to help developing countries), and tax expenditures (to encourage emissions reduction). The Climate Change Science Program (CCSP), which coordinates many agencies' activities, also reports on science funding.

This testimony is based on GAO's August 2005 report *Climate Change: Federal Reports on Climate Change Should Be Clearer and More Complete* (GAO-05-461). GAO examined federal climate change funding for 1993 through 2004, including (1) how total funding and funding by category changed and whether funding data are comparable over time and (2) how funding by individual agencies changed and whether funding data are comparable over time.

What GAO Recommends

GAO recommended, among other things, that OMB include data on existing climate-related tax expenditures. OMB agreed with most of GAO's recommendations and has implemented most of them. CCSP agreed with all of GAO's recommendations and has begun explaining changes in report format or content when they are introduced.

www.gao.gov/cgi-bin/getrpt?GAO-06-1122T.

To view the full product, including the scope and methodology, click on the link above. For more information, contact John B. Stephenson at (202) 512-3841, or stephensonj@gao.gov.

September 2006

CLIMATE CHANGE

Greater Clarity and Consistency Are Needed in Reporting Federal Climate Change Funding

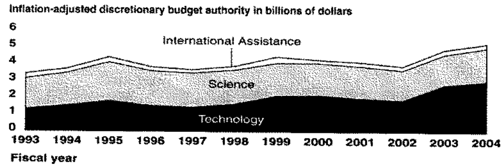
What GAO Found

According to OMB, from 1993 to 2004, federal funding for climate change increased from $3.3 billion to $5.1 billion (55 percent) after adjusting for inflation. During this period, reported inflation-adjusted funding increased for technology and science, but decreased for international assistance. However, it is unclear whether funding changed as much as reported because changes in the format and content of OMB and CCSP reports make it difficult to compare funding data over time. For example, over time, OMB expanded the definitions of some accounts to include more activities, but did not specify how it changed the definitions. OMB officials stated that it is not required to follow a consistent reporting format from year to year. Further, CCSP's science funding reports were difficult to compare over time because CCSP introduced new methods for categorizing funding without explaining how they related to previous methods. The Director of CCSP said that its reports changed as the program evolved. These and other limitations make it difficult to determine actual changes in climate change funding.

Similarly, OMB reported that 12 of the 14 agencies that funded climate change programs in 2004 increased such funding between 1993 and 2004, but unexplained changes in the reports' contents limit the comparability of data on funding by agency. For example, reported funding for the Department of Energy (DOE), the agency with the most reported climate-related funding in 2004, increased from $1.34 billion to $2.52 billion (88 percent) after adjusting for inflation. DOE and the National Aeronautics and Space Administration accounted for 81 percent of the reported increase in funding from 1993 through 2004. However, because agency funding totals are composed of individual accounts, changes in the reports' contents, such as the unexplained addition of accounts to the technology category, make it difficult to compare agencies' funding data over time and, therefore, to determine if this is a real or a definitional increase. Furthermore, GAO found that OMB reported funding for certain agencies in some years but not in others, without explanation. OMB told GAO that it relied on agency budget offices to submit accurate data. These data and reporting limitations make determining agencies' actual levels of climate change funding difficult.

Reported Federal Climate Change Funding by Category, 1993-2004

Inflation-adjusted discretionary budget authority in billions of dollars



Source: GAO analysis of OMB data.

Mr. Chairman and Members of the Committee:

Increases in the earth's average temperature that have already occurred over the last 100 years, combined with additional future increases projected by a consensus of scientists, have the potential to dramatically change life on earth. For example, changes in the frequency and intensity of rainfall, both possible effects of climate change, could affect agriculture and forest health in certain locations. Effects on planetary biodiversity are projected to be even more pronounced. For more than a decade, the federal government has funded programs to study the earth's climate and to reduce emissions of carbon dioxide and other greenhouse gases linked to climate change. According to the Office of Management and Budget (OMB), 9 of the 15 cabinet-level executive departments, along with 5 other federal agencies, received funding for climate change activities in 2004.

In annual reports and testimony before the Congress, OMB reported climate change funding for 1993 through 2004 using the following four categories:

- **Technology**, which includes the research, development, and deployment of technologies and processes to reduce greenhouse gas emissions or increase energy efficiency. Funding for this category focuses on programs for energy conservation, renewable energy, and related efforts.

- **Science**, which includes research and monitoring to better understand climate change, such as measuring changes in forest cover.

- **International assistance**, which helps developing countries to address climate change by, for example, providing funds for energy efficiency programs.

- **Tax expenditures** related to climate change, which are federal income tax provisions that grant preferential tax treatment to encourage emission reductions by, for example, providing tax incentives to promote the use of renewable energy.[1]

[1]The revenue losses resulting from provisions of federal tax laws may, in effect, be viewed as expenditures channeled through the tax system. The Congressional Budget and Impoundment Control Act of 1974, as amended, requires that the budget include the level of tax expenditures under existing law. Like the annual lists of tax expenditures prepared by the Department of the Treasury, this testimony considers only

Over the same time period, the administration also reported annually on funding specifically for climate change science, one of the four categories used in OMB reports. The Climate Change Science Program (CCSP)—a multiagency coordinating group—is currently responsible for preparing the climate change science reports, which duplicate to some extent OMB's science funding reports.

My remarks today are based on our August 2005 report on federal climate change funding from 1993 through 2004[2] and will focus on (1) how total funding and funding by category changed and the extent to which data on such funding are comparable over time and (2) how funding by agency changed and the extent to which data on such funding are comparable over time. We also examined whether OMB reports on climate change funding provided the data required by the Congress. It is important to note that in April 2006, OMB issued its fiscal year 2007 report to the Congress on federal climate change expenditures and has implemented several of GAO's August 2005 recommendations in that report. Likewise, in November 2005, CCSP issued its fiscal year 2006 report to the Congress and has also implemented a GAO recommendation in that report. My testimony today addresses only climate change spending and reporting through fiscal year 2004.

To determine how federal climate change funding by category and agency changed, we analyzed data from annual OMB and CCSP reports, as well as congressional testimony. To determine the extent to which the data on climate change funding were comparable, we analyzed and compared the contents of the reports and interviewed responsible officials. To determine whether OMB and CCSP reports provided the data the Congress required, we reviewed the reporting requirements, the legislative history of these requirements, and the data OMB and CCSP presented in their reports. The term "funding" in this testimony reflects discretionary budget authority, or the authority provided in law to incur financial obligations that will result in outlays, as reported by

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tax expenditures related to individual and corporate income taxes and does not address excise taxes.

[2] U.S. Government Accountability Office, *Climate Change: Federal Reports on Climate Change Funding Should be Clearer and More Complete.* GAO-05-461 (Washington, D.C.: Aug. 25, 2005).

OMB and CCSP in their reports.[3] Unless otherwise stated, we report funding in nominal terms (not adjusted for inflation), and all years refer to fiscal years.[4] This testimony is based on work that was conducted between July 2004 and August 2005 in accordance with generally accepted government auditing standards.

In summary, federal funding for climate change, as reported by OMB, increased from $2.35 billion in 1993 to $5.09 billion in 2004 (116 percent), or from $3.28 billion to $5.09 billion (55 percent) after adjusting for inflation. OMB reports show that, during this period, funding increased for technology and science. CCSP, which reports only science funding, generally presented totals that were consistent with OMB's, but provided more detail. However, changes in reporting methods used by both OMB and CCSP limit the comparability of funding data over time, and therefore it was unclear whether total funding actually increased as much as reported. Furthermore, we were unable to compare changes in the fourth category–climate-related tax expenditures–because OMB reported estimates for proposed but not existing tax expenditures from 1993 to 2004. Specifically, for 1993 through 2004:

- **Technology** funding, as reported by OMB, increased from $845 million to $2.87 billion (239 percent), or from $1.18 billion to $2.87 billion (183 percent) in inflation-adjusted dollars. The share of total climate change funding devoted to technology increased from 36 percent to 56 percent. However, we identified several ways that technology funding presented in OMB's more recent reports may not be comparable to previously reported technology funding. For example, OMB added accounts to the technology category that were not reported before or were presented in different categories, but it did not explain whether these accounts reflected the creation of

[3]An OMB official stated that there is no mandatory budget authority for climate change programs.

[4]When we adjusted for inflation, we used a fiscal year price index that we calculated based on a calendar year price index published by the Department of Commerce's Bureau of Economic Analysis. Unless otherwise specified, figures represent actual funding (not estimates), with the exception of 1993, 1994, and 2004, where we present estimated funding reported by CCSP because actual data are not available. For the purposes of this testimony, the term "agency" includes executive departments and agencies, and we use the term "account" to describe the budget accounts, line items, programs, and activities presented in OMB and CCSP reports. Throughout this testimony, we characterize all climate change science reports from 1993 through 2004 as CCSP reports, even though CCSP has been in existence only since 2002, and reports prior to 2002 were published by a predecessor organization. Totals and percentages may not add due to rounding.

new programs, or a decision to count existing programs for the first time. OMB also expanded the definitions of some accounts to include more activities without clarifying how the definitions were changed. Furthermore, OMB reports include a wide range of federal climate-related programs and activities, some of which–such as scientific research on global environmental change–are explicitly climate change programs, whereas others–such as technology initiatives promoting emissions reduction or encouraging energy conservation–are not solely for climate change purposes.

- **Science** funding increased from $1.31 billion to $1.98 billion (51 percent), according to both OMB and CCSP, or from $1.82 billion to $1.98 billion (9 percent) in inflation-adjusted dollars. However, its share of total climate change funding decreased from 56 percent to 39 percent. OMB and CCSP generally presented consistent climate change science funding totals from 1993 through 2004. CCSP reports also presented more detailed data, but these data were difficult to compare over the entire period because CCSP periodically introduced new categorization methods without explaining how the new methods related to the ones they replaced. Specifically, over the period CCSP used seven different methods to present detailed science funding data, making it impossible to develop consistent funding trends of the entire timeframe.

- **International assistance** funding reported by OMB increased from $201 million to $252 million (25 percent), but decreased from $280 million to $252 million (10 percent) in inflation-adjusted dollars. Moreover, its share of total climate change funding decreased from 9 percent to 5 percent. International assistance funding reported by OMB was generally comparable over time, although several new accounts were added without explanation.

- **Tax expenditures** were not fully reported by OMB for any year, even though climate-related tax expenditures amounted to hundreds of millions of dollars in revenue forgone by the federal government in fiscal year 2004. Although not required to do so, OMB reported *proposed* climate-related tax expenditures. However, OMB did not report revenue loss estimates for *existing* climate change-related tax expenditures. Whereas OMB reported no funding for existing climate change-related tax expenditures in 2004, the federal budget for that year listed four tax expenditures related to climate change in that year, including estimated revenue losses of $330 million for incentives to develop certain renewable energy sources.

OMB and CCSP officials told us that time constraints and other factors contributed to changes in report structure and content over time. For example, OMB officials said that the short timeline for completing the report required by the Congress (within 45 days of submitting the upcoming fiscal year's budget for the three most recent reports) limited OMB's ability to analyze data submitted by agencies. They also noted that they were not directed to use the same report format over time or explain differences in methodology from one report to another. Regarding tax expenditures, OMB officials said that they consistently included in the reports those proposed tax expenditures where a key purpose was specifically to reduce greenhouse gas emissions. They also stated that they had not included existing tax expenditures that may have greenhouse gas benefits but were enacted for other purposes, and that the Congress had not provided any guidance to suggest that additional tax expenditure data should be included in the annual reports. However, in response to a recommendation we made in our 2005 report, OMB in its fiscal year 2007 report to the Congress included existing tax expenditures that could contribute to reducing greenhouse gases. Because of these and other limitations, determining actual changes in federal climate change funding is difficult.

OMB reported that 12 of the 14 agencies receiving funding for climate change programs in 2004 received more funding in that year than they had in 1993, but it is unclear whether funding changed as much as OMB reported because unexplained changes in what was defined as climate change funding. Reported funding for the Department of Energy (DOE), the agency with the most reported climate-related funding in 2004, increased from $963 million to $2.52 billion (162 percent), or from $1.34 billion to $2.52 billion (88 percent) after adjusting for inflation. DOE and the National Aeronautics and Space Administration (NASA) accounted for 81 percent of the reported increase in funding from 1993 through 2004. However, because agency funding totals are composed of individual accounts, the changes in the reports' contents discussed earlier, such as the unexplained addition of accounts to the technology category, limit the comparability of agencies' funding data over time, making it difficult to determine if these are real or definitional increases.

We found that OMB reports presented information on budget authority, not—as required by the Congress–on expenditures. The Congress has required that information be provided on expenditures and obligations, the amounts actually spent or committed to be spent, while OMB reports generally have presented information on a different measure, budget authority, or the amount of funding provided by the Congress. OMB officials told us that they adopted their approach because the relevant congressional committees generally use budget authority. They told us that they reported on this basis because these committees have not objected to OMB's approach.

We recommended that OMB and CCSP, from year-to-year, use the same format for presenting data, explain changes in report content or format when they are introduced, and provide and maintain a crosswalk comparing new and old report structures when changes in report format are introduced. We also recommended that OMB include data on existing climate-related tax expenditures in future reports. Finally, we recommended that OMB request that the Congress clarify whether future reports should be presented in terms of expenditures and obligations or in terms of budget authority, and if the Congress prefers the former, OMB should request the necessary time to prepare reports on that basis.

We received oral comments from OMB on August 1, 2005, and written comments from CCSP in a letter dated July 28, 2005. OMB agreed with the recommendations relating to report content and format and said it was studying the other recommendations. CCSP agreed with all of our recommendations.

After our report was issued in August 2005, OMB released its fiscal year 2007 report to Congress on climate change expenditures. Several of our recommendations were implemented in that report. For example, OMB included data on existing climate-related expenditures. OMB also labeled its tables for the major types of funding with respect to fiscal year and budgetary metric (actual budget authority, enacted budget authority, obligations, outlays, and proposed budget authority). CCSP has implemented our recommendation about explaining changes in report content or format.

Background

In 1990, the Congress enacted the Global Change Research Act.[5] This act, among other things, required the administration to (1) prepare and at least every 3 years revise and submit to the Congress a national global change research plan, including an estimate of federal funding for global change research activities to be conducted under the plan; (2) in each annual budget submission to the Congress, identify the items in each agency's budget that are elements of the United States Global Change Research Program (USGCRP), an interagency long-term climate change science research program; and (3) report annually on climate change "expenditures required" for the USGCRP.[6] In 1992, the United States signed and ratified the United Nations Framework Convention on Climate Change, which was intended to stabilize the buildup of greenhouse gases in the earth's atmosphere, but did not impose binding limits on emissions.

In response to the requirements of the 1990 act, the administration reported annually from 1990 through 2004 on funding for climate change science in reports titled *Our Changing Planet*.[7] From 1990 through 2001, the reports presented detailed science funding data for the USGCRP. Federal climate change science programs were reorganized in 2001 and 2002. In 2001, the Climate Change Research Initiative (CCRI) was created to coordinate short-term climate change research focused on reducing uncertainty, and in 2002, CCSP was created to coordinate and integrate USGCRP and CCRI activities. CCSP is a collaborative interagency program designed to improve the government wide management of climate science and research. Since 2002, CCSP has been responsible for meeting the reporting requirement and has published the *Our*

[5]Pub. L. No. 101-606, 104 Stat. 3096 (1990) (partially terminated pursuant to the Federal Reports Elimination and Sunset Act of 1995, Pub. L. No. 104-66, § 3003 (1995)).

[6]The annual reporting requirement for climate change expenditures was terminated effective May 15, 2000. The reporting requirement had called for "(A) the amounts spent during the fiscal year most recently ended; (B) the amounts expected to be spent during the current fiscal year; and (C) the amounts requested for the fiscal year for which the budget is being submitted."

[7]To maintain consistency with OMB data, which are available from 1993 to 2004, we reviewed reported science funding from 1993 to 2004.

Changing Planet reports. The most recent report in this series was published in November 2005.

The Climate Change Technology Program (CCTP) is a multiagency technology research and development coordinating structure similar to CCSP. Its overall goal is to attain, on a global scale and in partnership with other entities, a technological capability that can provide abundant, clean, secure, and affordable energy and related services needed to encourage and sustain economic growth, while achieving substantial reductions in emissions of greenhouse gases and mitigating the risks of potential climate change.

In March 1998, OMB, in response to a congressional requirement for a detailed account of climate change expenditures and obligations, issued a brief report summarizing federal agency programs related to global climate change. OMB produced another climate change expenditures report in March 1999 and, in response to a request at a 1999 hearing, OMB provided climate change funding data for 1993 through 1998 for the hearing record. Each year since 1999, the Congress has included a provision in annual appropriations laws requiring OMB to report in detail all federal agency obligations and expenditures, domestic and international, for climate change programs and activities. As a result of these reporting requirements, OMB annually publishes the *Federal Climate Change Expenditures Report to Congress*, which presents federal climate change funding for the technology, science, and international assistance categories, and tax expenditures. The climate change activities and associated costs presented in OMB reports must be identified by line item as presented in the President's budget appendix. OMB has interpreted this to mean that the data in the reports must be shown by budget account. For the last 3 years for which we reviewed data, the Congress had required that the administration produce reports for climate change expenditures and obligations for the current fiscal year within 45 days after the submission of the President's budget request for the upcoming fiscal year. OMB's most recent report was released in April 2006.

OMB reports include a wide range of federal climate-related programs and activities. Some activities, like scientific research on global environmental change by USGCRP, are explicitly climate change programs, whereas others, such as many technology initiatives, are not solely for climate change purposes. For example, OMB reports included some programs that were started after the United States ratified the Framework Convention in 1992 and were specifically designed to encourage businesses and others to reduce their greenhouse gas emissions, for example, by installing more efficient lighting. OMB reports also included programs that were expanded or initiated in the wake of the 1973 oil embargo to support such activities as energy conservation (to use energy more efficiently), renewable energy (to substitute for fossil fuels), and fossil energy (to make more efficient use of fossil fuels), all of which can help to reduce greenhouse gas emissions, but were not initially developed as climate change programs.

Reported Federal Climate Change Funding Increased for Three of the Four Funding Categories, but Data May Not Be Comparable Over Time

Federal climate change funding, as reported by OMB, increased from $2.35 billion in 1993 to $5.09 billion in 2004 (116 percent), or from $3.28 billion to $5.09 billion (55 percent) after adjusting for inflation. Funding also increased for technology, science, and international assistance between 1993 and 2004, as shown in table 1. However, changes in reporting methods have limited the comparability of funding data over time; therefore it is unclear whether funding increased as much as reported by OMB.[8] OMB did not report estimates for existing climate-related tax expenditures during this period, although climate-related tax expenditures amounted to hundreds of millions of dollars in revenue forgone by the federal government in fiscal year 2004. OMB officials told us that changes in reporting methods were due to such reasons as the short amount of time available to prepare the report, the fact that the reporting requirement is not permanent law, but appears each year in their appropriations legislation, and changes in administration policy and priorities. As a result of our recommendations, however, OMB made changes in its report on climate change funding for fiscal year 2007, which was published in April 2006. For example, OMB more clearly labeled data throughout the report and added information on existing tax provisions that can contribute to reducing greenhouse gas emissions.

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[8]Technology funding increased as a share of total funding over time, while science and international assistance funding declined as shares of the total because technology funding increased at a faster rate than the other categories.

Table 1: Reported Federal Climate Change Funding by Category, Selected Years

Discretionary budget authority in millions of dollars

Category	1993	1997	2001	2004
Technology	$845	$1,056	$1,675	$2,868
Science	1,306	1,656	1,728	1,976
International assistance	201	164	218	252
Tax expenditures	[a]	[a]	[a]	[a]
Total	**$2,352**	**$2,876**	**$3,603**	**$5,090**

Source: GAO analysis of OMB data.
aOMB did not report revenue loss estimates for existing climate-related tax expenditures for this year.

Technology

From 1993 through 2004, technology funding increased as a share of total federal climate funding from 36 percent to 56 percent, as reported by OMB. Over this period, technology funding increased from $845 million to $2.87 billion (239 percent), or adjusted for inflation, from $1.18 billion to $2.87 billion (143 percent). For example, funding for energy conservation increased from $346 million to $868 million, and funding for renewable energy increased from $249 million to $352 million. Table 2 presents funding data for selected years for the seven largest accounts, which accounted for 92 percent of technology funding in 2004.

Table 2: Reported Technology Funding for Selected Accounts and Years

Discretionary budget authority in millions of dollars

Agency	Account	1993	1997	2001	2004
Department of Energy	Energy Conservation	$346	$414	$810	$868
	Energy Supply -- Fossil Energy Research and Development (R&D)	250	201	292	455
	Energy Supply --Renewable Energy	249	244	370	352
	Science (Fusion, Sequestration, and Hydrogen) [a]	[b]	[b]	35	333
	Energy Supply – Nuclear [c]	[b]	[b]	39	309
National Aeronautics and Space Administration	Exploration, Science, and Aeronautics	[b]	[b]	[b]	227
Environmental Protection Agency	Environmental Programs and Management	[b]	70	96	89
Other		[b]	127	33	235
Total		**$845**	**$1,056**	**$1,675**	**$2,868**

Source: GAO analysis of OMB data.

aSequestration can be defined as the capture and isolation of gases that otherwise could contribute to global climate change.

bOMB did not report a value in the technology category for this account for this year.

cFor 2001 Energy Supply -- Nuclear funding, we counted the Nuclear Energy Research Initiative and Energy Supply -- Nuclear budget accounts as presented by OMB. OMB did not separately present these accounts for 2004, and included funding for the Nuclear Energy Research Initiative within the Energy Supply--Nuclear account.

We identified three ways that the data on technology funding presented in three of OMB's recent reports may not be comparable to the data presented in previous reports. First, OMB added accounts that were not previously presented. For example, OMB reported that NASA had $152 million in funding for technology-related activities, which included research to reduce emissions associated with aircraft operations in 2003. OMB did not report this account in the technology category in 2002. In addition, OMB included and removed some accounts, without explanation, from reports in years other than 2003. For example, OMB reported combined funding of $195 million in 1999, and $200 million in 2000, for bio-based products and bio-energy at the Departments of Energy and of Agriculture. No funding for these accounts was reported from 1993 through 1998 or from 2001 through 2004. In each of these cases, OMB did not explain whether the new accounts reflected the creation of new programs, a decision to count an existing program for the first time, or a decision to re-classify funding from different categories as technology funding.

According to OMB officials, these changes in report structure and content for technology funding, as well as similar changes in science and international assistance funding, were the result of time constraints and other factors. They told us that the short timeline required by the Congress for completing the report (within 45 days of submitting the upcoming year's budget) limited OMB's ability to analyze data submitted by agencies. They said that they must rely on funding estimates quickly developed by agencies in order to produce the report within the specified timeframe, and that the reports are often compilations of agency activities and programs, some of which may or may not have been presented separately in prior years. Moreover, these officials told us that the presentation of data has changed over time for a variety of reasons other than short time limits, including changes in administration priorities and policy, changes in congressional direction, changes to budget and account structures, and attempts to more accurately reflect the reporting requirement as specified in the annual appropriations language. The officials also stated that in each report they ensured consistency for the 3 years covered (prior year, current year, and budget year).

Furthermore, OMB officials told us that the presentation of new accounts in the technology category, as well as the international assistance category, was due to the establishment of new programs and the inclusion of existing programs. They told us that the account-by-account display in the reports has been changed over time as the CCSP and the Climate Change Technology Program (CCTP), a multiagency technology research and development coordinating structure similar to the CCSP, have become better defined.

Second, OMB reported that it expanded the definitions of some accounts to include more activities but did not specify how the definitions were changed. We found that over 50 percent of the increase in technology funding from 2002 to 2003 was due to increases in two existing DOE accounts: nuclear energy supply and science (fusion, sequestration, and hydrogen). OMB reported funding of $32 million in 2002 and $257 million in 2003, for the nuclear energy supply account[9] and reported funding of $35 million in 2002, and $298 million in 2003, for the science (fusion, sequestration, and hydrogen) account. Although OMB stated in its May 2004 report that 2003 funding data included more

[9]We counted the Nuclear Energy Research Initiative (NERI) account as Nuclear Energy Supply funding for 2002. The NERI line item is counted in the aggregate Energy Supply – Nuclear budget account in OMB's 2004 and 2005 reports, and is no longer presented separately.

activities within certain accounts, including the research and development of nuclear and fusion energy, the report was unclear about whether the funding increases for these two existing accounts were due to the addition of more programs to the accounts or increased funding for existing programs already counted in the accounts. Finally, if new programs were counted in these accounts, OMB did not specify what programs were added and why.

OMB officials told us that the definitions of some accounts were changed to include more nuclear programs because, while the prior administration did not consider nuclear programs to be part of its activities relating to climate change, the current administration does consider them to be a key part of the CCTP.

Third, OMB did not maintain the distinction that it had made in previous reports between funding for programs whose primary focus is climate change and programs where climate change is not the primary focus. As a result, certain accounts in the technology category were consolidated into larger accounts. From 1993 through 2001, OMB presented funding data as directly or indirectly related to climate change. The former programs are those for which climate change is a primary purpose, such as renewable energy research and development. The latter are programs that have another primary purpose, but which also support climate change goals. For example, grants to help low-income people weatherize their dwellings are intended primarily to reduce heating costs, but may also help reduce the consumption of fossil fuels. OMB did not maintain the distinction between the two kinds of programs for 2002, 2003, and 2004 funding data. For example, OMB presented energy conservation funding of $810 million in 2001, including $619 million in direct research and development funding, and $191 million in indirect funding for weatherization and state energy grants. In contrast, 2002 funding data presented by OMB reflected energy conservation funding of $897 million, including $622 million in research and development, $230 million for weatherization, and $45 million for state energy grants, but did not distinguish between direct and indirect funding. OMB presented energy conservation funding of $880 million in 2003 and $868 million in 2004 as single accounts without any additional detail.

OMB officials stated that they had adopted a different approach to reporting climate change funding to reflect the new program structures as the CCSP and CCTP were being established. They stated that the result was, in some cases, an aggregation of activities that may have previously been reported on separate accounts. According to the officials, the 2003 and 2004 data more accurately reflect the range of climate change-related programs as they are now organized. OMB included a crosswalk in its May 2004 report that showed 2003 funding levels as they would have been presented using the methodology of previous reports. While the crosswalk identified funding for accounts that were presented in previous reports, it did not identify new funding reported by OMB or specify whether such funding was the result of counting new programs, a decision to start counting existing programs as climate change-related, or shifts between categories. OMB officials told us that the reporting methodology has changed since the initial reports and that it may be difficult to resolve the differences because of changes in budget and account structure. Finally, they noted that each report has been prepared in response to a one-time requirement and that there has been no requirement for a consistent reporting format from one year to the next or for explaining differences in methodology from one report to another. However, in its fiscal year 2007 report to the Congress, OMB responded to our recommendations by labeling the data more clearly and reporting changes were footnoted.

<u>Science</u>

According to both OMB and CCSP, the share of total climate change funding devoted to science decreased from 56 percent in 1993 to 39 percent in 2004, even though science funding increased from $1.31 billion to $1.98 billion (51 percent), or from $1.82 billion to $1.98 billion (9 percent) after adjusting for inflation. For example, according to OMB, funding for NASA on activities such as the satellite measurement of atmospheric ozone concentrations increased from $888 million to $1.26 billion.[10]

OMB reported new science funding for 2003 and 2004 to reflect the creation of CCRI. Funding for CCRI increased from $41 million in 2003, the first year funding for CCRI was

[10]The $1.26 billion includes NASA's reported funding for the United States Global Change Research Program. NASA funding for CCRI is reported separately.

presented, to $173 million in 2004, and included funding by most of the agencies presented in table 3. We present funding for CCRI as a separate program to illustrate the new organization's role in increasing reported climate change funding. Table 3 presents funding as reported by OMB for the eight largest agencies and programs in the science category, which accounted for 99 percent of the science total for 2004.

Table 3: Reported Science Funding by Agency or Program for Selected Years

Discretionary budget authority in millions of dollars

Agency or program	Account	1993	1997	2001	2004
NASA [a]	Science, Aeronautics, and Technology	$888	$1,218	$1,176	$1,256
National Science Foundation	Research and Related Activities	124	166	181	185
CCRI	Various accounts for eight agencies	[b]	[b]	[b]	173
DOE	Science (Biological and Environmental Research)	118	109	116	102
Department of Commerce - National Oceanic and Atmospheric Administration	Operations, Research, and Facilities	66	60	93	82
Department of Agriculture	Agriculture Research Service and four other accounts	55	57	51	64
Department of Health and Human Services	National Institutes of Health (NIH)	[b]	[b]	54	62
Department of Interior – U.S. Geological Survey	Surveys and Research	22	26	27	28
Other		33	20	30	24
Total		**$1,306**	**$1,656**	**$1,728**	**$1,976**

Source: GAO analysis of OMB data.

Note: OMB generally presented climate science funding with one account per agency.

aBeginning in 2004, NASA funding reflects full-cost accounting, meaning institutional activities such as personnel and facilities (which had been held in separate accounts) are included. NASA's climate change funding varies based on changes in its budget for space-observing platforms, the natural development cycle of its satellites, and revisions to mission profiles.

bOMB did not report a value in the science category for this agency or program for this year.

Science funding data from 1993 through 2004, as reported by OMB and CCSP, were generally comparable, although there were more discrepancies in earlier years than in later years.[11] Science funding totals reported by CCSP from 1993 through 1997 were within 3 percent of the OMB totals for all years except 1996 and 1997. Science funding totals reported by CCSP in 1996 and 1997 were $156 million (9 percent) and $162 million (10 percent) higher than those reported by OMB. Over 90 percent of the difference for those years occurred because CCSP reported greater funding for NASA than OMB reported. CCSP stated in its fiscal year 1998 report that it increased its 1996 and 1997

[11]CCSP's most recent report (July 2004) presents estimated 2004 funding, whereas OMB's most recent report (March 2005) presents actual 2004 funding. Whenever we compare 2004 science funding as

budget figures to reflect the reclassification of certain programs and activities in some agencies that were not previously included in the science funding total.

Total science funding reported by OMB and CCSP from 1998 through 2004 was identical for 4 of the 7 years. The largest difference for the 3 years that were not identical was $8 million in 2001, which represented less than 1 percent of the science funding total reported by OMB for that year. The other differences in total science funding were $3 million in 2002, and $1 million in 1999, and each represented less than 1 percent of the OMB science total for those years.

Science funding by agency, as presented by OMB and CCSP from 1993 through 1997, differed in many cases, with the exception of funding for the National Science Foundation (NSF), which was nearly identical over that time period. For example, CCSP reported $143 million more funding for NASA in 1996 than OMB reported, and OMB reported $24.9 million more funding for DOE in 1994 than CCSP reported. The greatest dollar difference related to NASA's funding in 1997. Whereas OMB reported funding of $1.22 billion, CCSP reported funding of $1.37 billion–$151 million, or 12 percent more than the OMB amount. The greatest percentage difference related to the Department of the Interior's funding in 1993. Whereas OMB reported funding of $22 million, CCSP reported funding of $37.7 million–$15.7 million, or 71 percent more than reported by OMB. Further, from 1993 through 1997, OMB did not report science funding by some agencies that were reported by CCSP. For example, CCSP reported that DOD's funding ranged from $5.7 million to $6.6 million from 1993 through 1995, and that the Tennessee Valley Authority received funding of $1 million or less per year from 1993 through 1997, but OMB did not report any such funding.

OMB officials told us that data used for the 1993 to 1997 science funding comparison with CCSP were collected too long ago to be able to identify the differences. However, they stated that the data from early years were produced in a very short period for use in testimony or questions for the record. According to OMB, this quick turnaround did not allow time for a thorough consistency check with other data sources.

reported by OMB and CCSP, we are comparing estimated 2004 funding presented in OMB's May 2004 report and CCSP's July 2004 report.

From 1998 through 2004, OMB and CCSP data on funding by agency were nearly identical. Both OMB and CCSP reported science funding for nine agencies over the entire 7-year period, for a total of 63 agency funding amounts. Of these, 52, or 83 percent, matched exactly. Of the 11 differences, there was one difference of $8 million, one of $2 million, and nine of $1 million or less. The greatest difference from 1998 through 2004 was $8 million in funding for the Department of Commerce in 2001, which was 9 percent of the Department of Commerce total, or less than 1 percent of total science funding as reported by OMB for that year.

The director of CCSP told us that changes to reports, such as the creation and deletion of different categorization methods, were made because CCSP is changing towards a goals-oriented budget, and that categorization methods changed as the program evolved. The director also said that future reports will explicitly present budget data as they were reported in prior reports to retain continuity, even if new methods are introduced. Another CCSP official told us that CCSP now works with OMB to ensure that consistent funding information is presented in *Our Changing Planet* reports and OMB reports, and that, beginning with the fiscal year 2006 report (which was published in late 2005), CCSP would attempt to explain when and why changes are made to reporting methods. In its 2006 fiscal year report, CCSP did explain changes to its reporting.

International Assistance

From 1993 through 2004, international assistance funding decreased from 9 percent to 5 percent of total federal funding on climate change, as reported by OMB. Over the same time period, international assistance funding increased from $201 million to $252 million (an increase of 25 percent), but after adjusting for inflation, decreased from $280 million to $252 million (a decrease of 10 percent). For example, reported funding for the Department of the Treasury to help developing countries invest in energy efficiency, renewable energy, and the development of clean energy technologies, such as fuel cells, increased from zero in 1993 to $32 million in 2004. Table 4 presents funding as reported by OMB for the three largest accounts in the international assistance category.

Table 4: Reported International Assistance Funding for Selected Accounts and Years

Discretionary budget authority in millions of dollars

Agency	Account	1993	1997	2001	2004
U.S. Agency for International Development (USAID)	Development Assistance	$200	$147	$112	$125
	Assistance for the Independent States of the Former Soviet Union	b	b	31	47
Department of the Treasury	Global Environment Facility[a]	b	14	41	32
Other		1	3	34	48
Total		**$201**	**$164**	**$218**	**$252**

Source: GAO analysis of OMB data.
aOMB did not include the Department of the Treasury's funding for the Global Environment Facility (GEF) in the international assistance category from 1994 through 2001. OMB presented GEF funding in the international assistance category from 2002 through 2004. To maintain consistency, we included GEF funding in the international assistance category from 1994 through 2004 for the purposes of this testimony.
bOMB did not report a value in the international assistance category for this account for this year.

International assistance funding reported by OMB was generally comparable over time, although some new accounts were added without explanation. In its reports, OMB did not provide an explanation of whether such new accounts reflected the creation of new programs or a decision to count existing programs as climate change-related for the first time. OMB officials told us that the presentation of new accounts in the international assistance category was due to the establishment of new programs and the inclusion of existing programs. They told us that the account-by-account display in the reports has been changed over time as climate change programs have become better defined.

Tax Expenditures

Although not required to provide information on tax expenditures related to climate change, OMB reported certain information related to climate-related tax expenditures for each year. Specifically, it listed *proposed* climate-related tax expenditures appearing in the President's budget, but it did not report revenue loss estimates for *existing* climate-related tax expenditures from 1993 through 2004. Based on the Department of the Treasury's tax expenditure list published in the 2006 budget,[12] we identified four existing tax expenditures that have purposes similar to programs reported by OMB in its climate

[12]The Department of the Treasury reported 2004 tax expenditures in the *Budget of the U.S. Government, Fiscal Year 2006* edition, Analytical Perspectives volume, chapter 19.

change reports. In 2004, estimated revenue losses amounted to hundreds of millions of dollars for the following tax expenditures:[13]

- $330 million in revenue losses was estimated for new technology tax credits to reduce the cost of generating electricity from renewable resources. A credit of 10 percent was available for investment in solar and geothermal energy facilities. In addition, a credit of 1.5 cents was available per kilowatt hour of electricity produced from renewable resources such as biomass, poultry waste, and wind facilities.

- $100 million in revenue losses was estimated for excluded interest on energy facility bonds to reduce the cost of investing in certain hydroelectric and solid waste disposal facilities. The interest earned on state and local bonds used to finance the construction of certain hydroelectric generating facilities was tax exempt. Some solid waste disposal facilities that produced electricity also qualified for this exemption.

- $100 million in revenue losses was estimated for excluded income from conservation subsidies provided by public utilities to reduce the cost of purchasing energy-efficient technologies. Residential utility customers could exclude from their taxable income energy conservation subsidies provided by public utilities. Customers could exclude subsidies used for installing or modifying certain equipment that reduced energy consumption or improved the management of energy demand.

- $70 million in revenue losses was estimated for tax incentives for the purchase of clean fueled vehicles to reduce automobile emissions. A tax credit of 10 percent, not to exceed $4,000, was available to purchasers of electric vehicles. Purchasers of vehicles powered by compressed natural gas, hydrogen, alcohol, and other clean fuels could deduct up to $50,000 of the vehicle purchase costs from their taxable income, depending upon the weight and cost of the vehicle. Similarly, owners of

[13]The Department of the Treasury calculated each tax expenditure estimate assuming other parts of the tax code remained unchanged. Because tax provisions can be interdependent, we do not report the mathematical sum of the revenue losses estimated for the four climate-related tax expenditures, and instead present this general gauge of the magnitude of revenue forgone for climate-related tax expenditures.

refueling properties could deduct up to $100,000 for the purchase of re-fueling equipment for clean fueled vehicles.

OMB officials said that they consistently reported proposed tax expenditures where a key purpose was specifically to reduce greenhouse gas emissions. They also stated that they did not include existing tax expenditures that may have greenhouse gas benefits but were enacted for other purposes, and that the Congress had provided no guidance to suggest additional tax expenditure data should be included in the annual reports.

OMB's decision criteria for determining which tax expenditures to include differed in two key respects from its criteria for determining which accounts to include. First, OMB presented funding for existing as well as proposed accounts, but presented information only on proposed, but not existing, tax expenditures. Second, OMB presented funding for programs where a key purpose was specifically to reduce greenhouse gas emissions, as well as for programs that may have greenhouse gas benefits but were enacted for other purposes. However, OMB presented information only on proposed tax expenditures where a key purpose was specifically to reduce greenhouse gas emissions. In response to GAO's recommendation to report existing climate-related tax expenditures, OMB's fiscal year 2007 report to the Congress includes existing tax expenditures that contribute to reducing global warming.

Reported Funding for Most Agencies Increased, but Unexplained Changes in Report Content Limit the Comparability of Data Over Time

OMB reported that 12 of the 14 agencies that received funding for climate change programs in 2004 received more funding in that year than they had in 1993. However, it is unclear whether funding changed as much as reported by OMB because unexplained modifications in the reports' contents limit the comparability of agencies' funding data. From 1993 through 2004, climate change funding for DOE increased more than any other agency, from $963 million to $2.52 billion, for an increase of $1.56 billion (162 percent). Adjusted for inflation, such funding increased from $1.34 billion to $2.52 billion, for an increase of $1.18 billion (88 percent). The second largest increase in agency funding was for NASA, which received a $660 million (74 percent) increase in funding over the same time period. NASA's funding increased $310 million (25 percent) over this period after adjusting for inflation. The funding increases for these two agencies accounted for 81 percent of the reported total increase in federal climate change funding from 1993 through 2004. Conversely, USAID experienced the largest decrease in funding—from $200 million in 1993 to $195 million in 2004 (3 percent), or, in inflation-adjusted terms, from $279 million to $195 million (30 percent). Table 5 shows OMB's reports on climate change funding by agency for selected years.

Table 5: Reported Climate Change Funding by Agency, Selected Years

Discretionary budget authority in millions of dollars

Agency	1993	1997	2001	2004
DOE	$963	$968	$1,665	$2,519
NASA	888	1,218	1,176	1,548
NSF	124	222	181	226
USAID	200	147	157	195
Department of Commerce	66	102	93	144
EPA	26	99	146	127
Department of Agriculture	55	57	54	115
Other	30	63	131	216
Total	**$2,352**	**$2,876**	**$3,603**	**$5,090**

Source: GAO analysis of OMB data.

Unexplained changes in the content of OMB reports make it difficult to determine whether funding changed as much as was reported by OMB. Because agency funding totals are composed of individual accounts, the changes in the reports' contents discussed earlier, such as the unexplained addition of accounts to the technology category, limit the comparability of agencies' funding data over time. For example, OMB reported Army, Navy, Air Force, and Defense-wide funding totaling $83 million in 2003, and $51 million in 2004, in accounts titled Research, Development, Test, and Evaluation, but did not report these accounts for prior years. OMB did not explain whether these accounts reflected the creation of new programs or a decision to count existing programs for the first time.

OMB officials told us that agencies can be included in reports for the first time when new initiatives or programs are started, such as the CCTP. In some cases, those initiatives or programs are made up of entirely new funding but in other cases they may be additions on top of a small amount of base funding. These officials told us that agencies sometimes include data that were not previously reported when they requested funding for those initiatives, but they assured us that the data are reported consistently for the 3 years presented in each report.

OMB Reports Presented Information on Budget Authority Rather Than—as Required by the Congress—on Expenditures and Obligations

The federal budget process is complex, and there are numerous steps that culminate in the outlay of federal funds. Among the key steps in this process are the following, as defined by OMB:

- **Budget authority** means the authority provided in law to incur financial obligations that will result in outlays.
- **Obligations** are binding agreements that will result in outlays, immediately or in the future.
- **Expenditures** are payments to liquidate an obligation. The Congress, in the Congressional Budget and Impoundment Control Act of 1974, as amended, has defined outlays as being the expenditures and net lending of funds under budget authority.

In simplified terms, budget authority precedes obligations, which precede outlays in the process of spending federal funds.

As noted above, since 1999, the Congress has required the President to submit a report each year to the Senate and House Committees on Appropriations describing in detail all federal agency obligations and expenditures, domestic and international, for climate change programs and activities. In response, OMB had annually published the *Federal Climate Change Expenditures Report to Congress* which presented budget authority information in summary data tables instead of obligations and expenditures, as the title of the report and the table titles suggested. The only indication that the table presented budget authority information, rather than expenditures, was a parenthetical statement to that effect in a significantly smaller font.

OMB officials told us that the term "expenditures" was used in the report title and text because that was the term used most often in the legislative language. They also said that the reports presented data in terms of budget authority because OMB hads always interpreted the bill and report language to request the budget authority levels for each activity in a particular year. They stated further that, from a technical budget standpoint, expenditures are usually synonymous with outlays, and that one way to think of budget authority is that it is the level of expenditures (over a period of 1 or more years) that is made available in a particular appropriations bill. OMB viewed this as an appropriate interpretation of the congressional requirements since the committees on appropriations work with budget authority and not outlays. Moreover, OMB told us that these committees had never objected to its interpretation of "obligations and expenditures" as budget authority and that OMB had always identified the data provided in the table as budget authority.

In our August 2005 report, we expressed several concerns with OMB's approach. First, OMB's approach of reporting budget authority did not comply with the language of the annual legal requirements to report on climate change "obligations and expenditures." Second, in reviewing the legislative history of these reporting requirements, we found no support for OMB's interpretation that when the Congress called for "obligations and expenditures" information, it actually meant "budget authority" information. Third, OMB's interpretation was not consistent with its own Circular A-11, which defines budget authority as stated above, not actual obligations and expenditures. Nonetheless, we recognize that it is not possible for OMB to meet the most recent reporting requirements because it must provide a report on climate change obligations and expenditures for the current fiscal year within 45 days of submitting the President's budget for the following fiscal year (which must be submitted the first Monday of February). For example, the President submitted the fiscal year 2006 budget on February 7, 2005, so OMB's report on fiscal year 2005 climate change expenditures and obligations had to be submitted in March 2005—approximately halfway through the 2005 fiscal year. However, complete expenditures data are available only after the end of each fiscal year. Thus, OMB could not meet both the timing requirement and report all actual expenditures and obligations in fiscal year 2005.

CCSP has also reported budget authority data in its *Our Changing Planet* reports. As noted above, CCSP, or its predecessor organization, initially was required to report annually on certain climate change "amounts spent," "amounts expected to be spent," and "amounts requested," but this reporting requirement was terminated in 2000. Currently, CCSP is responsible for reporting information relating to the federal budget and federal funding for climate change science, not climate change expenditure information. Since 2000, CCSP has fulfilled these reporting requirements by providing budget authority information in its *Our Changing Planet* reports.

Conclusions

In conclusion, we found that the lack of clarity in OMB's and CCSP's reports made it difficult to comprehensively understand the federal government's climate change expenditures. A better understanding of these expenditures is needed before it is possible to assess CCSP's and other federal agencies' progress towards their climate change goals. We therefore made seven recommendations to OMB and three to CCSP to clarify how they present climate change funding information. OMB agreed with most of our recommendations and has also implemented most of them. CCSP agreed with all of our recommendations and has implemented our recommendation about explaining changes in report content or format.

Mr. Chairman, this concludes my prepared statement. I would be pleased to respond to any question you or other Members of the Committee may have.

Contact and Staff Acknowledgments

For further information regarding this testimony, please contact me at (202) 512-3841. John Healey, Anne K. Johnson, and Vincent P. Price made key contributions to this testimony. Richard Johnson, Carol Kolarik, Carol Herrnstadt Shulman, and Anne Stevens also made important contributions.

(360764)

Chairman TOM DAVIS. Let me start quickly. What I will do is get to questions, Mr. Waxman, and then we are going to have to recess to go over for three votes.

Mr. Eule, the Federal Government spends about $3 billion on climate change technology research. Isn't that about it? Which I might add is the same amount of money that British business mogul Richard Branson on Thursday announced, $3 billion that he was going to put in personally to combat global warming over the next decade. But does CCTP play any role in determining how those funds are used?

Mr. EULE. Thank you, Mr. Chairman. Yes, good question. We have set up a process in the strategic plan. We have a process in the strategic plan and some mechanisms to do that. CCTP has a series of working groups, each of which is matched to one of the strategic goals in the plan, so we have a working group on reducing emissions and—

Chairman TOM DAVIS. So you are advisory, but you play a role? Is that it?

Mr. EULE. We are advisory. We have working groups that are the people that actually have influence on agency budgets. We also have outside experts come in and provide advice. And we also work through the management structure that the administration set up through the Cabinet-level committee on climate change science and technology integration and, more directly, through the box under that we call the blue box, which is the deputy level structure.

Chairman TOM DAVIS. But the plan that was released yesterday does not provide clear criteria for determining which program to fund, when to fund them, or how much funding to provide; isn't that right?

Mr. EULE. It provides a process to do that.

Chairman TOM DAVIS. Right. Not a plan, but a process. Who has the ultimate power to determine that?

Mr. EULE. The agency—

Chairman TOM DAVIS. You have a process, but ultimately who has the say-so? I mean, you get input into it, but CCTP is not the ultimate decisionmaker, right?

Mr. EULE. No, CCTP isn't designed to be the ultimate arbitrator; it is designed to coordinate and to help prioritize the budgets that the agencies produce, with input, obviously, from the Executive Office of the President.

Chairman TOM DAVIS. Do you think it would be helpful to have like an ARPA for climate change?

Mr. EULE. Well, I think the Department's position on ARPA is clear. We think it would take funds away from other programs. But I think in the case of climate change what you have to consider is that climate change isn't just about energy. Energy is a big part of that, obviously. About four-fifths of all greenhouse gas emissions are energy related. But there are other aspects of climate change technology, and expertise is in other agencies. For example, our expertise on non-CO_2 gas is at the Environmental Protection Agency. Our expertise on measuring and monitoring is in NASA. Basic research, Department of Energy.

Chairman TOM DAVIS. I guess the ultimate question is, on an issue of this magnitude are we better off having this expertise dispersed across different agencies with no sole authority, or are you better off having it under one roof with a strong focus and decision-making tree that is clear-cut? I think right now it tends to be rather process oriented.

Mr. EULE. Well, we think in the strategic plan we have set out a process that can do that, and we have set out some goals, long-term goals that will provide that. So I think we are satisfied with the plan that we have. We think it is a good structure, one that is workable through the management structure that the administration has developed.

Chairman TOM DAVIS. Mr. Stephenson, how much exploratory technology and research is being conducted by the Federal Government?

Mr. STEPHENSON. I don't know the answer in total.

Chairman TOM DAVIS. OK. Can you get back to us on that?

Mr. STEPHENSON. Yes, I will.

Chairman TOM DAVIS. We want to put something in the record. How does the administration identify spending on climate change related R&D?

Mr. STEPHENSON. It is a matter of looking at the individual agency budget submissions and accounts and rolling them up. I think the press release yesterday from the Department of Energy announcing the release of the plan summarizes it best in that it says that the plan organizes, not directs, not manages, but organizes roughly $3 billion in Federal spending.

Chairman TOM DAVIS. Do they differentiate between direct spending, such as polar ice cap research versus indirect spending, which would be, like, R&D with just kind of an ancillary climate change benefit?

Mr. STEPHENSON. No. There are no clear definitions to distinguish between direct and indirect climate change funding. It all gets merged at the summary level in the reporting.

Chairman TOM DAVIS. How comfortable are you with OMB's overall climate funding trends? It seems to me there are a lot of questions whether OMB's data is comparable over time.

Mr. STEPHENSON. It was very hard for us to tell whether the increases were due to inclusion of new programs or redefinition of existing programs, so we can't answer that question concretely, although most of the real increase, as I said, occurred in the technology portion of the climate change report.

Chairman TOM DAVIS. Has OMB agreed to all of your substantive recommendations, or have they just agreed to the suggested changes to report content format?

Mr. STEPHENSON. They have essentially agreed with all of the recommendations, although we haven't looked at this year's report to see how effectively they have been implemented. Our recommendations were more to get additional clarity and explanation in the reports so that they are more useful.

Chairman TOM DAVIS. OK.

Mr. Waxman.

Mr. WAXMAN. Thank you, Mr. Chairman.

Mr. Eule, in a hearing on climate change in July, Mr. Connaughton, the chairman of the President's Council on Environmental Quality, insisted that the administration is taking meaningful action to address global warming, and you have tried to make the same argument here today.

There are some basic facts we must recognize if we want to avoid dangerous global warming. One, we can't avoid dangerous global warming unless we sharply cut emissions of global warming pollution. Two, sharp cuts in emissions require significant changes in energy production, energy use, deforestation, and other activities.

Three, as eminent climate scientists such as NASA's Dr. James Hansen keep telling us, we must start now. We have about a 10-year window to start controlling emissions and we need to achieve large reductions by 2050 or the planet will be locked into irreversible dangerous global warming. Four, as the single largest emitter of global warming pollution and the wealthiest country in the world, this isn't going to happen without U.S. leadership.

The administration's climate change goal allows U.S. emissions to rise by 14 percent by 2012. Achieving that goal just locks us in more to do later. To be blunt, the administration's claim of meaningful action are simply nonsense, and the so-called CCTP strategic plan is simply a longer version of the same story—lots of talk but no action and no results.

Mr. Eule, the ultimate goal we must achieve is to stabilize the level of greenhouse gases in the atmosphere at a safe level. Does your plan set a goal, any goal, for stabilizing the level of greenhouse gases in the atmosphere?

Mr. EULE. The plan does not set a level. It was never intended to be a mitigation plan. It was always intended to be a strategic plan to develop cost-effective options that could, over the long run, contribute to mitigating climate change.

Mr. WAXMAN. In fact, your range of stabilization levels include very high levels that would allow devastating global warming to occur, such as temperatures that would melt Greenland, raise sea levels by 20 feet. If we don't pick a goal and the right goal, we may be aiming for disaster.

You say your plan is not to achieve a goal but to give some ideas for technology. In order to achieve stabilization we need to reduce our emissions. Does your plan set any quantified goal or timing for reducing U.S. emissions of global warming pollution?

Mr. EULE. The plan in the summary chapter, chapter 10, does lay out some broad overall goals for the mitigation potentials that we think the technologies in the program could achieve. We have looked at these potentials not only in terms of the amount of carbon or amount of greenhouse gases they could mitigate, but also in terms of the timing of these technologies, when they would be available. So while we don't set a goal, we have done scenarios analyses to look at different technology mixes and see how they could contribute to mitigating greenhouse gas emissions across a range of different scenarios.

Mr. WAXMAN. Well, as I see it you have a 100-year plan with no goal for where we want to end up and no time line for getting there. The plan also fails to address how we will get these new technologies into the marketplace. If people don't use the technologies, we are not going to avoid any greenhouse gas pollution.

Mr. Eule, I want to ask about the scenarios modeled in this report. The report relies on modeling to determine when the technologies could be deployed, and, even though you don't mention this in the report, that modeling assumes that there is a price on emissions that drives the use of these technologies; is that right?

Mr. EULE. It doesn't assume a price, it assumes carbon constraints.

Mr. WAXMAN. Well, even though your plan assumes that something beyond research is necessary for these technologies to be adopted, the Bush administration continues to strongly oppose any policy that would actually constrain emissions. The CBO pointed out in their report that research and development alone won't be cost effective or any way effective to reduce global warming. Dr. Kammen will testify today technologies do not adopt themselves.

There aren't any clear action items in your plan to implement, but even if it was faithfully followed over the coming decades, global warming pollution would continue to rise dramatically and global warming would reach dangerous, irreversible levels. A so-called strategic plan that utterly fails to address the problem isn't strategic, and I have to tell you it is not much of a plan, either.

Thank you, Mr. Chairman.

Mr. BILBRAY [presiding]. Thank you. We are going to have to adjourn until the end of this vote. The chairman said he will return immediately after that.

[Recess.]

Chairman TOM DAVIS [presiding]. Thank you for bearing with us. We had hoped to get you through.

Mr. Bilbray.

Mr. BILBRAY. Thank you, Mr. Chairman.

This question can be for either one of you: I was sort of taken by a comment by one of the Members, about the issue of transferring generation facilities from heavy oil and coal over to natural gases being a net benefit, but that doesn't reflect a consideration of a new facet of this whole issue that we are not talking very much about. The issue that I would like to ask: are you including in your strategies consideration for global dimming? And is global dimming being accepted as being one of the thresholds we need to consider when we are talking about global change issues?

Mr. STEPHENSON. That is really a DOE issue.

Mr. EULE. Are you talking geo-engineering?

Mr. BILBRAY. No. I am talking about the effect of particulates on the global warming issue and the benefits of particulates and what is called global dimming, the shadowing effect.

Mr. EULE. I think that would be an area of research that would probably be done under the climate change science probably but not the climate change technology.

Mr. BILBRAY. OK.

Mr. EULE. If I could get to your issue about coal switching, fuel switching from coal to natural gas, when we look at these technologies, the administration's climate change plan also looks at energy security and air pollution and climate change, so we combine the two. We look at it in a context, so, I think from an energy security issue, simple fuel switching from coal to natural gas, you also have to ask the question what impact is that going to have on your energy security, as well. So I think what we do was we take a more holistic approach in how we approach these technologies and start to consider these other factors.

Mr. BILBRAY. OK. An editorial note; North America still has substantial natural gas reserves. This is a big issue.

Mr. EULE. It does, yes.

Mr. BILBRAY. The other issue is, are we including—and I don't know if it is your department or should be the next panel—the issue of bioconversion and how much we are focusing on genetic alteration in our biofuel strategy. Arrangement we specifically including in our strategy the concept that we may want to be talking about bacterium and enzymes that have been genetically altered to be able to produce not only the fuel we want but also in a manner that is cost effective.

Mr. EULE. Absolutely. The Department of Energy has just announced recently that it was seeking $250 million to fund some centers that would look at those sorts of issues, using biotechnology not only to improve the feed stocks but also using biotechnology to improve the conversion process.

Currently we make ethanol from cornstarch, essentially, the sugars that are in the ear of the corn. We are working now on what you call a cellulosic technology where we construct these from other parts of the plant. We think our Office of Science is working it out. We think there is tremendous potential in biotechnology to make that process much more efficient and thus make bio-refining much more cost effective, so it is something we are looking at very closely.

Mr. BILBRAY. The issue of getting away from virgin products and going to "conversion" of trash products I think has just been grossly underestimated how important that is to make it work. A lot of people forget that gasoline was a trash product. It was a leftover trash from kerosene production. That is the only reason why we are driving around with gasoline now, not because gasoline was a secret formula that was developed somewhere down the line.

Mr. EULE. A couple of years ago USDA and DOE did a joint study called the Billion Ton Study to take a look at the amount of biomass that is available in the United States, and it came to the conclusion there was about 1.3 billion tons of biomass available in the United States annually on a sustainable basis. That is a huge resource, so if we can develop a cellulosic technology to tap into that resource we can significantly reduce the amount of gasoline that we use in our transportation fuels, for example.

Mr. BILBRAY. Go from that to the other end of the spectrum, the adaptation technology and theories or whatever. We have been getting reports that basically the Federal Government is walking away from adaptation concepts or technology. Where are we going with the whole concept of that other end of the spectrum?

Mr. EULE. Adaptation?

Mr. BILBRAY. Yes.

Mr. EULE. Adaptation is an issue that is handled in a number of agencies. CCSP, for example, climate change science program, does take a look at adaptation. Really what we need to help us with adaptation is regional level models that have much more specificity than they do now. We have made a great deal of progress in those models. More needs to be done.

But there are some what we call synthesis and exception products coming out of the climate change science program. They are looking at those sorts of issues. One that has relevance for the Department of Energy is a synthesis and exception product on the impact of climate change on energy production and use. So those sorts of things are being considered through the climate change science program. EPA has programs, as well as the Department of Interior and others.

Mr. BILBRAY. Mr. Chairman, I apologize, but there is one very simple but very big question I have that I don't think our colleagues on the other side of the aisle will bring up. Is there one major industrial nation in the world that has substantially reduced greenhouse gases? And, if there is, what technology did they use to do it?

Mr. EULE. That is an excellent question and the answer quite simply is no. We have taken a look at data that EPA reports to the U.N. Framework Convention, other countries report this data, as well, and if you take a look at the numbers for 2000 to 2004 emissions growth in the United States was 1.3 percent at a time when the economy grew by about 9.5 percent and population expanded by about 4 percent. The EU 15, which is essentially Western Europe, their emissions grew by 2.4 percent, so they performed worse than the United States. So I don't bring that up to denigrate all the things that are going on in the EU. They are all helpful. But it just goes to point out that no country is significantly cutting its emissions at this point.

Mr. BILBRAY. Who do you think is doing the best?

Mr. EULE. Well, I have a chart here. I could look. The Japanese are doing quite well. But, you know, we have heard a lot about cap in trade. I would point out the Japanese are doing well but they don't have a cap in trade policy in place. The Canadians don't have a cap in trade and they are not doing as well as the United States. So there is a mix but everybody is pretty much in the same place as far as emissions go.

Mr. BILBRAY. Thank you, Mr. Chairman.

Chairman TOM DAVIS. I want to thank this panel. Thank you very much. This has been very helpful for us as we move forward. Thank you.

We will take a minute break and get our next panel.

We have our next panel: Mr. Lee Lane, the executive director of the Climate Policy Center; Mr. Richard Van Atta, the senior research analyst at the Institute for Defense Analyses; Dr. Martin Hoffert, emeritus professor, New York University; Robert Socolow, the former director, Center for Energy and Environmental Studies at Princeton University; and Dr. Daniel Kammen, the director of Renewable and Appropriate Energy Laboratory at the University of California at Berkeley.

It is our policy to swear you in.

Dr. Van Atta, your daughter is where now in school?

Mr. VAN ATTA. UVA.

Chairman TOM DAVIS. Excellent.

Mr. Van Atta. Thank you.

Chairman TOM DAVIS. Excellent.

Mr. VAN ATTA. Your remarks about Jeb Stuart are very well taken.

Chairman TOM DAVIS. I knew you would appreciate it.

Mr. VAN ATTA. It is a wonderful model for people to look at in terms of how a school has been resuscitated and turned into a model.

Chairman TOM DAVIS. Yes. Excellent.

Mr. VAN ATTA. It is a real asset for our area.

Chairman TOM DAVIS. Well, I had two through there. One, Shelley, is at William and Mary, and Pamela is at Swarthmore, so they have done well.

[Witnesses sworn.]

Chairman TOM DAVIS. Mr. Lane, we will start with you and we will move on down. There is a light in front of you that is green when it starts, then it turns orange after 4 minutes and red after 5, but we are going to try to keep within that because your entire statement is part of the record. Thank you.

STATEMENTS OF LEE LANE, EXECUTIVE DIRECTOR, CLIMATE POLICY CENTER; RICHARD VAN ATTA, SENIOR RESEARCH ANALYST, INSTITUTE FOR DEFENSE ANALYSES; MARTIN HOFFERT, EMERITUS PROFESSOR, NEW YORK UNIVERSITY; ROBERT SOCOLOW, FORMER DIRECTOR, CENTER FOR ENERGY AND ENVIRONMENTAL STUDIES, PRINCETON UNIVERSITY; AND DANIEL KAMMEN, DIRECTOR, RENEWABLE AND APPROPRIATE ENERGY LABORATORY, UNIVERSITY OF CALIFORNIA AT BERKELEY

STATEMENT OF LEE LANE

Mr. LANE. Thanks a lot. I really appreciate the opportunity to appear here this afternoon, and I also really want to thank both you and the committee, as a whole, for conducting this hearing. I think this subject is one of tremendous importance. One of the attachments to my written statement is an editorial from the current issue of the Journal of Nature pointing out the enormous importance of government-funded R&D as a potential source of solutions to the problem of climate change.

As soon as we recognize that we really need government-funded R&D, in particular, it raises the question that the record of the Federal Government on energy R&D has been distinctly mixed, and so we really face a serious set of questions about how to do R&D to solve our climate problems in such a way that it actually is likely to get the results that we are looking for. It is a very hard, very big problem, climate change, as you know, so it is a very difficult problem and I think you are really to be commended for asking some of the questions about how to organize an R&D effort in such a way that it really works.

We have a very distinguished panel of experts here and they are going to discuss, I think, several of them, some of the more global aspects of the issue of how to do R&D, but I wanted to open my remarks by focusing on what I think are three pretty simple initial steps that could really get us started, things that are not necessarily global in nature but things that would, if we could do them, would really have an impact in enhancing the cost effectiveness of our Federal climate-related R&D effort.

The first of those, which is described in attachment B in my statement, would be to create a focused exploratory research program directed at finding new climate technology solutions. Several of us, four very distinguished scientists, including Dr. Hoffert and several others, and me, who is not a scientist at all, put together this straw man proposal describing a possible way of organizing an exploratory R&D program aimed at climate solutions.

I think that the two problems that such a program could solve are, first, that it could reduce the rigidity of the Federal climate change technology program. Bureaucracies tend to perpetuate themselves. All bureaucracies do that. It makes them rigid. It makes them slow to change. The program as we have designed it would go outside of the bureaucracy to open up the search for new ideas just as broadly as possible, and hopefully in doing that would encourage the flow of new ideas into our R&D portfolio.

The second thing it would do would be to counteract some of the tendency toward risk averseness, toward over-caution in the current portfolio of the climate change technology program. This is a problem that has been noted by some of DOE's own reviews of the climate change technology program.

We think that the proposal we have sketched out offers a possible way of counteracting both of those problems with the existing program. Our proposal for doing this—and there are other ways you could do it, but our proposal is to create an autonomous, not-for-profit Government-funded corporation to organize the exploratory R&D effort. We think it is better to create a corporation outside of the DOE in order to make sure that we don't simply perpetuate the same problems that exist within the existing organization.

Your opening remarks alluded to one of my other key points here, which is the need for expanding the R&D portfolio of DOE to include geo-engineering and adaptation in the CCTP. I think those are extremely important points. We could find ourselves with nasty surprises, and it would be much better to have done the research on those things beforehand.

I guess the third thing I will say, just in closing, is that it really is important to give DOE the planning staff of CCTP the resources that they need to do a better job of planning in the future. They have actually done, I think, yeoman's service given their resource limitations, and if we want them to do better we have to give them the resources to do that.

I conclude by just saying again I think that this hearing is enormously valuable. I thank you very much for your initiative in organizing it, and certainly the Climate Policy Center will do whatever we can to be helpful.

[The prepared statement of Mr. Lane follows:]

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HOUSE COMMITTEE ON GOVERNMENT REFORM

"CLIMATE CHANGE TECHNOLOGY RESEARCH: DO WE NEED A 'MANHATTAN PROJECT' FOR THE ENVIRONMENT?"

Thursday, 21 September, 2006

Testimony By
Lee Lane
Executive Director
Climate Policy Center

Introduction

My name is Lee Lane. I am the Executive Director of the Climate Policy Center, a non-profit, bipartisan Washington DC-based seeking to analyze climate policy options and to promote economically efficient policy responses to the challenge of climate change. CPC is supported primarily through grants from non-profit foundations.

To begin, I wish to thank Chairman Davis and the House Committee on Government Reform for calling this hearing. For reasons that I will explain, I believe that in doing so the Committee is posing the single most important question in climate policy – how can we best accelerate progress toward technological solutions to climate change. Within that larger question a focus on exploratory research and how to organize it also seems to me to be precisely on target.

My testimony this morning will begin with an explanation of why making organizational improvements to the US Climate Change Technology Program (CCTP) is extremely important to the prospects for long-term success in coping with the challenge of climate change. Then I will describe three near or mid-term steps that could potentially improve the existing program. My three candidates for prompt action are as follows:

1. Create a new entity to conduct government-funded research aimed at making high payoff scientific and engineering advances capable of dramatically reducing the potential future harm from climate change.

2. Conduct the R&D needed to make more informed choices about the potential pluses and minuses of various geoengineering responses to climate change and to lower the costs of adapting to climate change.

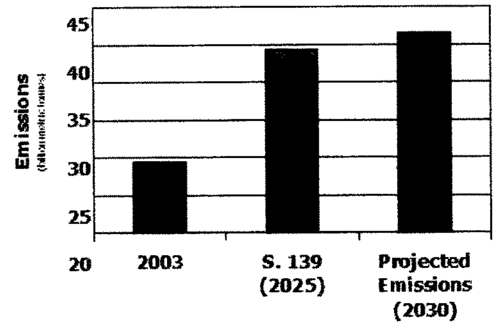
3. Congress needs to provide the management of the Climate Change Technology Program (CCTP) and to ensure that its recommendations and analysis receive due attention in future budgeting and organizational decisions about CCTP.

Government-funded R&D, a key to climate policy

Cost-effective government funding for R&D will be essential in meeting the challenge of climate change. Without truly revolutionary technological advances, comprehensive Greenhouse Gas (GHG) emission limits are likely to prove ineffectual in the industrialized world and not to be implemented at all in China and India.

Although the industrialized countries, including eventually the US, may adopt GHG controls, with current technology – *and given realistic assumptions about social willingness to pay for GHG abatement* – such controls will do little to curb the growth in global emissions. Thus, according to the US Energy Information Agency's estimate, by 2025, even the original version of S. 139 would have reduced global GHG emissions by a paltry 2.6 percent. To illustrate the point, Figure 1 shows the estimated emission reductions from the original version of S.139. It compares those hypothetical emission cuts with projected global GHG output and growth. Of course, for a still higher cost, controls could more tightly limit emissions. Yet the sponsors of S.139 withdrew this bill in favor of a less ambitious version. They took this step because they judged the initial bill's high costs as politically unacceptable, and even the scaled-back version has failed twice to attract majority support in the Senate.

Figure 1



In theory, more could be accomplished if China and India could be induced to curb their GHG emissions. But with current abatement costs, those countries seem most unlikely to institute GHG controls. Both the Chinese and Indian governments are under tremendous pressure to rapidly industrialize their countries. Strong GHG control measures would impede industrialization. These governments feel little domestic pressure to halt climate change. Even with great technological progress, the task of lowering Chinese and Indian emissions will be difficult and time consuming. Without new technology, the hopes of significantly limiting Chinese and Indian GHG emissions seem largely fanciful. (Even with a good deal of technological progress, this goal may be difficult to reach.)

Some proponents of GHG cap-and-trade policies argue that imposing controls would stimulate enough private sector R&D to produce the technological innovation needed to drive down abatement costs. While not entirely unfounded, such hopes are often exaggerated.

To a degree, placing a price on carbon emissions must occasion some change in the pattern of private sector R&D. However, GHG limits' induced-innovation effect will be small. Almost all economists recognize that market forces call forth a less than the optimal quantity of R&D. Once a private sector innovator demonstrates a new technology's feasibility and profitability, competitors are likely to imitate it. The imitators would escape paying the high fixed costs required to make the original discovery. Therefore, copycats could gain market share by undercutting the innovator's prices. By doing so, they deprive the initial developer of most of his hypothetical financial gain. Foreseeing this competitive response, firms avoid investment in many R&D projects that might have been profitable had the innovator been able to capture the full reward of his success.

The private sector's reluctance to rely on R&D strategies is likely to be especially strong with the kind of R&D activities needed to reduce GHG emissions. No large inexpensive emission-free energy sources lie just over the horizon. Thus, successful innovation in this area will require unusually high risks and long delays. As many economists (most recently Edmonds and Stokes) have noted because developing these technologies will entail breakthroughs in basic science, much of the most essential work will be ineligible for patent protection. These are precisely the conditions in which firms are least likely to invest in on R&D as an approach to problem solving.

I do not wish to overstate this case. Putting a price on GHG emissions would certainly encourage private sector R&D designed to commercialize new technology. Indeed pricing emissions is almost certainly the most cost-effective way to encourage such commercialization. Nonetheless, as the recent editorial of the journal *Nature* noted, government funding must play the central role in making the scientific breakthroughs without which no long-term climate policy success will be possible. (See Attachment A)

Climate Change Technology Exploratory Research

If only one change in US government climate policy could be made, it should be to initiate and sustain a properly organized exploratory research program like that described in Attachment B. Attachment B is a paper drafted by four accomplished scientists and me. It describes one possible 'straw man' proposal for how such an exploratory research program might be structured. My colleagues and I dubbed the proposed program Climate Change Technology Exploratory Research (CCTER).

Such a new program would conduct R&D aimed at fostering potentially high payoff (even if high risk) technological solutions to climate change. The key problem that this proposal is designed to address is the rigidity of the government's climate change technology R&D and the high entry barriers that often prevent innovators from gaining government financial assistance for testing and developing their ideas.

In particular, the existing program has seemed to slight longer-term potentially big-payoff high risk ideas. The organizational culture of the Department of Energy (DOE), its energy industry constituencies, and the legislatively mandated requirements for industry partnerships virtually ensure temporal myopia in DOE's research agenda. But the short-run focus clashes with the long-run climate policy vision. In the words of the report summarizing the conclusion of the expert workshops that recently reviewed CCTP's draft strategic plan:

> The need to place more emphasis on long-term, revolutionary technologies as well as programs that foster truly innovative, unconventional approaches emerged as essential for meeting the century-long challenge of climate change. This might require a greater percentage of funding to go to potential breakthrough technology versus research that provides only incremental improvements. There is a need for more high-risk but high pay-off research. (Brown *et al.* xi)

Without structural change, the more innovative longer-run orientation seems unlikely to receive the optimal attention or funding.

As one possible solution, my colleagues and I proposed creating a new organization that would provide seed money to a number of innovative concepts that fall outside the current R&D portfolio of CCTP. Eligible concepts might be classic 'Pasture's Quadrant' research, *i.e.* basic research with a high potential to advance technologies relevant to coping with climate change. They may also be more applied research.

The key criteria would be that the concepts not duplicate CCTP's current work and that their success would make a large improvement in the costs of halting climate change or coping with it. CCTP might not explore meritorious R&D concepts because they are more risky or more long-term; because they are narrowly focused on climate; because they are too multi-disciplinary or cross-cutting; or simply because they are too innovative. In all these cases, CCTER would be a possible alternative source of seed money. The Defense Advanced Research Projects Agency

(DARPA) experience seems to suggest that launching a systematic search for technological solutions that we cannot initially name or clearly describe can produce amazing results.

As we conceived it, CCTER's internal mode of operation would resemble that of DARPA. CCTER would adopt a flat organizational structure. Recruiting high quality staff would be a priority as would limiting the influence of purely bureaucratic constraints. It would use grants, contracts, and in my view prize competitions to produce research. It would not conduct intramural research – or very little. Competition through peer review and (perhaps) inducement prizes would determine specific financial rewards. (I do not recall that we actually considered inducement prizes in the discussions surrounding the preparation of our paper, but it is a tool that I personally believe deserves to be included in an exploratory research program.) Solicitations for potential grants, contracts, and awards would be broad, ideally worldwide.

One key organizational question is whether the goal should be to create CCTER or an Advanced Research Projects – Energy (ARPA-E). In principle, if an ARPA-E were created in DOE, it could be charged with climate-related exploratory research. This arrangement would entail some risk of losing the program's climate change focus amidst more pressing issues of energy price and security. In any case, for the next two years, the Administration's opposition to the ARPA-E concept effectively removes this option from the table. Under the circumstances, only a more narrowly climate-focused program like CCTER may be feasible.

Annual steady state funding would be at the level of $35-50 million. This number comes with the caveat that most of us thought that eventually higher expenditure levels would be desirable although we were conscious of the need to ramp up spending cautiously. One advantage of more funding would be that it would allow more opportunities to demonstrate the promise of technologies before requiring that further support come from traditional government or private sector R&D programs. Our hope is that the private sector would supply some of CCTER's money. This would also keep CCTER personnel in close touch with market realities. However, I personally believe that the program's raison d'être as a search for unconventional and highly innovative technologies would probably hold private sector investments to fairly low levels.

Determining how to fit CCTER into the larger structure of government is harder than envisioning how it might function internally. The option on which we settled was a private non-profit corporation. It would be governed by a board of directors that would include representatives of both government and the private sector. Government financial support would be funneled through DOE, but CCTER's governance arrangements would insulate it from bureaucratic interference.

Other options that we considered were to create an exploratory research program within DOE and to create a federally-funded R&D center under DOE. For my part, work by Dr. Van Atta on DARPA's history suggests that an innovative high risk R&D operation cannot survive and prosper within a federal bureaucracy without a high degree of top management support. The current views of DOE toward exploratory research and the concept of an ARPA-E raise serious doubts about whether that Department would provide a suitable environment for this kind of enterprise.

Back-up strategies for climate change

Currently, CCTP is focused exclusively on technology that would reduce GHG emissions. The program explicitly excludes R&D on geoengineering and adaptation. (US CCTP [Draft] Strategic Plan 2-2 note 2) This decision does not appear to have received an appropriate level of attention. To underscore this point one recommendation of the expert workshops conducted in the wake of the draft plan's publication was to expand the program's agenda to include geoengineering. (Brown *et al.* xi)

Broadly considered, three technology strategies are available for dealing with climate change. First, technological progress can lower the cost of GHG abatement. CCTP focuses on this goal. Second, technology can enable what is called 'geoengineering', use of technologies that would avoid harmful climate change even though emissions continue at relatively high levels. (Among other options, geoengineering could involve increasing earth's albedo (the proportion of sunlight striking the earth that is reflected back into space) to offset the warming effects of rising GHG concentrations.) Third, technological innovation could aid adaptation. Technologies like heat and drought resistant crops, stockpiling genetic material from endangered species, or hydrological projects that minimize the costs of rising sea levels can minimize the costs of the climate change that is already inevitable.

Some mix of the three technology strategies is most likely to meet the goal of minimizing the sum of the costs of climate change and the costs of countermeasures taken against it – the definition of an optimal climate policy. CCTP should develop the suite of technologies best able to implement this cost-minimizing strategy. Each of the two missing strategies is, in fact, potentially crucially important to overall success.

The fact is that some degree of human induced climate change is already inevitable. It is hard to be certain whether it will be a lot or a little or what affects it may have. But as one looks farther into the future, the chances of larger and more disruptive impacts grow. To many scientists the preferred policy response to these problems is to restrain GHG emissions so as to minimize the future risks. However, to some degree such efforts have already failed. Furthermore, some prominent economists who have studied the difficulty of forging an international agreement on GHG controls conclude that it may be impossible to do so, at least for several decades. If they are right, and so far the Kyoto Protocol experience suggests that they are, a substantial degree of climate change is inevitable.

Adaptation could significantly reduce net damages from this climate change. Many recent climate change damage estimates typically fall below those of earlier studies because the more recent studies have better accounted for adaptation. (Joel B. Smith 31) Adaptation's evident power to decrease damages suggests using R&D to boost that power.

> It [adaptation] means *inter alia* pushing ahead with both the basic science and applications of genetic engineering in many areas, especially agriculture, but also to provide potential substitutes for possible useful species that may be lost. That could be supplemented by a systematic program for collecting, cataloguing, and storing genetic material, mainly but not exclusively from plants, in the form of seed banks and DNA. (Cooper 1999, 43)

Other relevant work might involve a systematic study of how public and private infrastructure might be adjusted to minimize the costs of climate change. It may even be worth exploring adaptation's role in US assistance to foreign countries.

Taking the logic of adaptation one-step further implies conducting R&D on geoengineering. Climate policy must cope with the possibility of low probability but high cost events. (Nordhaus

& Boyer 98) Should the climate system manifest a large and harmful discontinuity, having a mechanism for 'scramming' the climate change process could prove invaluable.*

Indeed, unless we are prepared to assign a zero probability to "nasty surprises" from climate change, there seems good reason to undertake such research. (Keith and Dowlatabadi 293)

> Geoengineering in the climate change context refers mainly to altering the planetary radiation balance to affect climate and uses technologies to compensate for the inadvertent global warming produced by fossil fuel CO_2 and other greenhouse gases. An early idea was to put layers of reflective sulfate aerosol in the upper atmosphere to counteract greenhouse warming. Variations on the sunblocking theme include injecting sub-micrometer dust to the stratosphere in shells fired by naval guns, increasing cloud cover by seeding, and shadowing earth by objects in space. ... Climate model runs indicate that the spatial pattern of climate would resemble that without fossil fuel CO_2. Engineering the optical properties of aerosols injected to the stratosphere to produce a variety of climate effects has also been proposed." (Hoffert *et al.* 986)

As insurance against runaway climate change, research on geoengineering may be the only available option. Because emission reductions require so much time, a GHG control policy must be initiated many decades before it achieves its full effects – and long before the full extent of the problem is fully visible. Our political systems are not always far sighted enough to respond to such long-term threats.

Geoengineering, in contrast to GHG controls, could be implemented swiftly. For one thing, reaching international agreement for geoengineering would probably be largely about the sharing of monetary costs, a type of negotiation for which we have much experience. (Schelling 2005 592) Meantime, the costs would be confined to the R&D needed to prove-up the technology's feasibility. The future costs of actually deploying geoengineering solutions are highly uncertain; however, in the early 1990s, the U.S. National Academies of Science, after studying geoengineering, concluded, "Perhaps one of the surprises of this analysis is the relatively low cost at which some of the geoengineering options might be implemented." (NAS 1992 460)

The logic behind an exploration of geoengineering is so strong that it is beginning to erode the taboos that have hitherto blocked its consideration. The newly-elected president of the National Academy of Science has become an advocate for exploring various geoengineering concepts. A growing number of other scientists, including Nobel Laureate Dr. Paul Crutzen of the Max Planck Institute have begun proposing possible approaches. Yet these scientists note the continuing absence of governmental support for the exploration of the various technologies. (Broad 1-4)

At this point, however, the pros and cons of the various approaches to geoengineering remain poorly understood. The cost, effectiveness, limits, side effects, and ancillary benefits are matters of growing speculation, but little empirical research. The social and political dynamics of geoengineering solutions have also not been systematically explored.

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* A 'scram' is the rapid emergency shutdown of a nuclear reactor or other system.

To some degree, CCTER would be a good place to conduct early R&D need to launch the exploration of geoengineering and adaptation (especially geoengineering). Nevertheless, there is really no good reason for CCTP not to add geoengineering and adaptation to its research agenda. Doing so would necessarily change existing funding patterns. However, early stage R&D in these areas is likely to be relatively inexpensive, so the adjustment would be small. After all, the whole point of CCTP and its strategic plan is to periodically retune the program's spending pattern to optimize the development of the portfolio of new technologies best able to cope with climate change.

More support for CCTP management

The long delays in the release of the CCTP strategic plan illustrate a persistent problem. The planning process has been starved for resources. The resulting nearly four year gap between the program's inception and the finalization of the first strategic plan is understandable, but disappointing.

Then too, in some important respects, the scope of the Draft Strategic Plan was undesirably narrow. To the authors' credit, they highlighted the omission of geoengineering and adaptation and solicited the comments of those who might disagree. Yet the only apparent rationale for excluding these areas was that the government was not in fact doing R&D in these areas.

This comment is not intended as criticism of the people who drafted the CCTP strategic plan or their decision to narrow the plan's scope. Given the resource constraints, that judgment was probably correct. The narrowness of the resource constraints, however, is just the point. Because planning resources were so limited, the planning process could not adequately address important issues.

CCTP may also lack influence on wider technology policy. The draft strategic plan correctly designates supporting technology policy as a CCTP "core approach". (US CCTP [Draft] Strategic Plan 2-10 – 2-11) However, last year's energy legislation authorized several new putatively climate-related subsidies and tax subsidies – several of questionable cost-effectiveness. Does CCTP have the resources and standing to conduct analyze these larger policy questions and to win a serious hearing for its findings?

Finally, what will be the significance of the plan now that it is approaching its final form. A recent National Research Council study of the Climate Change Science Program noted the importance of a "Leader with sufficient authority to allocate resources, direct research effort, and facilitate progress." It also called for "A strategy for setting priorities and allocating resources among different elements of the program (including those that cross agencies) and advancing promising avenues of research..." (NRC 80) These requirements are equally crucial to the success of CCTP. So far, though, if the issue of exploratory research is any indicator, CCTP has had little apparent influence on the distribution of DOE spending.

Conclusion

I do not wish to appear too negative about CCTP or about its strategic plan. The people working on drafting the strategic plan have performed yeoman service. While the plan is in some ways less than I would have wished, it puts the US vastly ahead of the rest of the world in establishing a framework for its climate-related R&D. Many representatives of both European and Asian governments have privately admitted to me that they cannot even say how much their governments are spending on climate-related R&D, let alone articulate a coherent plan for the long-term future. The initial plan and our approximately $3 billion in annual expenditures compare favorably with other efforts.

Moreover, the US has many pressing demands on our national R&D resources. National and homeland security, healthcare, the need for continued growth in economic productivity all come readily to mind. Fiscal considerations, if nothing else, dictate that we may not be able to have all the R&D we would like. Given these competing demands, I would still wish to see climate-related R&D spending expand and several expert panels have also endorsed this idea. At the same time, it seems unlikely that climate relate R&D spending will burgeon to the unprecedented levels that some hope to see.

R&D cost-effectiveness is, therefore, likely to remain a high priority. I have proposed three steps to boost cost-effectiveness. These are, first, to create a climate-related exploratory research program outside of the DOE bureaucracy, second, to add preliminary R&D on geoengineering and on adaptation to the existing CCTP and third, to ensure that the management staff of CCTP has the resources to do their job and that their analyses receives due consideration in budgeting and management decisions.

By airing some of the potential problems with today's climate-related R&D and exploring the alternatives, this hearing contributes importantly to the search of climate policy solutions. It is an important step. And I commend Chairman Davis and the Committee for undertaking it.

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Energy shame

The history of energy research highlights the importance and inadequacies of markets, and a yawning gap in the priorities of governments. It's time for a radical change.

Frances Cairncross, chair of Britain's Economic and Social Research Council, has been thinking about the economics of climate change longer than most natural scientists and economists. In her presidential address to the annual meeting of the British Association for the Advancement of Science this week, she rightly emphasized one of the most important things that governments can do: invigorate and focus research into the basic and translational science needed for new energy-conversion technologies.

Solar power is a case in point. Its great economic attraction is that, unlike nuclear power or carbon capture and storage, it does not need vast capital investment in order to spread. Its products just need to be priced in such a way that consumers and companies want to buy them. Once that point is reached, a solar-cell factory can produce the capacity to generate electricity as easily as a power station does, thus offering the possibility of exponential growth.

As we report on page 19, a boom in the solar-energy business, led by Japan and Germany, has now attracted serious interest from, among others, the technologists and venture capitalists of California's Silicon Valley. The people who brought the world Moore's law are eager to help it sustain itself through clean technology while accumulating yet more wealth on the way. Its most vigorous proponents suggest that attracting the attention of high-tech entrepreneurs could in itself be an end to our energy woes — a "distributed Manhattan project that attracts the smartest, most ideal people for the task", as Bill Gross, serial entrepreneur and trustee of the California Institute of Technology, put it to *The New York Times* earlier this year.

But a healthy respect for the power of entrepreneurs and free markets cannot hide the fact that they do best when choosing between possibilities that are close to market, rather than inventing entirely new options. There is research into new materials and technologies that small start-up companies can't do, and that larger, more staid ones, if history is a guide, won't.

History may not be a guide, of course. But even the possibility that the research may not get done is a reason for government to step in and ensure that it does, while trying not to crowd out private capital in the process. The current solar boom is dependent on old and trusted technologies — the companies now piling in are mostly finding new ways to manufacture and process familiar products. If the current rate of heady growth is to keep going for the quarter-century needed to start making a real change in the world's energy outlook, we will need new materials to capture the Sun's power ever more cheaply and easily, and new solutions to the problem of storing it.

Many scientists are eager to set out in search of those technologies. It is essential that curiosity-led research should flourish in these areas, and that funding bodies should encourage it so to do.

There are also areas where directed research might come into its own — where the best approach may be to try out lots of possibilities, rather than go with what a few bright people think is best. One of the strengths of the Manhattan project was that it tried out as many roads to nuclear weaponry as seemed plausible. Governments need to be willing to take advice on directed research and then make it happen, rather than just hoping that curiosity will triumph unaided.

> **"It is to the abiding shame of the world's governments that over the past two decades, funding for energy research has actually fallen."**

Talk of a Manhattan project to tackle the generation and storage of 'clean' energy may seem overblown. It shouldn't. The challenge of increasing energy use in the developing world while at least stabilizing and ideally decreasing carbon dioxide emissions is immense. It is to the abiding shame of the world's governments that, as the threat to the climate has become ever more apparent over the past two decades, funding for energy research and development has actually fallen. To suggest that spending on energy research should be limited only by the capacity of scientists and technologists to make practical use of it is not to be profligate, but rational. ■

CPC

Climate Policy Center

www.cpc-inc.org

CLIMATE CHANGE TECHNOLOGY EXPLORATORY RESEARCH (CCTER)

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AUTHORS IN ALPHABETICAL ORDER:

Kenneth Caldeira, Department of Global Ecology, Carnegie Institution, 260 Panama Street, Stanford CA 94305 USA, kcaldeira@globalecology.stanford.edu.

Danny Day, Eprida, Inc., 6300 Powers Ferry Road, Atlanta, GA 30339 USA, danny.day@eprida.com.

William Fulkerson, Joint Institute for Energy and Environment, University of Tennessee, 314 Conference Center Bldg., Knoxville, TN 37996-4138 USA, wfulk@utk.edu.

Marty Hoffert, New York University, Andre and Bella Meyer Hall of Physics, 4 Washington Place, New York, NY 10003-6621 USA, marty.hoffert@nyu.edu.

Lee Lane, Climate Policy Center, 1730 Rhode Island Ave., Suite 707, Washington, DC, 20036 USA, lane@cpc-inc.org.

ABSTRACT

Low cost avoidance of the risk of dangerous interference of greenhouse gases in the climate system will require much better energy provision and end use systems than are currently available. Therefore, we propose the establishment of an extension to the Administration's Climate Change Technology Program (CCTP) that would seek to identify and provide initial seed money funding for new research ideas that could lead to cost-effective technological breakthroughs of global significance. This research would generally be high-risk and often multidisciplinary. Seed money is needed to support the search for innovative climate change solutions, and its use has been found to be an effective strategy. We call this seed money based process *Climate Change Technology Exploratory Research* (CCTER). We offer this as a straw man suggestion for consideration by DOE and Congress. We suggest that one option for organizing CCTER is the setting up of a not-for-profit corporation funded by both the Federal Government through CCTP and the private sector. We estimate that the cost of CCTER to the government might be in the range of $25 to 45 million per year after initial ramp up, about 1% of the current energy technology R&D budget. Since it is not known from where good ideas will come and climate change is a global problem, proposal solicitation should be very broad and include foreign investigators. All proposals would be submitted to peer review, assessment, and evaluation. Seed money R&D investments that show significant promise would be fed back to CCTP or the private sector for further maturation and development as required. CCTER should be evaluated periodically perhaps by the National Research Council.

1. Why is Exploratory Research so important and so needed?

Mitigating the rise of greenhouse gases in the atmosphere is generally understood to be an expensive proposition unless lower cost emission free energy systems can be invented, developed, and deployed. Our purpose for writing this short paper is to encourage discussion and stimulate debate about how best to find and generate new ideas for research that might lead to technology breakthroughs for mitigating climate change at lower cost. How might this he accomplished on a continuing basis?

Many promising technologies are being pursued by DOE, other agencies and the private sector under the auspices of the Climate Change Technology Program (CCTP). These include, for example, advanced nuclear power reactors, carbon capture and storage technologies leading to no net emission coal plants producing electricity, hydrogen or other low carbon fuels, lower cost solar and other renewable technologies, and cost effective high efficiency energy end-use systems all bolstered by a substantial investment in basic research. Similar research is in progress in other countries.

Despite this substantial effort, fossil fuels with concomitant atmospheric release of carbon dioxide are likely to remain the dominant energy sources for the world unless regulatory or tax forces are applied. Fossil fuels are generally least expensive, are widely available, are convenient to use, and they fit the existing infrastructure. No technology silver bullets have yet been discovered that could change this fossil trend at low cost. The objective of this short paper is to suggest an approach for stimulating the search for silver bullets. This search is what we call "Exploratory Research." It is a search for new ideas that, if successful, could make a big difference to the CCTP mission to stabilize the climate with continued economic growth. Exploratory Research is described in the draft CCTP Strategic Plan (www.climatetechnology.gov, p 9-13).

Several categories of Exploratory Research include: high-risk, long-term but potentially high-impact R&D; cross-cutting R&D that combine technologies and/or disciplines that may have exceptional systems value; novel concepts that may enable mitigating technologies or offset the impacts of rising levels of greenhouse gases; unconventional but mission oriented and potentially high-payoff basic research outside the normal disciplinary boundaries; and advanced decision support tools for better assessing the risks and impacts of Exploratory Research. Box 1.1 is a list of several examples of topics that might be good candidates for Exploratory Research. This list derives from the authors' knowledge and experience, but the examples are unvetted and are merely meant to be suggestive.

Most of the categories mentioned above are being pursued to greater or weaker extent within the CCTP framework, but there is very limited flexibility in the system. There is no seed money to fund Exploratory Research on an open, competitive, and appropriately organized basis. Seed money is needed to nurture and stimulate thinking outside the box on a continuing basis. It is needed to support ideas that are out of the mainstream, but that could have a large impact even though the chances of success may be low.

We propose that a seed money approach to Exploratory Research be set up as a part of CCTP. We call this seed money activity Climate Change Technology Exploratory Research. Thus, CCTER is conceived as an important part of CCTP, but as discussed in Section 3, it need not necessarily be organized within DOE. This is a straw person suggestion that we hope will be useful to DOE and to Congress.

We believe this seed money flexibility is essential for the stimulation, care and feeding of new ideas. We note that many of the best, most productive ideas for research in the national lab system over the past few decades have come from Laboratory Directed R&D (LDRD). DOE and Congress allow the labs to use up to 6% of their funding each year for this purpose. This funding flexibility stimulates the generation of new ideas. We believe that seed money flexibility (with clear program goals and fiscal restraint) will have the same effect for CCTER.

Box 1.1 Examples of potential CCTER candidate areas.

The ideas listed below are generally unvetted, and sources are not documented. The list is meant to be suggestive only. While many of CCTER ideas may never lead to a deployable system, the program would be a success if it enabled the development of just one "silver bullet" that could contribute greatly towards the mitigation of climate change. There is not a consensus by the authors on whether it would be better to consider adaptation technologies and strategies within CCTER or within a different program; support is needed for exploratory research into adaptation strategies, however. Careful delineation of the scope and function of CCTER will likely resolve this issue during its formation and funding.

- System analysis and small scale development and testing of enabling technology for **global-scale power transmission in low-resistivity power lines** could assess the benefits and costs of electricity wheeling between continents, time zones and day-night cycles. These grids could simultaneously address the problem of storage for solar and wind power and enable nuclear power reactors to be sited in secure environments with electricity dispatched worldwide. The development of high-temperature superconductor and/or carbon nanotube cables currently being pursued by DOE (as well as wireless power transmission) may make global electric grids feasible in the future.

- Accomplishing **low-cost carbon sequestration of agricultural residues in anoxic ocean environments could offset carbon emissions from efficient use of natural gas (including methane hydrates)** as a significant energy source in a greenhouse constrained world. Alternatively, biomass could be used to produce electricity while sequestering the resulting CO_2 to offset carbon emitted from fossil-fueled vehicles where the fossil fuel is made from coal with sequestration of carbon not incorporated in the fuel.

- **Use biomass (cellulosic waste or energy crops) to produce a char based fertilizer for sequestering carbon in soil.** Biomass is pyrolyzed to produce a porous char and producer gas. The producer gas is shifted to produce hydrogen for ammonia production and energy. The char can absorb CO_2 and NH_3 to produce ammonium bicarbonate resulting in a long release nitrogen fertilizer. The fertilizer production process can be used to scrub CO_2, NO_x, and SO_2 from flue gases. The net sequestration of carbon can offset the emissions from transportation, for example. The fertilizer can be used to improve the productivity of marginal land, and hence increase biomass productivity, and this can further contribute to the net extraction and sequestration of atmospheric carbon.

- **Hydrogen fuel might be manufactured from high-efficiency solar-thermal processes** as an alternative to PV- and wind- hydrogen from electrolytic decomposition of water. One technology for thermochemical hydrogen conversion of medium-grade heat to hydrogen employs a vanadium or iron redox cell and urea as an energy storage medium and transportation fuel.

Box 1.1 (Continued)

Tethered wind turbines flying at high-altitudes, deployed in the jet stream could harvest atmospheric kinetic energy more efficiently than ground wind machines. The high energy per unit frontal area available at altitude may make this more cost-effective than low-intensity winds at the surface. The idea is to harvest as much of this concentrated wind source as possible without adverse environmental impacts.

Engineering approaches may enable scavenging CO_2 directly from air. Living plants capture carbon dioxide directly from air, but it may be possible to engineer systems that could remove CO_2 more efficiently or more rapidly.

Artificial Photosynthesis involving extracting CO_2 from the atmosphere and reacting it with hydrogen from electrophotolysis (for example) might be used to make fuels for transportation. The carbon recycling system would have no net carbon emission.

Experiments and analysis are needed to evaluate the practicality of engineered aerosols injected to the stratosphere to scatter solar radiation back to space in amounts sufficient to counteract the radiative heating of CO_2 and other human greenhouse emissions. Alternate geoengineering ideas are mirrors and lenses in space at the interior L1 Earth-sun Lagrangian point to deflect sunlight. These alternatives might be a sort of insurance policy that should be explored further in case its use becomes necessary.

Develop methods to use biomass residues efficiently in the rural developing world e.g. by gasification to provide fuel for electricity, village heat and cooking.

Solar power satellites in geostationary orbit can beam power to PV collectors on Earth's surface with high-efficiency diode lasers 24 hours a day 7 days a week thereby solving the storage problem of surface PV as a base load electrical source. This technology is enabled by recent breakthroughs in solid-state lasers with orbiting thin film PV arrays on low-mass inflatable-rigidizable structures.

Power-plant flue gases could be used to dissolve limestone and the resulting solution could be placed in the ocean. This approach has the potential to store carbon in the ocean while protecting marine biota from ocean acidification. A similar process is used by salt-water aquarists to promote the growth of corals in fish tanks.

Low-mass car bodies from mass-produced carbon-fiber structures can enable very high fuel economies for hybrids and (eventually) hydrogen vehicles. In addition, vehicles built from macro-scale carbon nanotubes with strength-to-weight ratios 200 times higher than steels could in principle have masses as low as a few kg with the same strength as today's car bodies -- perhaps enabling a safe 100 mpg car.

Box 1.1 (Continued)

Using fusion to breed fissionable reactor fuel is an old idea that should be revisited because it could be important as a means to rapidly breed fissionable fuel & thereby vastly extend available fission reactor resources. Fissionable U-233 could potentially be bred from thorium in neutron-absorbing blankets, however this could pose a significant proliferation risk that would need to be mitigated perhaps by blending with U-238.

Adaptation technology and strategies ranging from mitigating the impacts of migration of whole ecosystems and associated animals including people to developing less expensive technologies to manage sea level rise, changes in precipitation patterns and increasing intensity of hurricanes represent a largely neglected but important area of R&D.

Also, the Office of Fossil Energy of DOE recently experimented successfully with a seed money approach to find novel new ideas in the area of carbon capture and storage. It used a committee of the National Research Council to help identify categories in which to search. The committee also helped design a solicitation and evaluate proposals. Some 109 proposals were received and 8 awards were made mostly for 3 year projects with a total cost of $ 4.6 million. The process did uncover important new ideas to explore and it brought new people into the field. It is not clear whether this process will be repeated, but the NRC committee recommended that it should be.

The conclusion is that seed money used properly is an excellent strategy to employ to discover new important ideas.

2. What is the mission and character of the organization managing CCTER?

The mission of CCTER is to seek, find, and provide initial funding for the best ideas. Proposals for research would be solicited very broadly including from foreign scientists and engineers. After all climate change is a global problem. This openness is essential because there is no way to predict the sources of the best ideas. CCTER should be an incubator for new ideas: a place for them to be tested rigorously for potential problems and showstoppers as well as for their potential to provide terawatts of energy impact on the global scale.

Ideas that pan out would be fed back into DOE-CCTP or the private sector or both for further maturation, development, and demonstration of economics, safety, and other benefits on a system-wide and global level. Feedback to CCTP and the private sector is a vital function of CCTER if it is to be fully successful.

CCTER should be funded partially by DOE and other federal agencies, of course, but it should also seek additional (perhaps matching) funding from private sector entities including businesses, foundations, and even individuals. The money from both sources should be managed seamlessly. Public and Private sector support should leverage each other. This global, long-term, social good issue requires a special government private sector partnership with a unique character. For example the constraints on the use of federal money to support foreign investigators or that make distinctions between the eligibility of some organizations should be relaxed.

We note that companies as well as foundations are beginning to invest in climate change mitigation research. Examples include the highly publicized Exxon Mobil investment (with other companies) in the Global Climate and Energy Program at Stanford University and the investment of Ford and BP in similar research at Princeton University.

Every proposal would be peer reviewed and scrutinized from the point of view of relevance to the mission and potential impact as well as technical merit. Intellectual property is handled to attract development, demonstration, and deployment funding if the R&D is fruitful. By managing intellectual property properly CCTER would seek to become a center for a network of investigators and entrepreneurs exchanging ideas and information actively and freely.

To avoid conflict of interest or diversion from the mission the CCTER staff should do very little research except as needed to secure and retain talented people (and this research should focus on system-level implications of funded or proposed projects). At any event, this in-house research should be a very small fraction of the total funds administered.

3. How might CCTER be organized?

Several options for organizing CCTER might work adequately. The most obvious is to organize CCTER within DOE itself. We see several potential problems with this option. These include the difficulties of recruiting and retaining very talented and creative people to lead and operate CCTER, managing the melding of public and private money seamlessly, avoiding turf battles that may arise from the politics within DOE, and insulating the organization from confining bureaucratic policies and regulations. This option is not impossible, but it will be difficult. One variation on this option would be to organize CCTER within one of the DOE national laboratories. For example, DOE funded a program managed by the National Renewable Energy Laboratory to support the top ten incubators in the US for encouraging new energy solutions. That three years of funding resulted in significant innovations, businesses, and jobs. http://www.nrel.gov/technologytransfer/entrepreneurs/pdfs/17_alliance_results.pdf.
However, the DOE labs were designed to conduct research, not to act as program managers for research conducted elsewhere; the labs are generally multiprogramming, and we seek an organization dedicated to one and only one mission. Also, some of the same problems as for the DOE option remain, although perhaps moderated, but jealousy between labs is an added possibility.

Nevertheless, CCTER within the DOE family could be to climate change mitigation what DARPA is to the military.

A second option might be a special Federally Funded R&D Center (FFRDC) such as the Air Force's Aerospace Corporation. Such a corporation could be created to provide more flexibility and more insulation from the requirements imposed than if CCTER were organized in DOE. This option should be carefully considered. One possible variation on this theme is the NASA Institute for Advanced Concepts (NIAC). It was set up administratively outside of NASA for the purpose of functioning as an independent source of revolutionary aeronautical and space concepts that could dramatically influence how NASA develops and conducts its missions.

The third option is a private not-for-profit corporation. An example is RAND Corporation set up originally after World War II as a think tank for the DOD, but now does work for many agencies. The difference is that CCTER would be a corporation that funds R&D using both private and public sector funds. Several NSF centers operate this way, for example, the Aspen Center for Physics is a not for profit corporation funded by NSF and others. Under this third option, CCTER would have a board of directors with representatives from both DOE and the private sector sponsors. It could have considerable insulation from DOE politics and bureaucracy as well as from private sector pressures. It could be very flexible, and it should be able to attract top talent. For these reasons and because of the need to manage private and public sector resources productively, we conclude this is our preferred option. Taking maximum advantage of private sector intellectual contributions is a very important in-kind asset that a private not-for-profit corporation can generate more readily than other organizational options.

4. How much government money is required?

The answer to this question is a judgment call. We believe that CCTER should operate in the following manner. The first year it should solicit proposals from which the most promising would be selected for support. Obviously, some exploratory research may require more money for proof of concept than other ideas. By their nature, some may require several millions of dollars a year to test while others may require only a few hundred thousand. This is clear from an examination of the examples in Box 1.1. It may be useful to divide the funding so that some expensive projects can be examined each year. Of course, it is probable that most ideas that show promise after CCTER seed money funding will require more resources to fully demonstrate and initiate deployment. This maturation investment could come from either DOE or other CCTP agencies or the private sector, and one vital CCTER function would be to fully encourage needed follow on support.

We suggest, therefore, two categories of proposed research. Category 1 projects would include paper studies or small laboratory scale proof-of-concept experiments with annual costs typically in the range of $100,000 to $500,000 per project. Category 2 projects would test the engineering and cost potential for ideas that have already been vetted at the paper study or bench-top scale. Annual funding levels for these contracts might average in the range of $500,000 to $1,000,000. In general, the Exploratory Research contracts would be for two or three years with extension possible but not common, although successful Category 1 projects could submit Category 2 proposals.

Assuming funding for 20 to 30 ideas per year with equal number of each category and 3 year funding, steady state expenditures for CCTER could be in the range of $35 to $50 million/y. To this must be added the costs of operation including organizing the peer review and evaluation process, and the cost of maintaining contacts with top talent and institutions around the world that may provide introductions to people with revolutionary new ideas and insights. These extra costs may be in the range of 10 to 20% of the contract awards. At steady state, the cost would be shared between the Federal government and private sector contributors. If it were on a 50/50 basis, the Federal cost would be in the range of $19 to $30 million per year. Conservatively we believe the order of $25 to 45 million/y of Federal money is needed at steady state because it is likely that private sector support will be less than 50/50, at least initially.

Of course, the CCTER should start at a much lower level until the concept and procedures are fully worked out and tested. No doubt, there will be some growing pains.

We suggest starting at $5 million per year for the first year, funding primarily Category 1 proposals, and ramping up from there to the steady state level in 5 years.

This Federal funding for CCTER is very small compared to the magnitude of the overall CCTP portfolio that is in the $3 billion per year range, but we believe this small flexible seed money type of investment will have payback far in excess of the investment.

5. What process should be used to select projects for funding and how should CCTER be evaluated?

Proposals would be solicited very broadly including from universities, commercial organizations, national laboratories, and even foreign organizations. Panels would be set up to evaluate the proposals, and these would include people from DOE and other agencies and from private sector donors as well as from the technical community at large.

The membership of the panels would be changed periodically.

Criteria for judging each proposal should include: 1) the potential impact of the proposed idea on climate change mitigation assuming realistic optimism for all relevant factors including cost, 2) the probability of success, 3) technical and scientific merit and risk, 4) the fully loaded project cost, and 5) potential confounding issues such as environmental impact, safety, infrastructure, and geography. The division of 1)*2) by 4) might give a crude estimate of return on investment. The portfolio of investments could also be balanced in terms of probability of success to provide some long shots and some medium-shots. Votes on these criteria could be measured on a median-basis so a few naysayers or zealots on the panels will not skew the results too badly.

Progress by funded projects should be evaluated annually. We suggest Category 1 projects be evaluated by CCTER management. Category 2 projects should be evaluated by peer review. This way mid-course corrections or even cancellation can be invoked to avoid waste.

CCTER itself should be evaluated periodically to assure the mission is being pursued effectively, and to evaluate whether the investment is yielding adequate return. We suggest that this evaluation be done by the National Research Council (NRC) with a committee composed of people with different backgrounds with no direct conflicts of interest. The measure of success is the number of unique ideas that are judged to have potential for making a big difference if the cost is right. This NRC report would go to DOE, associated sister agencies, other sponsors, Congress, and the public.

6. How could CCTER be initiated?

The first step is to generate enthusiasm for the idea of CCTER. It should be done within DOE, in the Congress and among the general public. The idea should be thoroughly vetted including in the private sector and academia. Assuming the vetting results are generally positive, a decision should be made between the three options of Section 3.

Assuming option 3 is chosen (or even option 2) a not-for-profit corporation should be set up. Money for this activity might be found from one or more foundations. We note that the formation of RAND was funded by a grant from the Ford Foundation. The corporation could then choose a CEO, appoint a board of directors and organize the solicitation for proposals. Simultaneously, work would go on with DOE CCTP, other agencies, OMB and Congress to propose, authorize and appropriate the first year of funding. With the arrival of funding, CCTER is operational.

Chairman TOM DAVIS. Thank you very much. That is very helpful.

Dr. Van Atta, welcome and thank you.

STATEMENT OF RICHARD VAN ATTA

Mr. VAN ATTA. I am not an energy specialist. My background is Defense and Defense research. I spent a fair amount of my career looking at emerging technologies and how they are made to emerge, and I teach a class at Georgetown on emerging technologies and security, and I emphasize the fact that emerging technologies are made to emerge. The question is the processes and the means by which you do that.

DARPA is a unique example of an entity that was created with that purpose in mind, and I think it is important to look at it in terms of why it succeeded and what made it succeed. In my testimony, which I will read portions of here, I emphasize that the research that DARPA does is unique and different, and is purposefully so. The organization, itself, is designed explicitly to allow it to do this unique and different type of research, and it has cultural features within its organization and management style that allow it to do that.

In the testimony I talk about the DARPA model and I also ask the question of which DARPA model, because DARPA has done many things in many different ways. It has been adaptive. It is very malleable. One cannot just say there is a DARPA and that we are going to take that and implant it some place else. You have to understand what it took to make it do what it could do and why it was able to change in those very effective ways. So it evolved over time and it has many successes, and those successes, in fact, were different because they were dealing with different problems.

We have to understand the way in which those successes were made and what it took to make those successful, and I will talk about a couple of examples of that.

DARPA's program managers are the core. They are, in fact, almost individual entrepreneurs. They are encouraged to challenge existing approaches. In the case of Defense, for war fighting and to seek results rather than just explore ideas. In addition to supporting technology and the components of the technology development, DARPA has also funded integration of large-scale systems demonstrations to look into what we would call disruptive capabilities.

There is a high-risk, high-payoff motif for DARPA that is a set of organizational and operational characteristics that include its relatively small size, its lean, non-bureaucratic structure, its focus on potentially change-state technologies, its highly flexible and adaptive research programs, but what is most important at the outset is that, in contrast to the existing Defense research environment, ARPA was manifestly different. It did not have labs. It does not focus on existing requirements. It is separate from any operational organization elements. What is explicit is that its charter is to be different so it could do fundamentally different things that had not been done in a research environment.

So when one looks at an energy ARPA or climate change ARPA, the question is what are the things that it is trying to do that are different and how do you set up an organization to do that.

DARPA was established as a research and development organization to assure the United States maintained the lead in the state-of-the-art technology for military requirements and prevent technology surprise. As one then looks at the characteristics of how it did that, first of all it was independent of other organizations.

Second of all, it is lean and agile. It was risk-taking and tolerant of failure, open to learning. You have to have a specific kind of research environment and organizational structure and a way in which your link to the rest of the organization will allow you to do that.

The program managers are, in fact, the technical champions who conceive their own programs and have to then sell those programs within the DARPA environment. The coin of the realm in DARPA is promising ideas. Gaining notion is not that the idea is well proven, but that it has high prospects for making a difference on the problem they are trying to solve. So you have to have an organization and culture that focuses on those kinds of innovations and those kind of directions.

In my testimony I talk a lot about DARPA's successes, and I don't have time to go into those here, but I will give you some key what I consider to be elements of that success.

First of all, focus on creating surprise, creating difference, not avoiding them.

Second, build what I call communities of change state advocates. One of the key things that is unique to DARPA is it doesn't create and do its own research, it incentivizes and creates a community of people to do that. If one talks about the current structure of DOE in the national labs, they do their own work with their own capabilities within their own operations. What DARPA did is it found the people who could do that. It developed the community. It found the new ideas out there and brought them together in a coherent manner.

The third element is to find challenges, develop solution concepts, and then demonstrate them. We can show examples of that in my testimony.

Finally, I would say if one were to ask the question what were the key things about climate change that relate to DARPA and the DARPA model, the first thing I would say is you have to understand the imperative that drove the creation of DARPA in terms of national security, the Sputnik issue, and ask the question: do we have the same imperative and understanding of imperative to make an ARPA-like organization work elsewhere?

You also have to have the understanding that it will work because of the protection, oversight, and interest of the Secretary of Defense and even the President to make it happen. Without that, just naming something ARPA will not solve your problem for you.

Finally, I would say you need to deal with not only leadership support but the issue of congressional oversight. ARPA has benefited from the fact it has a simple oversight structure, it is not being managed by multiple congressional committees simultaneously, and with that kind of multiple meddling you are not going to get anywhere. You have to deal with existing lab structure. An ARPA-like organization cannot succeed if, in fact, it was supposed to support and integrate all those labs and use that as its basis of success, and then they have to deal with the incumbent business interests.

One of the key things, examples of DARPA, was how it created information technology capability despite the fact that IBM dominated all of the information technology development at the time that it created that very successful program, but it did it by not having to directly address but create alternatives to those incumbent capabilities.

So my suggestion is that there is value in an ARPA energy that could be created, but if you are going to do that you have to understand that first of all you need to have that galvanized focus, you need to have an approach that is allowed to be independent, and it has to have top-level leadership if it is going to succeed.

Thank you.

[The prepared statement of Mr. Van Atta follows:]

ENERGY AND CLIMATE CHANGE RESEARCH AND THE "DARPA MODEL"

DR. RICHARD VAN ATTA[1]

Prepared Testimony for

The Committee on Government Reform

House of Representatives

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With energy and climate issues increasingly the focus of public policy discussions, the notion that a special research organization—sometimes referred to as ARPA-E—should be created has emerged as one alternative for focusing resources and management attention. More specifically, there have been calls to create a new entity, modeled on the notably successful Defense Advanced Research Projects Agency, DARPA, to perform advanced R&D directed at finding technological solutions to the climate change challenge.[2]

Having spent a fair amount of time looking at DARPA's research program over the years I have been asked what would it take for such an organization to be established and be successful drawing from the historical perspective of the unique organization that it would emulate—DARPA. This will be the focus of my remarks today.

Some key questions we might consider in our discussion are

1. How similar are the type of research tasks of DARPA to those entailed in addressing energy and climate change and how are they different?
2. What are DARPA's key organizational features that have contributed to success and could those features be replicated within the political and

[1] The author is a research staff member at the Institute for Defense Analyses. The views expressed in this testimony are solely those of the author, and they do not represent the views of the Institute for Defense Analyses, the Department of Defense or any other individual or organization.

[2] The DARPA model—sometimes referred to as ARPA-E, or E-ARPA, has been suggested in several venues, most notably in the National Academies' *Rising Above the Gathering Storm, Energizing and Employing America for a Brighter Economic Future*, National Academies, Committee on Science, Engineering, and Public Policy (COSEPUP), 2006,

economic environment surrounding energy and climate change in the executive branch, Congress, and private industry?

3. Are DARPA's 'cultural features' that have been central to its success reproducible under the various possible contemporary arrangements for addressing energy and climate change?

As a former Department of Defense and Department of Energy executive, Dr. John Deutch stated recently,

Appealing as the DARPA model is, energy and climate-related technology development would present new and different challenges. For example, DARPA does not create for the market – even though technology developed by DARPA has succeeded in the marketplace. Its customer is the Secretary of Defense and ultimately the armed services. Most of the technologies relevant to energy and climate solutions will have private sector customers. This is a problem that DARPA has not had to confront. Still, DARPA offers valuable lessons concerning managing and spurring successful technological innovation. It may be that an imperfect solution to the challenge of technology development still might improve on the record of existing institutions.[3]

Understanding DARPA

We begin this discussion with the following questions

- What is the "DARPA Model", which, as we will explain, raises the question "Which DARPA?"
- What were the origins of DARPA and how did it evolve?
- What have been DARPA's "successes"—why is it so well regarded?
- What is the basic "motif" of DARPA success and what are key factors in achieving success?
- What is relevance of DARPA model for other policy areas—particularly energy and climate research?

The "DARPA Model"

DARPA's primary mission is to foster advanced technologies and systems that create "revolutionary" advantages for the US military. Consistent with this mission, DARPA is independent from the military Services and pursues higher-risk research and development (R&D) projects with the aim of achieving higher-payoff results

[3] John Deutch, "What Should the Government Do To Encourage Technical Change in the Energy Sector?" *MIT Joint Program on the Science and Policy of Global Change*, Report No. 120, *May 2005.*

than those obtained from more incremental R&D. DARPA program managers are encouraged to challenge existing approaches to warfighting and to seek results rather than just explore ideas. Hence, in addition to supporting technology and component development, DARPA has on occasion funded the integration of large-scale "systems of systems" in order to demonstrate what we call today "disruptive capabilities."

Underlying this "high-risk—high payoff" motif of DARPA is a set of operational and organizational characteristics that Deutch and others have referenced including its relatively small size; its lean, non-bureaucratic structure; its focus on potentially change-state technologies; its highly flexible and adaptive research program. We will return to these characteristics later. **What is important to understand at the outset is that in contrast to the then existing Defense research environment, ARPA was manifestly different.** It did not have labs. It did not focus on existing military requirements. It was separate from any other operational or organizational elements. It was explicitly chartered to be different, so it could do fundamentally different things than had been done by the Military Service R&D organizations.

The reason for this dramatic departure was that President Eisenhower and his key advisors had determined that the existing R&D system had failed to respond to the realities of the emerging national security threat embodied by the Soviet Union. This threat was manifest in a crescendo event—the launching in 1958 of the Sputnik satellite. The response to this not only the creation of a research entity to perform research that others had not adequately pursued, but to embed this organization within a newly created oversight structure reporting to the Secretary of Defense—namely the Director, Defense Research and Engineering, or DDR&E.

DARPA's origins: Strategic Challenges ~1958

ARPA[4] was initially chartered in response to the orbiting of the Sputnik satellite, which raised the specter of the Soviet Union as a technological as well as political threat to the United States. Sputnik itself demonstrated that the USSR not only had ambitions in space, but also had developed the wherewithal to launch missiles with nuclear capabilities to strike the continental United States. Therefore, at the outset ARPA was focused initially on three key areas as Presidential Issues: space, missile defense and nuclear test detection.

- Regarding the first issue, space, soon after its birth a large element of ARPA was spun off to become NASA, based on President Eisenhower's determination that space research should not be directly under the DoD.[5]
- By 1959 ARPA had assignments on ballistic missile defense (DEFENDER) and nuclear test detection (VELA), and also pursued research in solid propellant chemistry, and materials sciences. Soon after ARPA initiated a program on information processing "techniques" with a focus on possible relevance to command and control also began. These became the major elements of ARPA's program over the next decade.
- Soon, based on the initiative of Director of Defense Research and Engineering (DDR&E), John S. Foster, a counterinsurgency program (AGILE) was started as the Vietnam War heated up.

[4] The original name, Advanced Research Projects Agency, ARPA, was changed in 1972 to *Defense* Advanced Research Projects Agency, DARPA. Briefly in 1993-95 the Clinton Administration reverted back to ARPA, but in 1996, the Congress mandated that the name be changed back to DARPA. In historical references I use the name of the organization at that time, either ARPA or DARPA, but for general discussion the current title, DARPA, is used.

[5] Herbert York states it was well understood in ARPA that its broad role in space programs was temporary, with the creation of NASA already in the works both in the White House and in Congress, see Herbert York, *Making Weapons, Talking Peace,* Basic Books, New York, 1987, p. 143.

What is DARPA?

DARPA was first established as a research and development organization immediately under the Secretary of Defense, reporting to the Director of Defense Research and Engineering, then the third highest official in the department with the mission to

- assure that the US maintains a lead in applying state-of-the-art technology for military capabilities

and

- prevent technological surprise from her adversaries.

DARPA's Unique Mission

ARPA was created to fill a unique role, a role which by definition and in its inception put it into contention and competition with the existing Defense R&D establishment. As the *Advanced Research* Projects Agency, ARPA was differentiated from other organizations by an explicit emphasis on "advanced" research, generally implying a degree of risk greater than more usual research endeavors. Former ARPA Director Dr. Eberhardt Rechtin emphasized that research, as opposed to development, implies unknowns, which in turn implies the possibility of failure, in the sense that the advanced concept or idea that is being researched may not be achievable. Were the concept achievable with little or no risk of failure, the project would not be a *research* effort, but a *development* effort.

DARPA over its history has grappled with how to interpret or pursue *advanced* research, both in contrast to the broad array of research being conducted within and for DoD, and relative to its perception of the needs at the time.

Recently DARPA stated its mission as follows:

> DARPA is a Defense Agency with a unique role within DoD. DARPA is not tied to a specific operational mission: DARPA supplies technological options for the entire Department, and is designed to be the "technological engine" for transforming DoD.... a large organization like DoD needs a place like DARPA whose *only* charter is radical innovation. DARPA looks beyond today's known needs and requirements.

It is clear from DARPA's history that within the scope of this mission the emphasis and interpretation of *advanced* research have varied, particularly in terms of (1) the degree and type of risk[6] and (2) how far to go toward demonstration of application. At times with changing circumstances the agency has had to reassess its project mix and emphasis due to determinations both internally and within the Office of the Secretary of Defense regarding the appropriate level of risk and the need to demonstrate application potential. In a sense these somewhat contradictory imperatives serve as the extreme points on a pendulum's swing. As DARPA is pulled toward one of the extremes, often by forces beyond itself, including Congressional pressures, there are countervailing pressures stressing DARPA's unique characteristics to do *militarily relevant advanced research.*

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[6] Risk has several dimensions: (1) lack of knowledge regarding the phenomena or concept itself; (2) lack of knowledge about the applications that might result if the phenomena or concept were understood; (3) inability to gauge the cost of arriving at answers regarding either of these; and (4) difficulty of determining broader operational and cost impacts of adopting the concept. As answers about (1) become clearer through basic research, ideas regarding applications begin to proliferate, as do questions of whether and how to explore their prospects. DARPA is at the forefront of this question and has the difficult job of determining whether enough is known to move toward an application and, if so, how to do so. At times this can be very controversial, as researchers may feel they do not know enough to guarantee success and are concerned that "premature" efforts may in fact create doubts about the utility and feasibility of the area of research, resulting in less funding and (from their perspective) less progress. DARPA, however, has a different imperative than the researcher to strive to see what can be done with the concepts or knowledge, even if it risks exposing what is not known and what its flaws are. This tension is endemic in DARPA's mission and at times has put it at odds with the very research communities that it sponsors.

At the other end of the spectrum, as projects demonstrate application potential, DARPA runs into another set of tensions, not with the researcher, but with the potential recipient of the research product. Given that the ideas pursued are innovative, perhaps revolutionary, they imply unknowns to the user in terms of how they will be implemented and how this implementation will affect their, the implementer's, overall operations. To this end the potential users seek to reduce their uncertainty, in what is a highly risk-intolerant environment, by encouraging DARPA, or some other development agency, to carry forward the concept until these risks are minimized, or simply ignoring, delaying or stretching out its pursuit. While achieving transition can be increased by additional risk reducing research, this also entails substantial additional cost and raises the issue of mission boundaries.

There have been several occasions in DARPA's history when its management has determined that it has done enough in an area to demonstrate the potential of a specific concept—such as Unmanned Air Vehicles (UAVs)—and that it is thus time for others to fund development of its application and acquisition. These decisions have at times resulted in a potential concept becoming a victim of the "valley of death", with the application either failing to be realized, or, as in the case of UAVs, taking over a decade with special high-level attention of OSD to come to fruition. Developing mechanisms to engage potential "customers" in an emerging concept and working with these prospective developers and users as the ideas mature is a key aspect of DARPA project management.

DARPA's Key Characteristics

It was recognized from the outset that DARPA's unique mission required an organization with unique characteristics. Among the most salient of these:

- **It is independent from Service R&D organizations**

DARPA neither supports a Service directly nor does it seek to implement solutions to identified Service requirements. Its purpose is to focus on capabilities that have not been identified in Service R&D and on meeting defense needs that are not defined explicitly as Service requirements. This does not mean that DARPA does not work with the Services, but it does mean that it does not work the requirements that drive Service R&D.

- **It is a lean, agile organization with risk-taking culture**

DARPA's charter to focus on "high risk; high payoff" research requires that it *be tolerant of failure and open to learning*. It has had to learn to manage risk, not avoid it. Because of its charter, it has adopted organizational, management and personnel policies that encourage individual responsibility and initiative, and a high degree of flexibility in program definition. This is one reason that DARPA does not maintain any of its own labs.

A primary aspect of DARPA's lean structure is that it centers on and facilitates the initiative of its Program Managers. **The DARPA Program Manager is the technical champion who conceives and owns the program**. As the Program Manager is the guiding intelligence behind the program, the most important decisions of DARPA's few Office Directors are the selection of and support of risk-taking, idea-driven Program Managers dedicated to making the technology work.

- **It is idea-driven and outcome-oriented**

The coin of the realm at DARPA is promising ideas. The Project Manager succeeds by convincing others—the Office Director and the DARPA Director—that he or she has identified a high potential new concept. The gating notion isn't that the idea is well-proven, but that it has high prospects of making a difference. The DARPA Program Manager will seek out and fund researchers within US defense contractors, private companies, and universities to bring the incipient concept into fruition. Thus, the research is out-come driven to achieve results toward identified goals, not to pursue science per se. The goals may vary from demonstrating that an idea is technically feasible to providing proof-of-concept for an operational capability. To achieve these results the Program Manager needs to be open to competing approaches, and be adroit and tough-minded in selecting among these.

Which DARPA?

While the concept of DARPA as a "high-risk—high pay-off" organization has been maintained, it also has been an intrinsically malleable and adaptive organization. Indeed DARPA has morphed several times. DARPA has "re-grouped" iteratively—often after its greatest "successes". The first such occasion was soon after its establishment with the spinning off of its space programs into NASA. This resulted in about half of the then ARPA personnel either leaving to form the new space agency, or returning to a military service organization to pursue military-specific space programs. A few years later then DDR&E John S. Foster required ARPA to transition its second largest inaugural program—the DEFENDER missile defense program—to the Army, much to the consternation of some key managers within ARPA. Also early in its history ARPA was tasked by Foster, acting at the behest of Secretary of Defense McNamara, to conduct a program of applied research in support of the military effort in Viet Nam. At the same time ARPA began what was to become its most famous program—the information technology program that among other things spawned the internet.

More important than the variety of the programs is that they demonstrate the quickness that DARPA took on a new initiative and also how rapidly its programs will move—sometimes more rapidly than its supporters within DARPA desire. However, rather than particular programs or technologies becoming the identifier of what DARPA is, its identity is its rapidly taking on and assessing new ideas and concepts directed at daunting military challenges or overarching application prospects. While the dwell time on new ideas may vary and DARPA may return to the concept iteratively over its history—most notably with its return to missile defense in the 1970s leading to SDI in the 1980s—its hallmark is to explore and create new opportunities, not perfect the ideas that it has fostered.

As an example of its adaptiveness, in the mid-1970s DARPA management in conjunction with the Office of the Secretary of Defense made some crucial decisions on refocusing the organization. With the transitioning of DEFENDER to the Army, ARPA went through a period of exploration and gestation that actually resulted in its budget dropping by 50%. In essence, ARPA management was looking for the next "big thing"—or in the words of Eberhard Rechtin, the Director at that time, "ARPA had more money than it had ideas". This period of technical exploration led to the incubation of incipient new ideas in sensors—some of which fostered night vision, electronics and information processing, and even weapons concepts—such as terminally guided submunitions. This period of introspection and exploration laid the ground work for a next generation of programs that scaled-up and integrated many of these ideas into major systems concepts—ranging from the internet, to stand-off precision strike weapons, to stealth.[7]

Over the next ten-years DARPA engaged in ambitious and risky scale-up proof-of-concept demonstrations of several of these incipient capabilities, introducing a set of demonstration programs that were radically different than the earlier exploratory technology projects. Over this period DARPA introduced new organizational and management approaches with the explicit purpose to not allow these big demonstrator projects to overwhelm the remaining research agenda, and to drive these demonstrators toward transition and out of DARPA.

Later in its history DARPA was given a range of other roles—some of which might be seen as incongruent to its name, as they were neither defense, advanced research, or even projects. Among these are SEMATECH and the Technology Reinvestment Program (TRP). These and other programs while ancillary and perhaps diversions from DARPA's core focus show how DARPA could quickly adapt and successfully take on such new, temporary excursions—both of which were relatively short-lived. Moreover, even though both of these were substantial undertakings; they did not interfere with DARPA's main mission of exploring highly innovative new concepts.

Thus from this quick synopsis of DARPA's perturbed history should come a conclusion:

> **There is not and should not be a singular answer on "what is DARPA"—and if someone tells you that—they don't understand DARPA**

[7] See Richard Van Atta and Michael Lippitz, *Transformation and Transition: DARPA's Role in fostering an Emerging Revolution in Military Affairs*, IDA Paper P-3698, (Alexandria, VA: Institute for Defense Analyses, March 2003).

DARPA's unique focus is "high risk—high payoff" research. But, clearly this has not been the only focus. Moreover, the content and focus of that research has changed with the circumstances and need. A crucial element of what has made DARPA a special, unique institution is its ability to re-invent itself, to adapt, and to avoid becoming wedded to the last problem it tried to solve.

DARPA roles

While we have emphasized DARPA's adaptability, this is not to say that there aren't some underlying elements to what DARPA does. While there have been some additional ad hoc activities thrown in over time, such as its oversight of SEMATECH, DARPA has had significant roles—with a varying mix—in the following:

- Turning basic science into emerging technologies
- Exploring "disruptive" capabilities (military and more generic)
- Developing technology strategy into a Defense strategy
- Foster revolution or fundamental transformation in a domain of technology application (e.g., the internet or stand-off precision strike)

Key elements of DARPA's success

There are several key elements in DARPA's succeeding in its unique role as an instigator of radical innovation.

- **Create surprise; don't just seek to avoid it**

  DARPA mission is to investigate new emerging technological capabilities that have prospects to create disruptive capabilities. It is differentiated from other R&D organizations by a charter that explicitly emphasizes "high-risk, high payoff" research.

- **Build communities of "change-state advocates"**

  DARPA program managers may often themselves foster a specific concepts or technological approach that they seek to explore and develop. But they almost never are they main, let alone sole, investigator of the notion. Rather it is DARPA's motif to instigate cooperation among a group of forward-looking researchers and operational experts. . In this sense, **DARPA's success depends on it being a leader and catalyst in developing this community of interest.**

- **Define challenges, develop solution concepts, and demonstrate them**

  One aspect of DARPA's success has been efforts to define strategic challenges *in detail.* Since its inaugural Presidential Issues, DARPA has been problem focused, seeking breakthrough, change-state approaches to overcome daunting issues. This has been true in the military realm from the outset. DARPA-sponsored researchers under Project DEFENDER conducted detailed assessments of intercontinental missile phenomena for both defense and offense.[8] Later in the late 1970s, DARPA funded studies to understand how the Warsaw Pact was postured against Western Europe in order to determine how technology could provide a means to offset the Warsaw Pact's numerical and geographic advantages. This planning led to DARPA research in both stealth and stand-off precision strike, which provided the basis for Secretary of Defense Harold Brown's and Director of Defense Research and Engineering William Perry's "Offset Strategy".[9]

  Such detailed conceptual work also facilitated DARPA's non-military research—explicitly that in information technology. JCR Licklider came to DARPA as head of the Information Processing Techniques Office with a vision on man-computer symbiosis that grew in specificity as he collaborated with others, especially Robert Taylor, to present a perspective of internetted computers providing capabilities for collaboration and data interchange amongst researchers.[10] Overtime IPTO grew this initial concept into an increasingly inter-connected strategy.

Tension between DARPA roles

DARPA has been a pursuer of new breakthrough technologies *independent of defined needs.* It also has been a developer of concept prototypes and demonstrations that *address needs* (but not defined requirements). While complementary, these are substantially different roles requiring different management approaches and different types of researchers. The first type of endeavor requires an exploratory, somewhat unstructured approach seeking out alternatives amongst competing ideas. The latter focuses on taking a specific set

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[8] For example, in the 1960s and 1970s DARPA funded studies at the then new Institute for Defense Analyses on missile offense and defense first under the STRAT-X project on ICBM offense-defense followed by then PEN-X study which assessed both US and Soviet capabilities to penetrate missile defense systems.

[9] Richard Van Atta and Michael Lipptiz, Transformation and Transition: DARPA's Role in fostering an Emerging Revolution in Military Affairs, IDA Paper P-3698, (Alexandria, VA: Institute for Defense Analyses, March 2003).

[10] JCR Licklider, "Man-Computer Symbiosis," *IRE Transactions on Human Factors in Electronics,* volume HFE-1, pages 4–11, March 1960 and JCR Licklider and Robert Taylor, "The Computer as a Communications Devise," *Science and Technology,* April 1968.

of emerging capabilities and combining them into a demonstration of proof-of-concept. Such demonstrations are generally larger in scale and more resource intensive than exploratory research. Moreover, rather than exploratory, they are aimed at assessing the merit of a specific concept. Indeed, demonstration prototype efforts can be "resources sumps", as they are both uncertain and costly. Therefore the DARPA Director has needs to attentively oversee these while maintaining and protecting the more exploratory research efforts.

DARPA's Successes

Over the nearly fifty years since its inception DARPA has had several major accomplishments that distinguish it as an innovative organization. While these have been recounted elsewhere, it may be useful here to summarize to illustrate the scale, scope, and varying types of innovative capabilities that DARPA helped to instigate.[11]

3rd Generation Info Tech—the Creation of Interactive Information[12]

The singularly most notable technology accomplishment that DARPA is known for is the development of what is now known as modern computing, as embodied in the personal computer and the Internet. While this achievement had its origins in remarkable vision of one man, JCR Licklider, its coming to fruition speaks volumes for the nature of DARPA as an organization and the willingness of its management to support and nurture the pursuit of such an extraordinary perspective.

The vision that Licklider brought to DARPA was one of a totally revolutionary concept of computers and how they could be used. He foresaw that rather than being fundamentally highly automated calculating machines, computers

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[11] DARPA's most notable past technical accomplishments have been documented in several prior studies. For an overview of many of DARPA's programs from its inception see Richard Van Atta, et al, *DARPA's Technical Accomplishments*, Volumes I-III, IDA Papers P2192, 1990, P-2429, 1991, and P-2538, 1991. For a more in-depth review of a set of key programs in the 1970s and 1980s that had transformational impact on US military capabilities see Richard Van Atta and Michael Lippitz, et al, *Transformation and Transition: DARPA's Role in Fostering an Emerging Revolution in Military Affairs,* IDA Paper P-3698, (Alexandria, VA: Institute for Defense Analyses, March 2003). DARPA's formative role in information technology has been reviewed in detail by Arthur L. Norberg and Judy E. O'Neill. *Transforming Computer Technology: Information Processing for the Pentagon, 1962-1986* (Baltimore, 1996) and M. Mitchell Waldrop, *The Dream Machine: JCR Licklider and the Revolution that Made Computers Personal*, 2002.

[12] M. Mitchell Waldrop. *The Dream Machine.*

could be employed as tools in supporting humans in creative processes.[13] However, to do so would require entirely new, yet non-existent computer capabilities that included the underpinnings for

- interactive computers
- Internetted computing
- Virtual reality
- Intelligent systems

Licklider's extraordinary notion of "man-computer symbiosis" was a fundamental vision that foresaw using new types of computational capabilities to achieve first augmented human capabilities and then possibly artificial intelligence.

He then identified prerequisites that were the underpinnings for this entirely new approach to using computers, which included

- Entirely new types of data-processing equipment and programs that facilitated researchers interacting with *their* computers in real-time.
- Taking advantage of the speed mismatch between the computer, which can perform nearly instantaneously and the slower and more deliberative human. To overcome this mismatch, the computer must divide its time amongst several users [the concept of time-sharing].
- The creation of the "Thinking Center" "a Network of libraries and information storage connected by wideband communications...to individual users"
- Memory and memory organization developed and optimized for search and retrieval
- Entirely different computer language that is "goal oriented" rather than step by step process oriented
- Completely novel input and output mechanisms to overcome the cumbersome punch cards and reams of computer printout with such radical notions as touch-screen displays and even speech recognition

Licklider brought these inchoate notions to DARPA when he was named Director of its Information Processing Techniques Office (IPTO). He brought a powerful vision of what could be and used this as the basis for sustained investment in the underlying technologies to achieve the vision. These investments were aimed at adventurous innovators in academia and in industry—mostly small enterprises on the fringe of the information processing industry then

[13] JCR Licklider, "Man-Computer Symbiosis."

dominated by IBM, such as Bolt, Baranek and Newman (BBN). Moreover, there was an underlying concept of how this investment would lead to applications relying on an entrepreneurial dynamic. Thi s effort became the gestation of a concerted effort that culminated in the ARPANET, as well as a number of technological innovations in the underlying computer graphics, computer processing, and other capabilities that led to **DARPA's fundamental impact on "making computers personal"... a truly change-state vision which had fundamental impact in fostering a transformational concept and the creation of an entire industry.**

DARPA's Role in Creating a Revolution in Military Affairs[14]

DARPA has been instrumental in developing a number of technologies, systems and concepts critical to what some have termed the **Revolution in Military Affairs** (RMA) that DoD implemented in the 1990s based on R&D DARPA conducted over the prior fifteen years. It did so by serving as a virtual DoD corporate laboratory: a central research activity, reporting to the top of the organization, with the flexibility to move rapidly into new areas and explore opportunities that held the potential of "changing the business." It was a virtual laboratory because DARPA did not perform research directly but rather acted as a catalyst for innovation by articulating thrust areas linked to overall DoD strategic needs, seeding and coordinating external research communities, and funding large-scale demonstrations of disruptive concepts. In doing so, the DARPA programs presented senior DoD leadership with opportunities to develop disruptive capabilities. When these programs received consistent senior leadership support, typically from the highest levels of the Office of the Secretary of Defense, they transitioned into acquisition and deployment. At other times, without this backing from highest reaches of the department, only the less disruptive, less joint elements moved forward.

[14] This section draws upon Richard Van Atta and Michael Lippitz, et al, *Transformation and Transition: DARPA's Role in fostering an Emerging Revolution in Military Affairs*, IDA Paper P-3698, (Alexandria, VA: Institute for Defense Analyses, March 2003).

An example of one of the most successful DARPA programs is its championing of stealth. While a radical and controversial concept, DARPA's stealth R&D had most of the properties listed above. DARPA harnessed industry ideas. Low-observable aircraft had been built before, for reconnaissance and intelligence purposes, but not pursued for combat applications. The Air Force had little interest in a slow, not very maneuverable plane that could only fly at night. After considerable engineering work, the HAVE BLUE proof-of-concept system enabled top OSD and Service leadership to proceed with confidence to fund and support a full-scale acquisition program. OSD leadership kept the subsequent F-117A program focused on a limited set of high priority missions that existing aircraft could not perform well—e.g., overcoming Soviet integrated air defenses—and worked with Congress to protect its budget, with a target completion date within the same administration. The result was a "secret weapon" capability—exactly what DARPA and top DoD leadership had envisioned.

VISION: DARPA conception, development and demonstration of disruptive capabilities

DARPA's higher-risk, longer-term R&D agenda distinguishes it from other sources of defense R&D funding. ***Perhaps the most important effect of DARPA's work is to change people's minds as to what is possible.*** A fundamental tension for DARPA is balancing its pursuit of high-risk research independent of a defined need with its demonstration of capabilities that address a specific strategic problem (but not defined requirements). Although integration projects may be just as "high risk" as research projects, philosophically, culturally, and managerially, these are very different processes. The DARPA Director needs to mediate between these missions and, more importantly, bridge the two communities. DARPA has been effective in part because a strong axis between DARPA and top OSD leadership formed around ambitious *outcomes*, not technologies per se. An outcome orientation is particularly important in explaining to Congress what DARPA is doing and why.

LEADERSHIP: Acquisition and Deployment of Disruptive Capabilities

DARPA's history shows that *if fielded disruptive capabilities are the objective, it is insufficient for DARPA to create an example and then rely upon the traditional Service acquisition system to recognize its worth and implement it.* Because acquisition and deployment of disruptive capabilities challenge existing programs and bureaucracies, it is difficult to find eager Service customers for them. Also, because new capabilities are not technically mature or operationally robust, the Services will generally be reluctant to take on the significant and potentially costly risk reduction efforts required to move them into acquisition. Hence, rapid acquisition and deployment of disruptive capabilities requires an integrated and consistent senior leadership effort, typically from the Director of Defense Research and Engineering or the Under Secretary of Acquisition, Technology and Logistics. These senior OSD leaders must judiciously exercise their authority to overcome the resistance of people to new ideas, of acquisition organizations to perceived competition, and of requirements and acquisition organizations to uncertainty and risk.

Energy and Climate Change—A DARPA Model?

DARPA's successes in spurring technological innovation have led to numerous calls for applying "the DARPA model" to other issues than national defense. As noted above, one area that has received particular attention is energy technology. Does the DARPA model provide a useful approach to address issues of energy research and development? The foremost question is what is the imperative for radical, transformative R&D in energy technology equivalent to DARPA's national security concern? Are energy security and stemming climate change and its effects comparable motifs?

DARPA is chartered to identify and pursue potential technological capabilities that could provide fundamental advantage to the US relative to existing or potential adversaries. The need to be ahead of all others to "avoid technological surprise" in the interest of national security is a recognized imperative for making exploratory high-risk investments. Do such interests as "energy independence" or ameliorating climate change provide sufficient imperatives for energy-related advanced research?

DARPA has had the imprimatur of the Secretary of Defense to both engage in highly uncertain R&D not explicitly focused on identified requirements and to promote the application of emergent, often disruptive capabilities based on such research. In essence the Secretary of Defense has played the role of the Chief Executive Officer protecting and supporting the Director of DARPA as the director of innovation—seeking new technological capabilities that can redirect and revitalize an enterprise. While the Department of Energy has pursued advanced S&T in its Office of Science, DOE has not had the type of implementation-focused efforts of advanced technology that have been promoted by DoD leadership in bringing DARPA developments into fruition. While DOE clearly has an important, perhaps dominant role in current energy research, and this research has repercussions for climate change, the two are not synonymous. For example, most of the current energy research agenda is driven by energy efficiency and security concerns focusing on incremental improvements of existing approaches. Also, the scope of climate change R&D goes well beyond the scope of DOE. Evidencing this, the Bush Administration has organized its climate change science and technology efforts via an interagency working group that coordinates a Climate Change Science Program (CCSP) and a Climate Change Technology Program. Each of these programs entails activities of multiple departments and agencies, including DOE, DOC, NASA, DOD, NSF, and the EPA. Moreover, it is debatable whether some major aspects of a climate change focus are within DOE's venue—especially those related to possible measures to combating the effects directly—such as "geoengineering" related to mitigating the effects of atmospheric changes caused by green house gasses. Indeed, such radical notions as dispersing particles in the atmosphere, are the type of high-risk, high payoff research that is most commonly associated with DARPA. Yet, it is not clear whether any individual agency has the responsibility to direct and oversee such research.

Thus, the organizational question for "ARPA-E" is much more problematic than that faced by DARPA. DARPA's job explicitly is national security—and the main government focus has been the Department of Defense. DARPA has been stretched into broader venues including support for the intelligence community and also the support of more generic commercially-related programs—at one time labeled "dual use" technologies. The intelligence-related aspects of DARPA, while at times collaborated and coordinated with non-DOD interests, particularly the CIA, are clearly linked to the national security mission and the fact that DoD operates its own vast intelligence operations.

This raises another vexing question: How would results of an Energy ARPA be brought into fruition? DARPA has developed an established network of implementation paths that varied by technology and application. It has developed strategies for interacting with military users and developers for bringing military capabilities into application using the support of OSD when needed. It has developed various mechanisms for supporting incipient technological capabilities in universities and small enterprises and provided systematic support that builds an interlinked set of underpinning technologies that together, iteratively have moved closer to an ultimate transformational vision. Can an Energy ARPA obtain the freedom of movement to organize such implementation focused investment strategies? Who would be the organizations that would take the results of ARPA-E's proof-of-concept research and move it into the next level of development? In creating an ARPA-E how clearly defined should be the mechanisms it would draw upon to move its ideas forward? It would be an unfair reading of history to say that all of this was well understood when ARPA was founded. For the military side of the equation the role of the Secretary of Defense and the DDR&E cannot be overstated. Particularly in the 1960s through the 1980s OSD interacted closely with the Director of DARPA in laying out priorities and directions—while the Director was clearly responsible for research.[15]

[15] The interaction between the DARPA director and OSD is important here. This was not a one-way street with OSD handing down specific focus for research, rather it was a dialogue in which the OSD, usually through the DDR&E, today the USD(AT&L), would lay out military and technical challenges it saw as priorities and DARPA would develop its perspective on what emerging technical capabilities might address these. DARPA, often in conjunction with other organizations, such as the Defense Nuclear Agency (DNA), would conduct studies and provide input to high-level DoD leadership on options for addressing daunting strategic concerns.

The path undertaken by DARPA in bringing its technical results into application has been that of a somewhat distant or indirect supporter of the implementation process. In essence DARPA's role in technology transition has been to support technology demonstrations often in conjunction with potential users or through a series of "boot strapped" implementations of new technologies by employing the technology development as inputs to other DARPA research. This latter approach has been particularly effective in the area of information processing technologies, where for example, the DARPA-supported computer workstations were specifically acquired for use by DARPA-funded integrated circuit technology development programs.[16] When the results of the technology development most likely would have to be adopted and adapted by the commercial sector the DARPA approach has generally been one of encouragement, but not direct involvement. The concern that commercialization is a function that is best left to others than those in government has led to proposals for creating alternative, non-governmental mechanisms, such as an Energy Technology Corporation, as suggested by John Deutch.[17]

In employing a DARPA-model to another area of research, it is important to understand that DARPA began as relatively small, highly focused organization that was explicitly taking on problems that were of relatively little priority to existing military R&D organizations. Yet, the issues were of great importance and priority to senior leadership—including the Secretary of Defense and the President. Later, as the policy and technological circumstances changed, DARPA morphed and adapted. In particular, DARPA has been focused on pursuing advanced technology projects that could potentially "make a difference"— and wedded not to the success of any particular project. It has been an "innovation farm" and idea incubator. It has only exceptionally taken on the actual implementation of a technology—and then only as a last resort, or as a very incipient step in application

[16] Van Atta, et al, *DARPA Technical Accomplishments,* Volume II, Chapter XVII, "VLSI : Enabling Technologies for Advanced Computing," Alexandria, VA: Institute for Defense Analyses, April 1991.
[17] John Deutch, "What Should the Government Do To Encourage Technical Change in the Energy Sector?" *MIT Joint Program on the Science and Policy of Global Change*, Report No. 120, *May 2005.*

prototyping. If another department were to stand up an "ARPA-like" organization, it should not try to invent a full-blown, full scale operation based on DARPA after 30 years. Rather, it should endeavor to build the organization organically, adaptively focusing on explicit high priority mission challenges. The idea should not be to make something look like DARPA; it should be to identify and organize advanced research around imperatives that are similar in nature to those that have driven DARPA.

DARPA has been able to take on high-level issues that are disruptive of current operations and technical interests. The example of stealth, above, shows how it fostered a concept that was received hostilely by the main service that was to employ it—the Air Force—and initially rejected by the Navy. Even in its information technology research DARPA confronted a major, well-ensconced vested interest in IBM, who at the time totally dominated not only the computer industry, but also computer research.[18] Can a civilian organization maintain independence of its technology program from such powerful "vested interests"? DARPA had certain advantages that may be difficult to emulate in a non-DoD organization, particularly today. First, at its inception it had the cover of the initial set of Presidential Issues, vested on it directly from the Secretary of Defense. It was given a charter to take on issues that the existing Service R&D structure had failed to give adequate priority to and the results of which were manifestly wanting. As it successfully addressed its initial set of programs it further gained the support of OSD which gave it the top cover it needed. If an Energy ARPA is to have any chance of success it will need this level of support from both the Secretary of Energy and the White House.

[18] See Kenneth Flamm, *Creating the Computer*, Washington, DC: Brookings Institute, 1988, for a discussion of IBM's dominant role in computer research in the early 1960s.

Issues in Establishing an ARPA-E

Some key elements that would need to be addressed, and in some cases directly overcome, if an effective ARPA-E were to be created, are

1. Leadership support – As discussed above, ARPA had President Eisenhower's direct and strong support, and this support has generally been sustained with both the White House and the Secretary of Defense.
2. Congressional oversight – One issue for ARPA-E, relative to DARPA is that DARPA enjoys Congressional oversight that is relatively simple, and has generally had the backing of key members and staffers.
3. Existing Lab structure – ARPA -E will need to contend with a research infrastructure in the National Laboratories, that had no such precedent in DoD. The Service R&D structure lacked the scale and scope of the current "energy labs" and also the support on Capitol Hill that these labs have.
4. Incumbent business interests – DARPA has succeeded by developing and fostering a community of interest ranging from academics to business. It developed these communities piece by piece from the ground up, based on technological capabilities and prospects. It has been able to find within that community interested and innovative participants who were willing to experiment with new ideas. In its information processing technology development, DARPA was able to build an alternative base despite the dominant presence of IBM. It is unclear whether the firms currently in energy production and usage will be open to such experimentation and whether alternative firms and even alternative sectors can grow within the energy industrial structure.

An Energy ARPA has been proposed as a way to respond to critical energy needs by accelerating research in game-changing technologies. Advocates of this new approach need to make a strong case on what it is they see as needing to be done that the current R&D processes are not doing successfully. In essence, they need the moral equivalent of their Sputnik to galvanize support for such a novel agency. Is the lack of a robust hybrid automobile program in the US an example that has similar sway? Is the hydrogen energy effort in this country similar to the ineffective Service response to Soviet ICBMs in the 1950s to provide a stimulus to creating an Energy ARPA? Is the recognition of the anthropogenic climate change impacts reaching a point where high-level policy makers have come to realize that incremental approaches based on existing technologies is so insufficient that a radical enterprise is needed?

Chairman TOM DAVIS. Thank you very much.
Dr. Hoffert, thanks for being here.

STATEMENT OF MARTIN HOFFERT

Mr. HOFFERT. Thank you, Mr. Chairman. You may have to bear with me. I have a bit of a cold.

What I would like to do is outline some of the specific attributes of the climate energy problem that make it a candidate for ARPA or DARPA-like R&D, but I would also like to distinguish between several contexts which are being used interchangeably.

A Manhattan Project or an Apollo Program Project is not the same as a DARPA-type organization, and neither is an exploratory research program, so let me just discuss what I think is the objective problem, the objective climate energy problem.

What we are faced with is a kind of existential challenge to our high-technology civilization. Almost universally all the countries of the world are in favor of continued economic growth, roughly at 2 or 3 percent a year. That is built into all of the models. At the same time, those of us who have worked on the climate problem—and that includes myself.

I have worked on this for almost 30 years. I was, in fact, a colleague of Jim Hansen's at the Institute for Space Studies back in the 1970's. We have, over time, evolved a pretty good understanding quantitatively of this issue, and if we were to say that we don't want the planet to warm more than 2 or 2½ degrees, which might lead to irreversible melting of the ice caps, and at the same time require that economic growth continue at 2 or 3 percent a year—and that seems to be what everyone wants to do—that imposes mathematical constraints on not only the amount of emissions that we would be allowed to emit but on the amount of energy that we would have to either produce by alternate energy technologies that don't emit CO_2 or energy demand reducing technologies that would give us the same end products but with less input.

We have written several papers on this. The first paper we wrote was in 1998 where we first floated the idea of an Apollo or a Manhattan Project for energy. The week after that paper appeared in Nature, the editorial writers of Nature said this is really a bad idea because we know that the Jimmy Carter energy program had a lot of boondoggles, it wasn't really effective, and researcher is no substitute for political action. I want to come back to that in a minute, but because it is so important I must be sure that I say this at the beginning and don't forget.

There is a perception in some quarters that research can be used as an alternative to prompt implementation of things that we know how to do right now. I want to as strongly as possible say that is not the case. I favor a metaphor, a sort of World War II type metaphor. I think the problem we are facing is at least as challenging as winning the second world war.

We didn't stop fighting the second World War while the Manhattan Project was going on. We did the Manhattan Project, but by the time the war ended it did deliver a remarkable piece of technology that managed to change the shape of the world for the next 50 years, for better or for worse.

So I think that, although I won't refer to this any more, it is very clear that whatever we do on the R&D front has to be done in parallel with implementing everything that we have on the shelf right now.

Having said that, let me go to some specific problems that I think could benefit from an intense R&D of—I believe that the DARPA model might be very valuable in some of these problems.

What do we actually have in the coffers now to provide the levels of energy that we need to run the world, which is something like 300 to 400 percent of the energy that we are using right now? In order to stabilize at 2 degrees warming or less, we are going to have to have some energy source X if we are going to do it with supply that can provide between 100—or a combination of sources—between 100 and 300 percent of all the energy that we use now without putting CO_2 in the atmosphere.

To put this into context, Fermi's first nuclear reactor in 1942 was farther in time than 2050 is from us, and roughly 5 percent of our primary power comes from nuclear power. So whatever this energy source is, it will have to grow something like 20 to 60 times faster than the last revolutionary energy source we had.

That is an immense challenge, if you put it in that framework. There are other ways of stating it. My colleague Rob Socolow uses the metaphor of wedges. But it is a major, major job and it is not going to get done, in my opinion, unless we have a targeted program to develop three classes of technology, each one of which has a number of variants.

The first class is coal, with carbon sequestration or carbon capture. There is a lot of coal, and if it weren't for global warming this would really be a problem for the 22nd century or beyond. We can make synthetic fuels out of coal, but CO_2 and the climate problem has moved it to the agenda where we have to start working on this right now. In fact, 850 new coal-fired power plants are being built right now by the United States, China, and India, and the emissions from those plants are going to overwhelm Kyoto emission reductions by a factor of five.

The U.S.'s response to climate change, as put forth by Negotiator Harlan Watson at the recent round of Kyoto discussions in Montreal, was something called future gen, where DOE is going to build a plant that will make hydrogen and electricity from coal gassification. We don't even have a location for that plant, and the contribution that we can expect from that technology is very small compared to what we are already doing. So, although coal is important, we are rapidly building precisely the wrong infrastructure marching in the wrong direction, tying up capital for 50 to 75 years.

The second general category are safe or so-called green nuclear reactors. Nuclear power has come a long way, although we haven't in this country built a new reactor for at least 30 years. We need to come to grips with the issue of what it would take to generate nuclear power sustainably, and it is not clear that once the reactor is burning the U235 isotope can do it.

That is less than 5 percent of natural uranium. There are alternative ideas that involve breeders that may involve using folium. Those were always parts of the discussion back in the 1970's, but the institutional memory of that has dimmed, and I believe we are far too modest in our plans for nuclear and could really use some innovative ideas to drive us toward a sustainable energy source.

The third category and the one that I am most identified with and favor the most is renewable energy, primarily solar and wind energy. These energy sources are low intensity, intermittent, and widely distributed. If we wanted to use these sources, if we wanted to get, let's say, one-third of our primary power from renewables, one-third from green nukes, and one-third from coal sequestration, we really need to invent and deploy entirely new systems for transmitting and storing this energy. Indeed, the transmission and the storage of the renewable energy may become the cost pacer in the implementation of renewable energy beyond the point where renewables can penetrate as a niche market. I think that is another area that could benefit from a DARPA-like program.

This emphasis on technology, which in no way should be construed as an alternative to prompt action, I also think is a way that we might entrain a bipartisan support for this. I had the pleasure yesterday of appearing before a different committee, the House Committee on Science, and Congressman Rohrabacher was there and made some remarks to the effect that he doesn't accept the theory of global warming, which I know, and that was fine.

But I also know Congressman Rohrabacher to be a proponent of space solar power, solar power satellites where one collects solar energy in Earth orbit and beams it to the Earth. He has given many talks in conferences on this that I have attended. On this score, we are technologically simpatico. I think it would be very important to have an R&D program in space solar power. After all, the world is spending $13 billion to build an experimental thermonuclear reactor that isn't even going to generate any power.

There is essentially zero funding for space solar power right now, although we did have a program in the 1970's. It is another discussion, but the one problem is that, if that technology or other related technologies like global super-conducting transmission lines, auto gyros that might be suspended in the upper troposphere which have the potential of providing all the electricity on Earth are not being supported because there is no champion within the Government agencies, particularly the Department of Energy. How are we ever going to start working on those ideas?

I think that I would imagine a sequence of events in which we might start with a relatively modest exploratory research technology program that would examine the feasibility of these ideas and start looking into experiments to test them. That might be eventually correlated with an ARPA-E program and, if it looks like it is very promising, it might transfer eventually to the Department of Energy.

I don't think I have very much time left but I have one more point that I think is vitally important. Many Americans believe that the job of the Department of Energy is to develop alternative energy sources that would be sustainable and allow us to live harmoniously with nature and yet retain our high-tech civilization. That is not the job, as you well know. DOE has two jobs, one is called stockpile stewardship, which means to make sure that the nuclear weapons we have will actually work if we ever had to use them, and the other is toxic waste cleanup. I put it to the committee that the Department of Energy, itself, should be reorganized. This is not such a far-out idea.

As you may well know, NASA has recently been reorganized and tasked with the mission of going back to the moon and going to Mars, perhaps without adequate funding but certainly heads rolled and there were internal reorganizations. I don't bring this up because I necessarily agree with that direction. In fact, I am quite unhappy about the loss of monitoring programs from space that have applicability to climate change. But I bring it up because it is not impossible for a Government agency to be reorganized and to be retasked, and I cannot think of a more important task for this century, a more important organizing principle than developing sustainable energy sources in harmony with natural ecosystems.

Thank you.

[The prepared statement of Mr. Hoffert follows:]

Testimony of
Dr. Martin I. Hoffert

"An Energy Revolution for the Greenhouse Century"

Before the United States House of Representatives Committee on Government Reform

"Climate Change Technology Research: Do we need a 'Manhattan Project' for the Environment?"

September 21, 2006

Martin Hoffert

An Energy Revolution for the Greenhouse Century

> When there is no vision, the people perish.
>
> —Proverbs 29:18

> You see things: and you say, "Why?"
> But I dream things that never were; and I say, "Why not?"
>
> —George Bernard Shaw, *Back to Methuselah* (1921)

> We choose to go to the moon in this decade and do the other things, not because they are easy, but because they are hard, because that goal will serve to organize and measure the best of our energies and skills, because the challenge is one that we are willing to accept, one we are unwilling to postpone, and one we intend to win. . . .
>
> —John F. Kennedy, Rice University, 1962

THE REALITY OF GLOBAL WARMING FROM THE BUILDUP OF FOSSIL FUEL CARBON dioxide in the atmosphere is no longer in doubt. Arctic sea ice, tundra, and alpine glaciers are melting, tropical diseases like West Nile virus and malaria are penetrating higher latitudes, and sea surface temperatures have risen to the point where Katrina-like hurricanes are not only more probable, but actually occur. Also taking place are the extinction of plants and animals adapted to cooler regimes but unable to migrate poleward fast enough to keep pace with a warming climate. Polar bears, already far north, may have nowhere to go. Ominously, the melting of Greenland and Antarctic icecaps is accelerating, threatening worldwide major sea level rise and coastal inundation (Hansen, 2006; Gore, 2006; Kolbert, 2006; Flannery, 2006).

These are well-documented facts, not alarmist predictions by desperate environmentalists in search of funding (Crichton, 2003) or some colossal hoax on the American people (Inhofe, 2003). Atmospheric warming from water vapor, CO_2, and other greenhouse gases is a basic principle of atmospheric science. It is responsible for maintaining earth as a habitable zone for life, and for making Venus, with its pure CO_2 atmosphere 100 times thicker than earth's, hot as metaphorical Hell. Cooling can result from suspended aerosol particles also produced by burning fossil fuels, but aerosols remain in the atmosphere a much shorter time than CO_2 and their cooling effect, so far, has mainly served to mask the full impact of warming from CO_2 emissions. (Some propose "geoengineering" climate by intentionally injecting aerosols to cool regions most threatened by global warming, such as the Arctic; see for example Teller, Wood, and Hyde, 2002). Heat temporarily stored in oceans can also delay or mask committed greenhouse warming, as can variations in the output of the sun and volcanic eruptions. But volcanoes, the sun, and the oceans cause surface temperature to rise and fall in a narrow range. In retrospect, it was inevitable that the explosive growth (on a geological time scale) of human CO_2 emissions, driven by population growth, industrialization and, most of all, by fossil fuel energy use, made it inevitable that human-induced warming would overwhelm climate change from all the other factors at some point. And we are at that point.

That fossil fuel atmospheric carbon dioxide would warm the planet was predicted over a century ago (Arrhenius, 1896). Roughly half the CO_2 input by humans remains in the atmosphere. The rest mostly dissolves in the ocean, creating excess acidity that marine organisms may not be able to tolerate, which is another problem. By the third quarter of the twentieth century, CO_2 buildup in the atmosphere was evident, although greenhouse warming did not emerge from background "noise" until the late 1980s. Hans Suess and Roger Revelle recognized early on that transferring hundreds of billions of tons of carbon in fossil fuels (coal, oil, and natural gas) formed over hundreds of millions of years and locked up in earth's crust to the atmosphere as CO_2 in a few hundred years was "grand

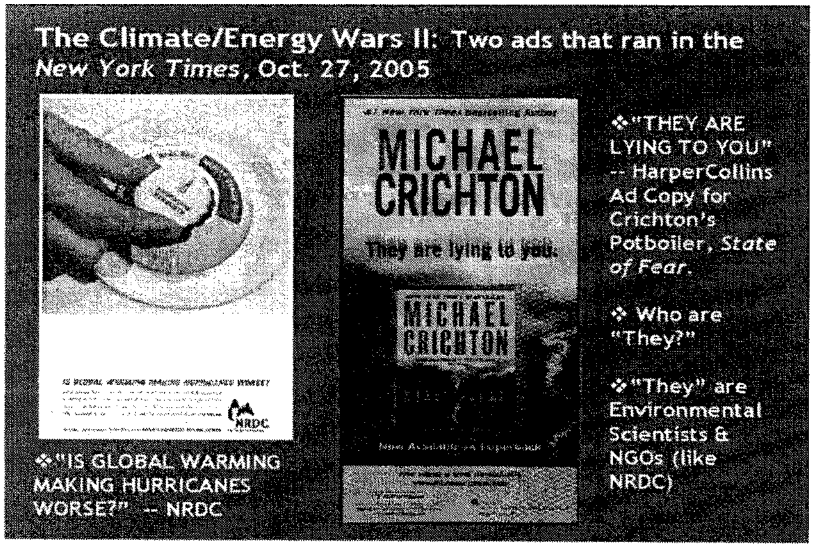


Fig. 1

geophysical experiment" on a scale unseen in human history (Revelle and Suess, 1957). Revelle was to be an influential professor of Al Gore's at Harvard, with ramifications reverberating today (Gore, 2006). By the late 1960s, Syukuro (Suki) Manabe, to my mind, an "Einstein" of atmospheric science, had worked out the detailed physics of how greenhouse gases affect atmospheric temperature from the surface to the stratosphere, including the water vapor feedback that roughly doubles warming from CO_2 alone (Manabe and Weatherald, 1967).

The discovery of global warming is a fascinating chapter in the history of science (Weart, 2003). Many phenomena that we are now seeing—heat going into the oceans, greater warming at the Arctic, volcanic and aerosol effects—were predicted decades ago. One group, including Steve Schneider, Richard Sommerville, Jim Hansen and this author, worked on this problem in the 1970s, primarily as an intellectual challenge in theoretical climate modeling and computer science at the Goddard Institute of Space Studies (GISS), a NASA-funded research institute near Columbia University started by Robert Jastrow while he was still in his twenties.

Back then, global warming was not yet politicized as it is now (figure 1). A "back of the envelope" calculation I did at GISS in the 70s suggested fossil fuel greenhouse warming would emerge from background temperature variations by the late 80s. So I thought it might be a good idea to publish some papers predicting this, which I did, as did colleagues at GISS and elsewhere. That limiting CO_2 emissions to avoid adverse global warming might disrupt consumerist civilization and multinational energy companies while putting a damper on industrialization of China and India was implicit, but academic.

Ironically, in light of the conclusive support for it developed at the research institute he founded (Hansen et al., 2005), Jastrow was highly critical of the global warming hypothesis. He never published peer-reviewed climate research, in stunning contrast to the present GISS director, Jim Hansen; but, on taking early retirement from NASA, Jastrow and Fred Seitz of Rockefeller University founded the Marshall Institute in Washington, D.C., a bastion of climate change deniers allied with the American Enterprise Institute, the Cato Institute, and other conservative think tanks in opposition to US participation in the CO_2-emissions-limiting Kyoto Protocol—the first implementation of the UN Framework Climate Change Convention (FCCC).

The United States, China, and India have not ratified Kyoto. Indeed, 850 new coal-fired power plants to be built in these countries by 2012 will overwhelm Kyoto emission reductions by a factor of five (Clayton, 2004). Avoiding "dangerous human interference with the climate system," the goal of the UN FCCC, is a daunting technological challenge because 85 percent of the world's energy comes from fossil fuel; and stabilizing global temperature at acceptable levels will require a revolutionary change in the world's energy systems (Hoffert et al., 1998; 2002; "Energy's Future," 2006). Although global warming is settled science, a public relations battle continues to rage.

Problems exist on both sides of the red-blue divide. In a searing critique of environmental nongovernmental organizations (NGOs) like the National Resources Defense Council and Environmental Defense, Shellenberger and Nordhaus (2005) argue that, despite major campaigns, environmental lobbies have had little success on the global warming front. The authors discount efforts by states in the United

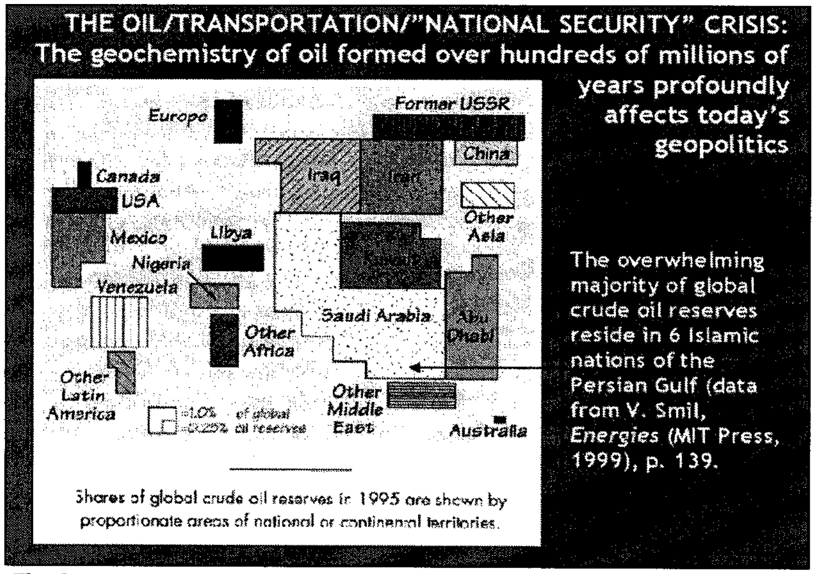


Fig. 2

States to create renewable energy portfolios with ambitious targets for alternate energy as so much public relations. They claim, with some justification, that "not one of America's environmental leaders is articulating a vision of the future commensurate with the magnitude of the crisis."

Why? Global warming is not only different in scale from prior environmental challenges (acid rain, heavy metal contamination, DDT, etc.)—its long-term planet-changing nature requires forethought and imagination to a much greater degree than the threats to which Homo sapiens has evolved adrenaline-pumping instinctive responses. The growth of human population, CO_2 emissions, and global warming in the past millennium are very recent from a human evolutionary perspective. For the first time in its history, Homo sapiens has begun to interact more or less as a unit with the global environmental system (Eldridge, 1996). Because modern technology developed *after* we evolved biologically, we lack appropriate instincts to deal with it—these having been unlikely to confer survivability in our evolutionary past. By default, we have to deal with the climate/energy problem cognitively. So far, we are not doing too well. As Carl Sagan observed, our reptilian brains motivate aggressive and tribal, as opposed to thoughtful, responses in ways we barely perceive and across many spheres of human behavior.

In the climate wars, deniers often get more vociferous as the evidence against their views gets stronger (Hoffert, 2003). The so-called hockey stick curve (developed by paleoclimatologist Mike Mann and colleagues) was recently attacked from the floor on Congress by Representative Joe Barton (R-Texas), based on cherry-picked information suggesting their statistics were flawed reported in the *Wall Street Journal*. Would that Rep. Barton, and legislators in general were better educated in statistical and scientific issues. But my experience briefing legislators and aides is that scientific illiteracy and intellectual laziness are rampant. Educated mainly as lawyers, many do not get it that nature does not care about human politics. (Unfortunately, some academics that should know better likewise argue that science is more a "consensual reality" than an objective description of nature deduced by the scientific method.) Too few bright and imaginative students pursue careers in science and engineering today. We need such students badly.

The hockey stick curve that shows a dramatic recent uptick in global temperature with much more to come is easily perceived as a threat not only to Big Oil and Big Coal, but also to election campaign funds. Easier to blame the messenger than think critically about this. The general trend of the Mann et al. (2003) hockey stick was independently verified by other researchers in a recent report by the National Research Council (NRC, 2006). Overwhelmingly, research-active climate scientists know we are entering climatic territory unseen in human history (Hansen, 2006). Our rapidly melting planet is so dominated by humankind's emissions that the present climatic era is being called the anthropocene (Crutzen and Ramanathan, 2003).

Most knowledgeable researchers are very concerned about global warming. Some, including this author, argue for research and development programs on an Apollo space program-like scale to create low-carbon alternate energy supply and demand-reducing technologies in time to make a difference (Hoffert et al., 1998, 2002; Rees, 2006). This effort should include prompt implementation of energy conservation, efficiency, and existing alternate energy sources (Lovins, 1989; Metz et al., 2001; Pacala and Socolow, 2004; Socolow, 2006).

Whatever the deep evolutionary reasons, the climate/energy issue competes for attention with other problems in the mind of the average citizen. A frequently asked question is: "Why even care about global warming and climate change?" The worst effects occur decades to centuries from now. In cost-benefit accounting, many economists strongly discount the present value of adverse future impacts and "externalize" (that is, neglect) the cost of environmentally degrading the global commons (Daly and Townsend, 1994). Economics is, of course, a legitimate branch of behavioral biology dealing with the allocation of scarce resources by Homo sapiens, one of millions of biological species inhabiting this planet. But, so far, in its predictive mode, it resembles astrology more than a hard science. Economist John Kenneth Galbraith went so far as to say, "The only reason for economists to produce forecasts is to make astrology look respectable" (Jaccard, 2005). Undaunted, Bjorn Lomborg, the "skeptical environmentalist" (Lomborg, 2001), convened a group of economists to prioritize investments in various challenges facing humankind. The group concluded in its "Copenhagen Consensus" that climate change, even if real, is near the bottom (Bohannan, 2004). Reading the group's findings, one is struck by how evolutionarily blind our species can be to existential threats. Among the problems with this indifference—noted by Harvard energy policy analyst John Holdren, and in his film and book, *An Inconvenient Truth*, by Al Gore—is that climate change is more an ethical than an economics problem.

An even more basic flaw to this physical scientist is that the environmental constraint of global warming on energy was entirely missed by the Copenhagen group. The late Nobel laureate Rick Smalley astutely observed that, although civilization has many problems, energy is key to them all. Smalley's list of problems encompasses energy, water, food, environment (including global warming), poverty, terrorism and war, 136

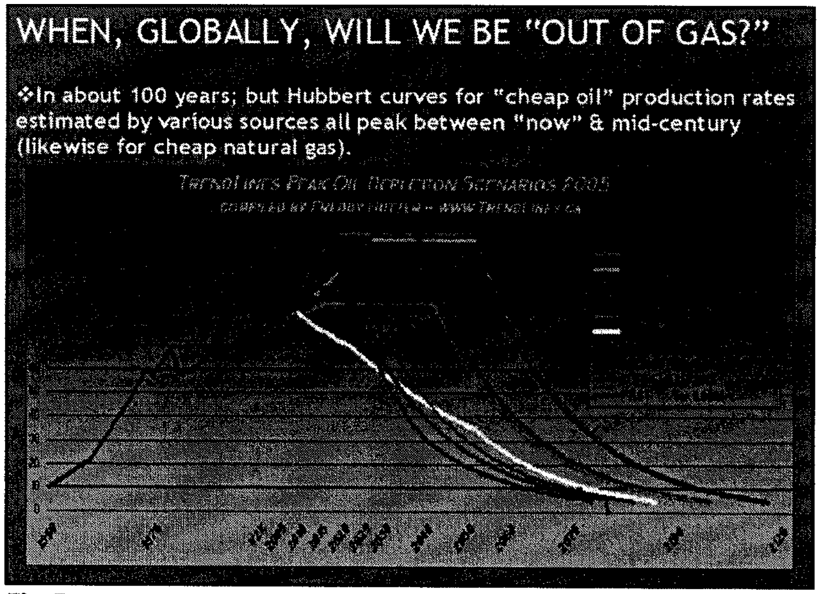


Fig. 3

disease, education, democracy, and population (Smalley, 2005). Energy is key because solving all these problems requires sustainable power on a global scale. Without it civilization collapses. Concentrated fossil fuels are a one-shot boon of nature. Coal being still relatively abundant, humankind might have deferred an energy revolution to another primary power source to the twenty-second century, or even later, were it not for global warming. Coal burned for electricity and even shortages caused by peak oil can be handled at higher cost by making synthetic fuels from coal. But potentially catastrophic global warming is the "canary in the mine." It trumps everything else; moving the climate/energy issue to the front of the list.

To generalize the Shellenberger-Nordhaus thesis, there is little evidence that politicians of *any* persuasion appreciate the magnitude of the problem, or can articulate a vision to address it. The most relevant questions are being asked by energy scientists and engineers: Are there technologies likely to lead to a low-carbon world in time and still allow global GDP to continue growing 2 to 3 percent per year ("Energy's Future," 2006)? What global energy systems should we be aiming at? Can we get there in time? One leading economist put it this way: "The trouble with the global warming debate is that it has become a moral crusade when it's really an engineering problem. The inconvenient truth is that if we don't solve the engineering problem, we're helpless" (Samuelson, 2006).

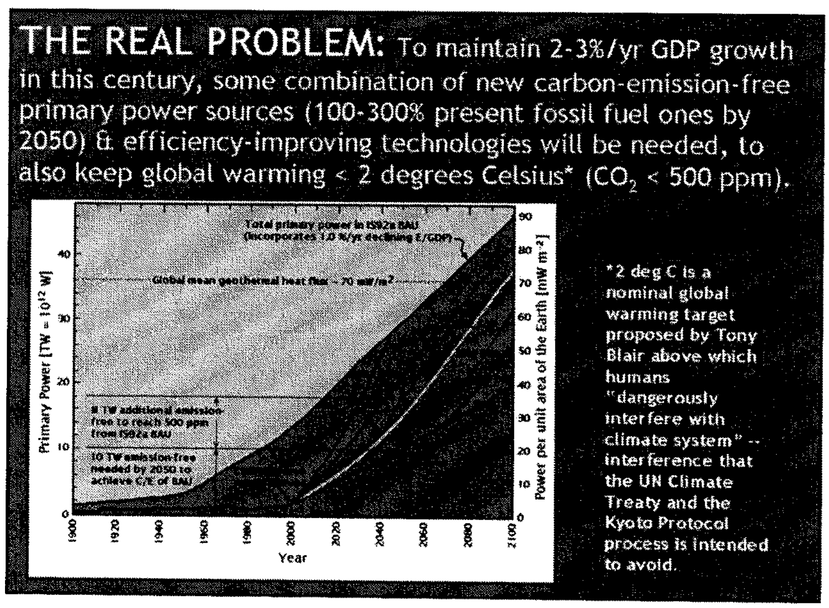
The issue of "energy security" makes the need for an energy technology revolution a viable policy option even for "red" states and others indisposed see global warming for the threat it is. Two hundred years of innovation—the famous "Yankee ingenuity"—are behind America's ascent to world power (Evans, 2004). Applied science and entrepreneurship enabled by government research and development since World War II (Bush, 1945) are a historically appropriate response for the United States.

The need is clear. Figure 2, from Smil (1999), shows oil reserves around the world, with the lion's share in the Persian Gulf. But Saudi Arabia, Iran, and Iraq are powderkegs of post-9/11 Islamic fundamentalism. Some Al Qaeda ideologues have drawn up a plan aimed at establishing an Islamic caliphate throughout the Middle East, in which attacks against the petroleum industry are critical to the deterioration of American power through constant expansion of the circle of confrontation (Wright, 2006). And because oil is internationally traded, it is irrelevant whether oil imports by the United States originate under a particular Middle Eastern desert. The more oil money that flows to Saudi Arabia, Iran, etc., the more money that flows to Al Qaeda, Hezbollah, and other terrorist groups that we are ostensibly at war with. As Tom Friedman of the *New York Times* has repeatedly emphasized, our addiction to oil combined with lack of any serious policy to develop alternatives is why the United States is funding *both* sides of the "War on Terror."

We know that world hydrocarbon resources are limited. Virtually all major crude oil and natural gas reservoirs have been mapped by seismic probes. Every day, the world consumes about 80 million barrels of oil, a rate that has been increasing with economic growth but is ultimately constrained by geological abundance to peak in coming decades (Deffeyes, 2001). From a global warming perspective, the coming oil peak, accelerated by China and India with booming GDPs, is problematic because it is forcing a transition back to coal for primary energy and thus "recarbonizing" the energy supply since coal emits more CO_2 per unit of energy than oil or natural gas. And, of course, oil prices are rapidly rising, headed for $100 per barrel or more. Figure 3 shows the current range of oil production rate projections. As with the climate change deniers, some "cornucopian" economists say the oil peak is overblown. But consider that oil companies are motivated to inflate, not deflate, their reserve estimates to raise their corporate valuations on Wall Street. Royal Dutch Shell, for example, was recently compelled by the US Security and Exchange Commission to revise its reserve estimate downward 20 percent, suggesting an oil peak sooner rather than later. In any case, most petroleum geologists agree the world will be "out of gas" by the end of the century.

I want to be clear that I am a technological optimist. I believe we can solve the climate/energy problem. But there is no silver bullet and it will not be easy. It will take the greatest engineering effort in history; bigger than the Manhattan project to build the bomb, bigger than the

Fig. 4



Apollo program to land a man on the moon, bigger than the mobilization to fight World War II. Moreover, the effort has to be international in scope with sufficient inducements for developing giants China and India to sign on. This problem will not solve itself through the invisible hand of the market. Relevant costs and values are not being captured. We are moving rapidly in the wrong direction. Particularly serious is that we are investing in the wrong infrastructures for a sustainable energy world. Vision and imagination are critical. Sooner or later the world will realize this. The longer we wait, the harder the job will be.

Exponential growth cannot be sustained indefinitely on a finite planet. We could, and I believe should, try to maintain 2 to 3 percent per year world GDP growth to the end of the century (a likely minimum for developing nations to attain income equity) as CO_2 emissions are held constant, decreased, and eventually phased out by mid-century. This would—based on our best current models—keep the atmospheric CO_2 concentration below 500 parts per million (ppm) and global warming below 2 degrees Celsius. Higher than 2 degrees could trigger dangerous human interference with the climate system, according to criteria recently adopted by the European Union (Edmonds and Smith, 2006). Two degrees may not sound like much, but more could put us on a planet-changing trajectory with irreversible melting of the Greenland and Antarctic icecaps, which would inundate the world's coastal zones (Hansen, 2006; Gore, 2006). A big job, given that atmospheric CO_2 has already risen to 380 ppm—100 ppm above the preindustrial level from fossil fuel burning and deforestation so far. To do it, some combination of emission-free primary power sources and primary power demand-reduction equivalent to generating 100 to 300 percent of present power from some as yet unidentified set of power systems will be needed by mid-century (figure 4, based of Hoffert et al., 1998; 2002).

How hard is that? Consider that 2050 is nearer in the future than when Fermi's first nuclear reactor (then called an "atomic pile") went critical in December 1942 at the University of Chicago is in the past. We now produce about 5 percent of primary energy worldwide from nuclear power (this is virtually all for electricity; roughly 18 percent

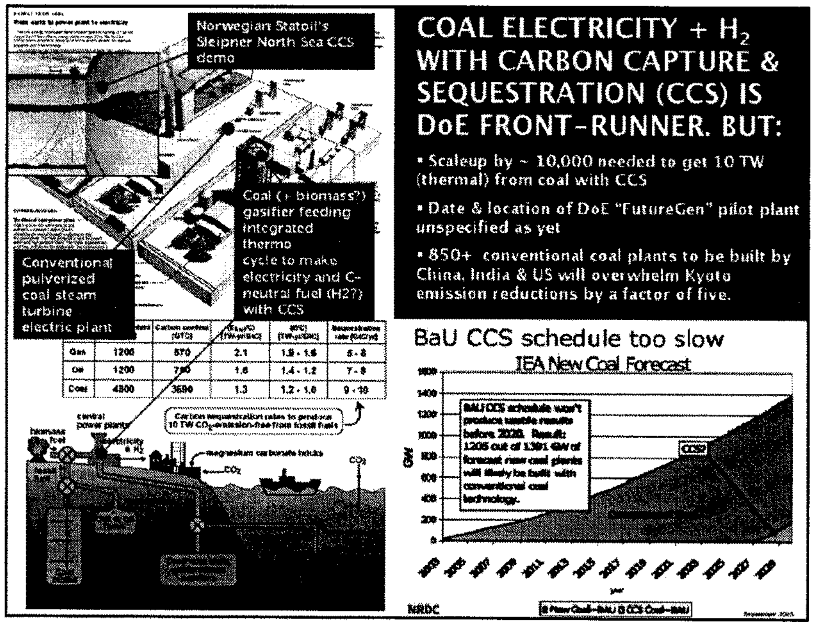


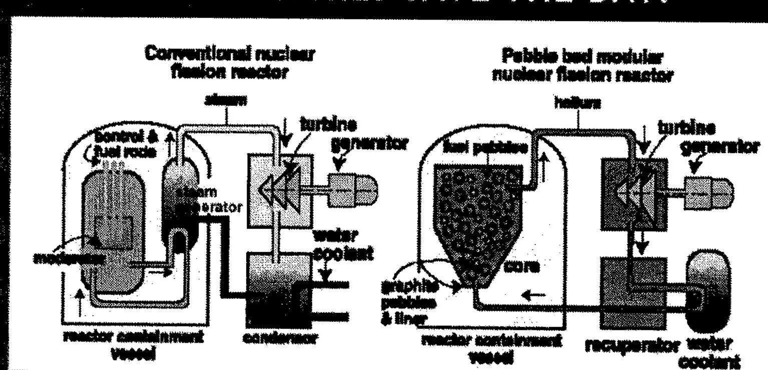
Fig. 5

of electricity generation is nuclear; the rest is from fossil fuels, mostly coal and hydroelectricity). If we need some new carbon-emission free "energy source X" 50 years hence, the implied growth of these new power sources is 20 to 60 times faster than nuclear power, the last revolutionary power source deployed on a large scale. Not impossible, but we do have to concentrate. Below are some ideas that could work if we get serious.

For starters, we could dramatically accelerate what some engineers believe is the most ready for prime time major emission-free energy source: coal with carbon capture and sequestration (CCS). Figure 5 depicts coal gasification plants making electricity and hydrogen with the CO_2 pumped to reservoirs underground, the rationale being that we have large coal resources that can play a role in a transition to a sustainable energy system if we can get the energy out while putting CO_2 (and other pollutants) away in reservoirs underground. One problem is that coal with CCS deployment is unlikely before pilot plants demonstrate that the combined technology works. Iindividual components like coal gasification, combined cycle power plants, and even CO_2 sequestration have been shown, but the technology is too costly without a carbon tax or "cap and trade" emissions policy in place. The United States, China, and India have not agreed on emission limits, and these are precisely the countries with massive coal resources where planned buildup of conventional coal electric power stations is most intense. The lower right panel of Figure 5 shows how conventional coal plants in the works will overwhelm proposed CCS plants. A Department of Energy-funded CCS pilot plant called "FutureGen" was cited by this administration at climate negotiations in Montreal as the US premier effort, in partnership with the coal industry, to combat global warming (Revkin, 2005). But this plant is unlikely before 2012 and its location is still unannounced. Experts believe it may be more expensive to retrofit conventional coal plans with CCS than build gasification plants with CCS from scratch. Suppose global warming got bad—really bad. Will conventional coal plants be abandoned, as the $6 billion Shoreham nuclear plant was after Three Mile Island (TMI) and Chernobyl? Once they are generating electricity from cheap coal, with capital costs "sunk" for 50 to 75 years, it might be so expensive to shut

Fig. 6

CAN "GREEN" NUKES SAVE THE DAY?



Light water reactors (LEFT) have had operational safety, cost, waste disposal & proliferation problems. New helium-cooled pebble bed reactors (RIGHT) are theoretically immune to coolant loss (TMI) and criticality (Chernobyl) accidents. Other problems may be technically soluble also.

BUT: U-235 resources burned at 10 TW with "once-through" reactors will only last 6-30 years: WE'D NEED TO START BUILDING BREEDERS NOW!

down and build new ones that ratepayers would balk even to slow a global warming juggernaut. This is not a good scenario.

Another class of low-carbon primary power now being reconsidered after a disastrous start is "green" nukes (figure 6). No one has started building a new nuclear reactor in the United States for the past 30 years, though some are planned. Classic problems of nuclear power are operational safety, waste disposal, and weapons proliferation. However, for global warming mitigation, the major constraint may be that planned reactors are "once through" and use the supply-limited uranium 235 (U-235) isotope, which makes up less than 1 percent of natural uranium. The energy content of U-235 in identified deposits is less than natural gas. We would run out of fuel in 30 years employing such reactors at rates sufficient to supply present primary power demand. As with coal, we do not have the luxury of investing in the wrong nuclear power infrastructure. Longer-term, we will need to breed U-238 (99 percent of natural uranium) into plutonium or more abundant thorium to U-233, a fuel I favor for several technical reasons. Why not start now? Infrastructure and weapons proliferations issues need to be faced now if we are serious about green nukes as alternative energy.

The third class of primary power, my own preference, is renewable energy, currently less than 1 percent of primary power (figure 7). Space limitations prevent an adequate discussion, but I and colleagues at the National Renewable Energy Laboratory (NREL) in Golden, Colorado, and elsewhere believe solar and wind power can be scaled up, with a proper infrastructure of transmission and storage, to provide 30 percent or more of primary emission-free power by midcentury (Pew Center, 2004). President Jimmy Carter, a strong advocate of renewables, created the Solar Energy Research Institute, the precursor of NREL. And Jerry Brown, dubbed California's "governor moonbeam" by critics, in the 1970s initiated tax and other incentives leading to the now cost-effective Altamont wind farms. It is hard to overestimate the damage done by Ronald Reagan who, on becoming president, symbolically ripped the solar panels Carter had put on the roof of the White House, likewise dismantling most of Carter's energy research and development initiative. We have not recovered. Carter's administration

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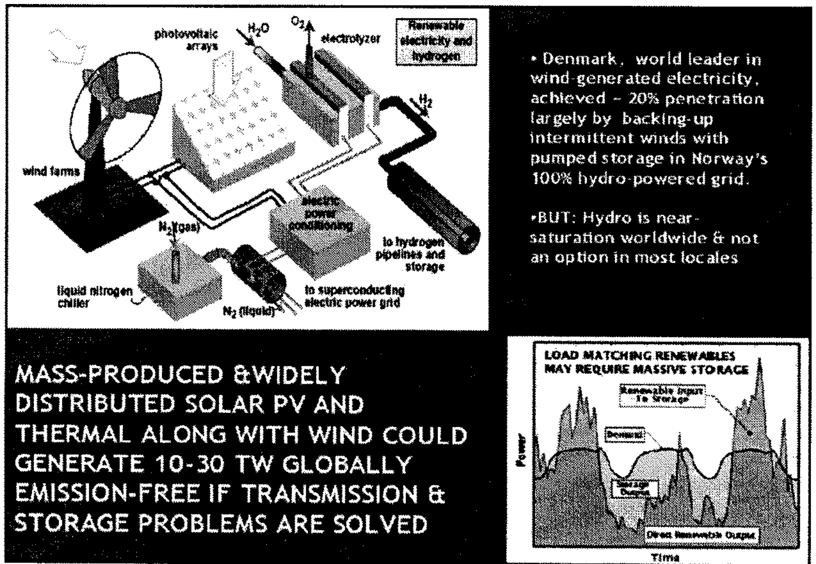

Fig. 7

a quarter century ago was the last time the US had a pro-active alternate energy policy. Unfortunately, the institutional memory of this has dimmed. Whatever the problems of Carter plan, and there were some, the United States, and because of our leadership, the world, was headed toward a sustainable energy future. Not now.

What colleagues and I propose as a goal is that by mid-century, renewables should supply roughly a third of the world's power; clean, safe and sustainable nukes another third; and coal gasification with CCS the final third. The total would amount to 100 to 300 percent of present energy demand. There are major roles for business and talented entrepreneurs, but I do not see how we get there without the stimulus of massive Apollo-like government-funded research and development, perhaps starting with ARPA-E (Advanced Research Projects Agency–Energy; after DARDA, the Defense Research Projects Agency, which gave us, among other things, the Internet) proposed by the National Academy of Science (Committee on Science, 2005).

At the same time, we need to implement everything we have in our alternate energy arsenal immediately. I do this myself as best I can. I drive a hybrid and get my home's electricity from green power, mainly wind power purchased by my utility from upstate New York (Hoffert, 2004). At this point, I pay a premium for this "privilege." I do not claim any special virtue as an early adopter. I do think both ethics and "cool" technology can be early drivers of alternate energy. At least until it become cost-effective to the average person, perhaps stimulated by carbon and gas taxes and/or cap-and-trade schemes. We need work on a broad spectrum of possible solutions; picking technology winners is notoriously uncertain, even by experts (Clarke, 1982).

This is not the forum to elaborate on the most innovative high-tech ideas that could allow us to live sustainably on the planet. Interested readers should consult Hoffert et al. (2002) and the special issue of *Scientific American* on "Energy's Future Beyond Carbon" (2006). Climate and sustainable energy is a political as well a science and engineering problem. With the memory of Rick Smalley's brilliant exposition in mind (he gave a most engaging and accessible public lecture at an Aspen Global Change Institute conference that I co-organized a few years ago), I hold that energy and global warming, not terrorism and mind-numbing dogma, are the appropriate organizing principles for this century. There is no guarantee high-tech civilization will survive into an ever richer future. But I find no solace in joining with the peak oilers to hunker down to a long slow decline with a return to agrarian (and eventually hunter-gatherer?) lifestyles as energy runs down and sea levels rise (Urstadt, 2006). Likewise, keep me away from Ted Kaczynski, the "Unabomber," who would destroy even a solar-powered high-tech world (Kaczynski, 2002).

I am optmistic enough about technology to believe policies based on science and engineering can solve the climate/energy problem; that with enough effort, thoughtful energy policies, instead of the usual pork packaged for public relations, can become part of political party platforms by the next US presidential election. The stakes are high. We owe to ourselves and generations to come to fight for our remarkable technological civilization, with all its imperfections, built on the shoulders of earlier generations. It will be hard. We will need every ounce of creative imagination. If we do make it through the twenty-first century without imploding, perhaps someday we might even find a way to cope with those problems our pre-technology evolutionary history has left us quite unprepared for.

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Chairman TOM DAVIS. Thank you very much.
Dr. Socolow, thank you for being with us.

STATEMENT OF ROBERT SOCOLOW

Mr. SOCOLOW. Chairman Davis, ladies and gentlemen, I have titled my remarks One Hand Clapping. You have heard a very strong case for moving forcefully forward with technological responses that address climate change. We need early deployment of technologies that we already know are matched to the job and we need long-term research to expand the list of options. Congressional action is critical in both areas. To accelerate the deployment of the technological strategies whose promise is already clearly identified, requires price signals for carbon. To raise the energy R&D effort to a new level requires greatly expanded, durable funding of research with a long time horizon. To do one without the other, that is like one hand clapping.

I want to share with you work that I have done over the past 2 years with my ecologist colleague Steve Pacala that has added coherence to discussions of climate policy. Please look at the figure on the screen. This, by the way, is in the Scientific American in September 2006, the current issue. The upward trajectory envisions 50 years of inaction while carbon dioxide emissions double, followed by aggressive action to hold global emissions constant for the following 50 years. Following the upward trajectory, the world will find it difficult to avoid tripling the preindustrial carbon dioxide concentration and a rise in the average surface temperature of roughly 5 degrees celsius.

The lower trajectory, the blue one, envisions immediate action to hold global emissions constant, followed in half a century by a second aggressive program to reduce global emissions roughly in half. Following the lower trajectory will enable the world to beat doubling—that is, to keep the concentration below twice its preindustrial concentration—with a rise of roughly 3 degrees.

The stabilization triangle is that orange and yellow area between the two trajectories. You can see that it is divided into seven stabilization wedges. A stabilization wedge is a strategy that produces a reduction of 1 billion tons of carbon and global carbon dioxide emissions 50 years from now relative to what would happen in the absence of attention to climate problem.

The size of the world's job for the next 50 years is to achieve seven wedges, if we can live with a 3 degree temperature increase. If we want to stay below 2 degrees celsius, more wedges will be needed.

I note that the climate change technology plan published yesterday, if you look at 2055, also has exactly seven wedges. They have 16 minus 9 instead of 14 minus 7, but there is a complete agreement about the scale of the job that is associated with avoiding a 3 degree temperature rise between the DOE and our own analysis.

In a world in 2056 that emits the same amount of carbon as today, the United States will emit less CO_2 than today, and the trajectory that we will need to follow from here to there must depart from its expected business-as-usual trajectory immediately and must peak in about a decade, and global emissions would peak soon after.

You must not underestimate the size of the policy intervention required to turn U.S. emissions downward. A too-low price for carbon dioxide emissions will lead industries and consumers to treat these expenses as routine costs of business. The required price schedule for CO_2 emissions must induce fundamental changes in the energy system beginning within a decade or less. We figure out how much we have to spend by how much will create action.

Pacala and I estimate that the price needed to jump-start this transmission is in the ballpark of $100 to $200 per ton of carbon, that is to say $25 to $50 per ton of CO_2. Arrangements, for example, would make it cheaper for new coal plants to capture and store CO_2 rather than to vent it. Based on its carbon content, $100 per ton of carbon is $12 a barrel of oil, $60 a ton of coal, $0.25 a gallon of gasoline, and $0.02 per kilowatt hour for electricity made from coal.

Policy-induced scale-up of existing technology can only succeed if accompanied by R&D to squeeze down costs and to solve the problems that inevitably accompany widespread deployment. Along with such programmatic R&D, we will also need another kind of research program that we are talking about here, more blue sky, a program able to capture the imagination and the loyalty of the world's best scientists and engineers like the Manhattan Project and the Apollo program. Both of those historic programs provided dependable research support, which is a necessary condition to induce the most productive scientists and engineers, to reorient their research careers, and to induce the most ambitious students to adopt these retooling scientists and engineers as their mentors.

But energy research must be international and must heavily involve the private sector. Those are two characteristics that the Apollo program and the Manhattan program did not share.

I repeat my main message: we need a serious expansion of high-risk R&D, but not only R&D. As Marty Hoffert also said. We also need policy that elicits carbon responsive investments by industry and carbon-saving practices on the part of consumers. R&D in the absence of near-term technology-forcing policy is like one hand clapping.

Thank you.

[The prepared statement of Mr. Socolow follows:]

Testimony of

Professor Robert H. Socolow
Princeton University

"One Hand Clapping"

Before the United States House of Representatives
Committee on Government Reform

"Climate Change Technology Research: Do we need a 'Manhattan Project' for the Environment?"

September 21, 2006

You have heard a very strong case for moving forcefully forward with technological responses that address climate change. I am in complete agreement with the case for urgency. I will use my few minutes with you to emphasize the need for a full-court press: We need early deployment of technologies that we already know are matched to the job, and we need long-term research to expand the list of options.

Congressional action is critical in both areas.

> To accelerate the deployment of the technological strategies whose promise is already clearly identified requires price signals for carbon. By expanding the cap and trade model to carbon dioxide and adopting specific policies tailored to individual sectors, one can create a market incentive to use today's lower-emitting technologies
>
> To raise the energy R&D effort to a new level requires greatly expanded, durable funding of research with a long time horizon. New legislation can create a durable program that insulates researchers from fickle changes in research direction and from pressures to respond to very short term objectives.

Technology-forcing price signals for carbon to promote available technologies and expanded support for R&D go hand in hand. Literally. To do one without the other: that's like one hand clapping.

For the past several years, I have worked to strip down the presentation of the CO_2 and climate problem, so that policy discussions can become more coherent. With my ecologist colleague, Stephen Pacala, I wrote an article in *Science* in 2004 and a second article in this month's *Scientific American*, that made two simple contributions. First, we introduced the "stabilization wedge" as a new unit of measure for quantifying climate mitigation strategies, focusing on the next 50 years. Second, we introduced the "stabilization triangle" as our estimate of the size of the job. A stabilization wedge is a strategy that produces a reduction of 1 billon tons of carbon in global CO_2 emissions fifty years from now, relative to what would happen in the absence of attention to the climate problem. (Ramping up to 800 one-thousand megawatt coal plants equipped with CO_2 capture and storage technology by 2056 is an example of a wedge.) The size of the world's job is seven wedges – under specific assumptions about the world's emissions if there is no attention to carbon and about the highest level of CO_2 in the atmosphere judged to be tolerable. See Figure 1.

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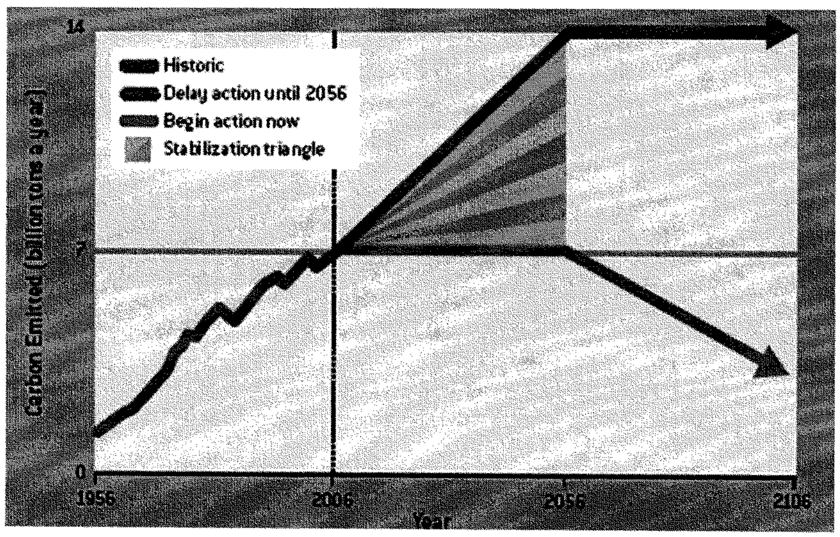


Figure 1. Two trajectories for future global carbon emissions to the atmosphere (as carbon dioxide). The upper trajectory envisions fifty years of inaction, while CO_2 emissions double, followed by aggressive action to hold global emissions constant for the following 50 years. The lower trajectory envisions immediate action to hold global emissions constant, followed in half a century by a second aggressive program to reduce global emissions roughly in half, down to a level where remaining emissions are canceled by absorption of CO_2 by the ocean and land, so that the global atmospheric CO_2 concentration stabilizes. Following the upper trajectory, the world will find it difficult to avoid tripling the pre-industrial CO_2 concentration and a rise in the average surface temperature of roughly 5°C. Following the lower trajectory will enable the world to "beat doubling," that is, to keep the concentration below twice its pre-industrial concentration, with a rise in average surface temperature of roughly 3°C.

****

Our diagram is now widely known. The principal criticism we have received over the past two years is that it underestimates the size of the job. Some people think the world's CO_2 emissions will more than double in the next 50 years in the absence of deliberate attention to the climate problem. Others think that the world's goal should be to beat doubling by a large amount, not to cut it close, thereby aiming for a 2°C, rather than a 3°C, rise in global surface temperature. Global emissions fifty years from now, in that case, would need to be about half of today's. In short, our critics are urging us to assert that the world will need to achieve *at least* seven wedges.

Pacala and I learned, through our wedge analysis that there is an abundance of promising options, even when we restrict the list to options that involve the scaling up of technologies that have already been commercialized somewhere in the world. In our articles, we listed 15 options and noted that our list was incomplete. The huge size of the mitigation assignment convinced our readers that no option could do the whole job, or even half the job, so that solutions to the climate problem require portfolios of technological strategies. Through a process of international coordination, countries can choose their own portfolios.

A world that emits no more CO_2 in fifty years than today will require that the U.S. emit less CO_2 in fifty years than today. Thus, the solution to the CO_2 problem has three phases:

1. Constant U.S. emissions
2. Constant global emissions
3. Constant atmospheric concentration.

To achieve the CO_2 targets widely advocated by earth-system scientists, including Marty Hoffert here today, will require a trajectory for U.S. emissions that departs from its expected (Business As Usual) trajectory essentially immediately, and peaks in about a decade. Global emissions would peak within two or three decades. These are big assignments. Accordingly, it is critical not to underestimate the size of the policy intervention that will be required to motivate deep changes in the energy system. We could lose much precious time if, after so many years of delay, we implement carbon policy that establishes such a low price for CO_2 emissions that production and consumption patterns hardly change, and industries and consumers simply treat these expenses as routine costs of business.

The criterion for the necessary size of the policy intervention is: Will the price schedule for CO_2 emissions induce fundamental changes in the energy system beginning within a decade or less. Experts in industry economics will be able to guess the right level, and an iterative process should be built in. In our *Scientific American* article, we gave our own estimate of the cost of CO_2 emissions required to produce dramatic changes in the world's forthcoming investments in the energy system:

> "We estimate that the price needed to jump-start this transition is in the ballpark of $100 to $200 per ton of carbon— the range that would make it cheaper for

owners of coal plants to capture and store CO2 rather than vent it. The price might fall as technologies climb the learning curve. A carbon emissions price of $100 per ton is comparable to the current U.S. production credit for new renewable and nuclear energy relative to coal, and it is about half the current U.S. subsidy of ethanol relative to gasoline. It also was the price of CO_2 emissions in the European Union's emissions trading system for nearly a year, spanning 2005 and 2006. (One ton of carbon is carried in 3.7 tons of carbon dioxide, so this price is also $27 per ton of CO2.) Based on carbon content, $100 per ton of carbon is $12 per barrel of oil and $60 per ton of coal. It is 25 cents per gallon of gasoline and two cents per kilowatt-hour of electricity from coal."

This vision of policy-induced scale-up of existing technology still requires R&D. As Pacala and I wrote in *Scientific American*: "Achieving nearly every one of the wedges requires new science and engineering to squeeze down costs and address the problems that inevitably accompany widespread deployment of new technologies. But holding CO2 emissions in 2056 to their present rate, without choking off economic growth, is a desirable outcome within our grasp."

The meeting today is about still another kind of research, more blue sky, more capable of eliciting a certain kind of scientific creativity that the world must also engage, as part of the full-court press. Both the Manhattan Project and the Apollo Program are apt metaphors for programs that captured the imagination and the loyalty of the world's best scientists and engineers. Both programs provided dependable research support, which is a necessary conditions to induce the most productive scientists and engineers to reorient their research careers and to induce the most ambitious students to adopt these retooling scientists and engineers as their mentors. But both models miss two crucial aspects of the job ahead: It must be international, and it must heavily involve the private sector.

Pacala and I concluded our *Scientific American* article by placing ourselves in 2056 and looking back on the 50 years that had just passed. We asked: "If global emissions of CO2 are indeed no larger than today's, what will have been accomplished?"

We answered our own question:

> "The world will have confronted energy production and energy efficiency at the consumer level, in all economic sectors and in economies at all levels of development. Buildings and lights and refrigerators, cars and trucks and planes, will be transformed. Transformed, also, will be the ways we use them. The world will have a fossil-fuel energy system about as large as today's but one that is infused with modern controls and advanced materials and that is almost unrecognizably cleaner. There will be integrated production of power, fuels and heat; greatly reduced air and water pollution; and extensive carbon capture and storage. Alongside the fossil energy system will be a non-fossil energy system approximately as large. Extensive direct and indirect harvesting of renewable energy will have brought about the revitalization of rural areas and the reclamation of degraded lands. If nuclear power is playing a large role, strong

> international enforcement mechanisms will have come into being to control the spread of nuclear technology from energy to weapons. Economic growth will have been maintained; the poor and the rich will both be richer. And our descendants will not be forced to exhaust so much treasure, innovation and energy to ward off rising sea level, heat, hurricanes and drought.
>
> "Critically, a planetary consciousness will have grown. Humanity will have learned to address its collective destiny – and to share the planet."

I repeat my main message: We need all possible forms of commitment to combating global warming. The commitments of the basic research community will require a serious expansion of high-risk R&D. But much more is needed. We must create carbon-responsive investments by industry and commitments to carbon-saving practices on the part of consumers. R&D in the absence of technology-forcing policy is like one hand clapping.

Thank you.

Chairman TOM DAVIS. Thank you very much.
Dr. Kammen.

STATEMENT OF DANIEL KAMMEN

Mr. KAMMEN. Chairman Davis, thank you very much for the opportunity to speak today.

[Slide presentation.]

Mr. KAMMEN. If we could move to the next slide, I share many of the points in common with the two previous speakers. I would like to highlight a number of what I think are the key issues of a serious approach to this problem.

The first is a major commitment to energy. Leadership and sustainability is needed. It is long overdue and it would benefit this country. There is a global lack of leadership in this area. We would profit financially, as well as environmentally, by taking on that role.

Energy environmental sustainability is a marathon. It is not a sprint. Like in a marathon, where your worst of many miles times can dramatically affect your performance, cutting the funding and cutting support on a given year critically cuts programs that are otherwise successful. The best graduate students leave fields. The best researchers leave fields. Companies don't see it as a serious effort if funding levels fluctuate up or down dramatically, so having a sustained, long-term program that is much wider than just DOE is going to be critical to make this happen.

We have the scientific and technological foundation not necessarily to get us all of the way there but to make major inroads, and we learn by doing. We must start that process in a much more aggressive way than the CCTP even lays out the beginning of. I would submit that the next serious stage is to do what the CCTP has looked at within DOE in a much broader way across not only other Federal agencies but also with those States and those foreign governments that are making serious inroads here. That was largely lacking in the process.

The benefits of investing in innovation are well documented by the world's economists. They are significant. They reach across many sectors of the economy. If we did this in the energy sector, the so-called clean tech area, we would see those benefits.

Innovation leads to more innovation, whereas stagnation does not. We need to invest and we need to make clear signals where we want to get to.

Finally, the point that Congressman Waxman so kindly made, and that is technologies do not adopt themselves. Programs that are technology-only focused will not succeed in this area. A critical difference not yet discussed with the differences between a DOE program is that there was essentially a single client for DOE efforts. Our clients here are companies, homes, utilities in the United States and around the world. It is not the same thing as having a single client, the Secretary of Defense, and sending a project forward. We need a broad strategy that marries in a sustained way energy R&D with efforts to bring technologies into the market. That is a critical step.

On the next slide I highlight two things. One is the oft-reported growing U.S. emissions in carbon. If we move ahead, that is our business-as-usual trajectory, depressing as it is. You will notice the next point forward shows not only where the administration's target, the so-called reduction in energy intensity, which in my view is a false and misleading way to lead out the strategy. Nature does not care how much we change our energy intensity; nature cares how much we reduce our loading of the environment with carbon. We need to have a target that is absolute and not a target that is a function of a percentage growth rate change.

I highlight this with the Kyoto protocol target and a red line indicating what California has adopted through a series of measures, Assembly Bill 1493, Assembly Bill 32, Senate Bill 1, the million solar roofs measure that has near-term targets that we know are achievable. We believe we can do and we know how to do 20 to 25 percent reductions in the State, and we have heard excellent comments from Congressman Bill Ray about how the California Air Resources Board tasked to do that has done it in the past.

The rest of the path we do not know how to do. The parts of this line to bring our emissions down in this later part of the picture we do not have a recipe for, but to look for single-technology solutions, very expensive individual programs, without building out the first part of the curve is not to learn from the process of technology, innovation, and development that has been successful in many other areas.

Run the marathon through here and determine your strengths down here. Do not delay until you think you have the magic bullet to get you down to the target.

If you advance the slide one more time you will see a target is dramatic. If you can advance one more slide, the stabilization regime is down here. It is an 80 percent reduction. It is a large, overall process. Notice there is a gap, as Dr. Socolow calls it, a wedge here. If you go to the next slide there is a remarkable experience in the United States. The top lines show the overall increase in electricity use per person in the United States. The lower lines show the California and New York experiences.

If we advance the slide, you will notice there is a remarkable wedge of energy efficiency savings. That was not envisioned and developed by a one-stop, one magic energy efficiency technology. It was a combination of better light bulbs, water heaters, standards for buildings, shading homes, etc. It was a cumulative process, the same sort of process we can expect to see if we invest significantly in energy efficiency in renewables as we do in energy efficiency.

If we move to the next slide, we are seeing now in the world of ethanol, whether it is ethanol made from corn or ethanol made from cellulose, a dramatic increase in ethanol production and use, and many States are adopting more and more aggressive ethanol targets, and our lab has been involved in that process through a fairly high-profile paper in this area.

This is an effort of increasing R&D and market opportunities at the same time. We must look for those in both areas, not just R&D, not just markets, but those working in concert.

If we jump ahead a few more slides, this unfortunately is our current situation. The top line shows Federal energy R&D, the $3 billion number we heard before, the number here, and the black line below it shows private sector R&D. We have a mis-match of private sector spending in this area. In fact, this does not have to be the pattern.

If we look at the next slide, in the area of health care private sector R&D has been increasing for several decades, while in the energy sector it has been decreasing. A friend and colleague of mine, a former assistant secretary in DOE, noted sadly that this means that we will be alive to see the folly of our lack of investment in the energy sector.

I conclude with the fairly simple but clear set of comments on the last slide, and that is this committee, with a largely bipartisan interest in these areas, has demonstrated that we are able to raise our expectations and raise our standards for investment in this area, that clean energy can be an area of tremendous innovation for the economy, an area that we would export to the world and benefit from. If we support States that enact aggressive policies such as the New England States, the mid-Atlantic States, California, some of the northwest States that are adopting renewable energy content requirements for their power, we can assist those areas undertaking experiments that we all want to see happen to determine which policies are the most effective and not wait for a magic bullet, single-size-fits-all, DOD-mimicked solution.

I would like to note, as well, if we jump to the next feature, that over the last 3 years we have observed a carbon tax of roughly $270 per ton in the run-up in gasoline prices. None of that has effectively gone into clean-tech R&D. We have paid this out of our pockets with that money going overseas without capturing it, as Dr. Socolow said, with a significant carbon tax. I recommend a much more modest initial tax to gain experience with the process, but that is exactly how we need to start to send the right signals to industry that we are serious about it, that we expect performance, and that we will award the performance in this area.

I would like to again thank you for the chance to speak, and I urge us to take advantage of the opportunity to be the environmental leader that the United States is currently not doing relative to a number of other nations. It is our opportunity and our challenge to take on that leadership.

Thank you very much.

[The prepared statement of Mr. Kammen follows:]

Committee on Government Reform, United States House of Representatives
Testimony for the September 21, 2006 Hearing on:

Climate Change Technology Research: Do We Need a 'Manhattan Project' for the Environment?

by

Daniel M. Kammen

Professor in the Energy and Resources Group (ERG)
Professor of Public Policy in the Goldman School of Public Policy
Co-director Berkeley Center for the Environment
Director, Renewable and Appropriate Energy Laboratory (RAEL)
University of California, Berkeley

http://socrates.berkeley.edu/~kammen *http://rael.berkeley.edu*

Introduction

Representative Tom Davis, Chair, Ranking Minority Member Henry Waxman, and other members of the House Committee on Government Reform, I am grateful for the opportunity today to speak with you on the critical issue of the United States' approach to the great challenges that climate change presents our nation and the planet. At the heart of my comments is the finding that leadership in protecting the environment and improving our economic and political security can be achieved not at a cost, but through political and economic gain to the nation in the form of reasserted leadership both technologically and financially, through increased geopolitical stability and flexibility, and through job growth in the 'clean energy' sector. To accomplish these goals, not only will a comprehensive strategy – a plan – be needed, but most critically we must develop a balanced approach that utilizes 'technology push' and 'demand pull' mechanisms equally in the emerging clean energy sector. A fundamental finding is that simple, low-carbon resource arguments are insufficient to flesh out a roadmap that is either scientifically or economically meaningful.

I hold the Class of 1935 Distinguished Chair in Energy at the University of California, Berkeley, where I am a professor in the Energy and Resources Group, the Goldman School of Public Policy, and the Department of Nuclear Engineering. I am the founding director of the Renewable and Appropriate Energy Laboratory, an interdisciplinary research unit that explores a diverse set of energy technologies through scientific, engineering, economic and policy issues. I am also the Co-Director of the University of California, Berkeley Institute of the Environment. I have served on the Intergovernmental Panel on Climate Change (IPCC), and have testified before both U. S. House and Senate Committees on the science of regional and global climate change, and on the technical and economic status and the potential of a wide range of energy systems, notably renewable and energy efficiency technologies for use in both developed and developing nations. I am the author of over 160 research papers, and five books, most of which can be found online at http://rael.berkeley.edu

In July of last year the Honourable R. John Efford, the then Minister of Natural Resources Canada, announced my appointment, as the only U. S. citizen, to serve on the Canadian National Advisory Panel on the Sustainable Energy Science and Technology (S&T) Strategy. The Panel provides advice on energy science and technology priorities to help Canada develop sustainable energy solutions, and is tasked to produce a document similar in objectives to the Climate Change Technology Program Strategic Plan, which we are here today to discuss.

Overview of Climate Change and Innovation in the Energy Sector

As described in the CCTP Strategic Plan, climate change presents our nation with a serious, long-term challenge. Central to the difficulty of this challenge is that reducing the risks posed by climate change will require us to transform the largest industry on the planet, the energy industry. Energy is important, not only for its direct contribution to 10% of economic output by our nation's private sector, but also as the fundamental enabling infrastructure for an array of economic activities, from manufacturing to agriculture to healthcare. The availability of reliable and affordable energy should not be taken for granted. The challenges of renewing the U.S. energy infrastructure to enhance economic and geopolitical security and prevent global climate change are particularly acute, and depend on the improvement of existing technologies as well as the invention, development, and commercial adoption of emerging ones. Recent trends in the energy sector—which show declining levels of technology investment and innovation—heighten the need for an aggressive response (Appendix A). The CCTP provides a tremendous opportunity to reverse this trend, open up new technological options, and stimulate economic growth through the development of a new clean energy-based sector of the economy. Key strengths of the CCTP Strategic Plan are its leadership by the President, the acknowledgement of the long-term nature of the problem, and the breadth of its technology portfolio. Yet the CCTP Strategic Plan, in its current draft, is seriously flawed. The goal that it seeks to reach, and the basis on which we are here to evaluate it today, is far too modest; it is not commensurate with the magnitude of the challenges we face and not reflective of our nation's capacity for innovation. This testimony will outline the magnitude of effort that will be required, an overview of the innovation environment in the energy sector, and recommendations for improvement.

The nation's climate technology program should be based on a goal that reduces emissions

The most significant shortcoming of current approaches to carbon management and the innovation pipeline is that our allocation of resources are not commensurate with the magnitude of the challenges posed by climate change and other energy-related problems. In evaluating the CCTP strategic plan one must first seriously consider what goal it is trying to achieve. To avoid the adverse impacts of climate change we will need to stabilize concentrations of greenhouse gases in the atmosphere. This will require real reductions in the amount of carbon dioxide and other greenhouse gases that we emit. As the strategic plan itself asserts:

> Stabilizing GHG concentrations, at any atmospheric concentration level, implies that global *additions* of GHGs to the atmosphere and global *withdrawals* of GHGs from the atmosphere must come into a net balance. This means that growth of *net* emissions of GHGs would need to slow, eventually stop, and then reverse, so that, ultimately, *net* emissions would approach levels that are low or near zero." (p 2-2)

However, today we are here to evaluate the program based on its ability to meet the Administration's emissions intensity target of an 18% reduction in GHG intensity by 2012. Throughout this testimony, I will argue that a flaw in the CCTP plan is that it is designed to meet a goal that is wholly inadequate to the challenge we face. Only when we take this challenge seriously across the economy will we be able to meaningfully mobilize our nation's scientific, technological, and economic resources to meet it, as well as to reap the benefits of international leadership in the clean and sustainable energy sector.

The need to reduce uncertainties in current climate science around climate sensitivity and expected impacts is often cited as a reason for delaying commitments to emissions reductions. Yet, the plan is correct in pointing out that scientific uncertainty is neither a valid justification nor a wise strategy for choosing to delay. In fact, there is not much uncertainty about the basic problem and its magnitude. Estimates done at Lawrence Livermore National Lab of carbon emissions which assume we find a way to reduce emissions to zero by 2050 while meeting energy service demands – i.e. very conservative estimates – will still almost certainly result in CO_2 levels exceeding 550ppm in the atmosphere, if not more. Given that the CO2 level is now 380ppm -- 30% higher than it has been at any point in the last 650,000 years-- we are essentially conducting an unprecedented experiment with the Earth. Despite the long time horizons of the climate change problem, the availability of carbon-free energy technologies is a relatively urgent matter because the 100-year residence time of CO_2 in the atmosphere, the 30 to 50-year lifetime of capital stock in the energy industry, and the typical decades-long diffusion curve for infrastructure-related technologies are to varying extents outside of our control. The response to this combination of uncertainty and urgency should be a commitment to the creation of a multitude of new technological options, not a timid approach that narrows the range of possibilities at our disposal in the future.

In contrast, meeting the Administration's current target will require only a slight change from the business as usual case (Figure 1) (EPA 2005). More relevant to the climate problem, reaching this target would actually allow emissions to grow by 12 to 16%. This target would thus represent a larger increase than the 10% increase that occurred in the previous decade. If we are to be serious about meeting the climate challenge we need to set a goal consistent with the CCTP's objective of moving toward zero net emissions. While the Kyoto Protocol has its flaws, its targets do represent a substantial shift toward reducing emissions. Similarly, the Governor of California's GHG emissions targets announced last summer (EE 3-05) and the 25% GHG reductions adopted via AB32 (the Pavley/Nuñez Bill) include both near-term and longer-term goals – including market-based cap and trade mechanisms -- that delineate a path of emissions *reductions* toward climate stabilization. The administration should set a series of targets that show a clear path to emissions reductions.

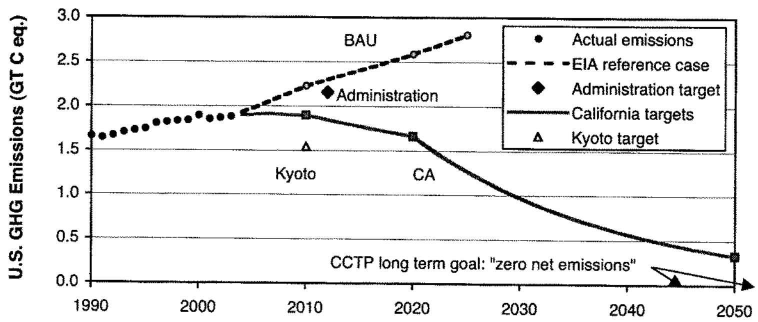


Figure 1 Historical U.S. GHG emissions and targets

Figure 1 shows actual U.S. GHG emissions from 1990 through 2003 (EPA 2005) in giga-tons of carbon equivalent. Four future paths for future U.S. emissions are shown; circles show the business-as-usual (BAU), or "reference case," as calculated by the Energy Information Agency (EIA). The diamond shows the Administration's GHG intensity target for 2012 of 18% below 2002 level in tons of carbon per unit of GDP, or a 3.6% reduction in emissions from BAU. The squares show U.S. emissions if the nation were to meet the percentage reductions that have been announced in California for 2010, 2020, and 2050 (California Executive Order 3-05, and California AB32, the "Pavley-Nuñez Bill'). The triangle shows the U.S.'s target for 2010 under the Kyoto Protocol. Arrows indicate the levels required to meet the CCTP's long-term goal of "levels that are low or near zero" (p. 2-2).

What is needed is a serious and sustained commitment to emissions reductions and a time scale that conveys to the country the urgency of the need to open future options. Much as President Nixon's announcement of a program in the early-1970s to reduce reliance on foreign oil stimulated efforts by the private sector to invest in alternative energy sources, the articulation of a bold and clear target for emissions reductions would send a signal to the private sector that would leverage the federal government's direct investments in new technologies.

Raising climate technology investment to adequate levels

In recent work, we calculated the investment in R&D required to reach a climate stabilization level of 550 ppm, a level that would double the amount of GHG in the atmosphere relative to that at the beginning of industrialization in the eighteenth century. Using emissions scenarios from the Intergovernmental Panel on Climate Change and a previous framework for estimating the climate-related savings from energy R&D programs (Schock *et al.*, 1999), we calculate that U.S. energy R&D spending of $15-30 billion/year would be sufficient to stabilize CO_2 at double pre-industrial levels (see Appendix for calculations). A strategy that employs a diversified portfolio approach to manage technological uncertainty is diluted quickly when funding levels are 5 to 10 times below their socially optimal levels.

The plan itself states, "*successful development of advanced technologies could result in potentially large economic benefits*"(p. 3-28). As an example of the effect of policy on abatement costs, we can observe how a combination of R&D and demand-side policy has stimulated cost reductions in energy technologies (Duke and Kammen, 1999, Margolis and Kammen, 1999). For example, solar cells, known as photovoltaics, have declined in cost by more than a factor of 20 and wind turbines by a factor of 10. Accelerating future cost reductions in these and other technologies will require further investments in technology development and market creation.

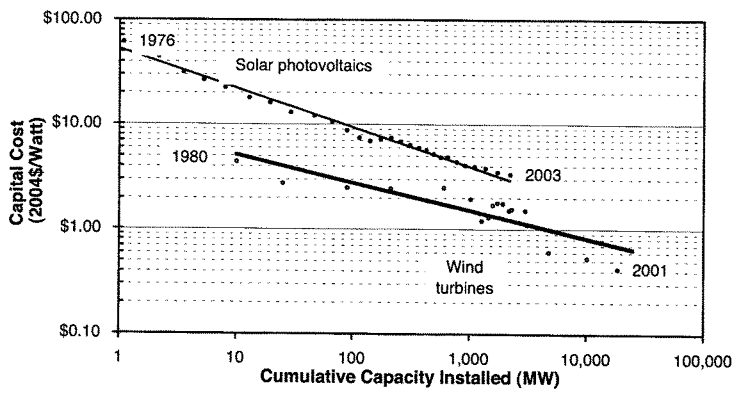


Figure 2 Cost reductions in carbon-free energy technologies

Figure 2 shows the capital costs of photovoltaics and wind turbines in constant 2004 $ per Watt. The horizontal axis shows cumulative worldwide installations of each technology (Duke and Kammen, 1999).

Climate change programs would address other problems as well

An important finding in ours and previous work on energy R&D is that many of the same programs that would help abate the climate problem would address other societal problems too. Adoption of improved zero emissions energy production and end-use technologies would offset the adverse health effects associated with emissions of mercury, sulfur dioxide, and oxides of nitrogen. Increased use of renewables-based power and fuels would reduce our sensitivity to energy production in politically unstable regions. A more distributed power system based on smaller scale production would enhance the robustness of the electricity system and reduce dangerous and costly power outages. And a more diverse mix of technologies and fuels would lessen the macro-economic effects of rapid changes in energy prices.

Comparing a major R&D initiative on climate to past programs

In our recent work we have asked how feasible it would be to raise investment to levels commensurate with the energy-related challenges we face. One way to consider the viability of such a project is to set the magnitude of such a program in the context of previous programs that this committee has participated in launching and monitoring. Scaling up R&D by 5 or 10 times from current levels is not a 'pie in the sky' proposal, in fact it is consistent with the scale of several previous federal programs (Table 1), each of which took place in response to a clearly articulated national need. While expanding energy R&D to five or ten times today's level would be a significant initiative, the fiscal magnitude of such a program is well within the range of previous programs, each of which have produced demonstrable economic benefits beyond the direct program objectives.

Table 1 Comparison of energy R&D scenarios and major federal government R&D initiatives

Program	**Sector**	**Years**	**Additional spending over program duration (2002$ Billions)**
Manhattan Project	Defense	1942-45	$25.0
Apollo Program	Space	1963-72	$127.4
Project Independence	Energy	1975-82	$25.6
Reagan defense	Defense	1981-89	$100.3
Doubling NIH	Health	1999-04	$32.6
War on Terror	Defense	2002-04	$29.6
5x energy scenario	***Energy***	***2005-15***	***$47.9***
10x energy scenario	***Energy***	***2005-15***	***$105.4***

"Major R&D initiatives" in this study are federal programs in which annual spending either doubled or increased by more than $10 billion during the program lifetime. For each of these eight programs we calculate a "baseline" level of spending based on the 50-year historical growth rate of U.S. R&D, 4.3% per year. The difference between the actual spending and the baseline during the program we call additional program spending. Kammen, D. M. and G. F. Nemet (2005). "Reversing the Incredible Shrinking U.S. Energy R&D Budget." *Issues in Science and Technology* 22: 84-88.

Declining investment in energy R&D

My students and I have documented a disturbing trend away from investment in energy technology—both by the federal government and the private sector (Figure 3). The U.S. invests about $1 billion less in energy R&D today than it did a decade ago. This trend is remarkable, first because the levels in the mid-1990s had already been identified as dangerously low, and second because, as our analysis indicates, the decline is pervasive—across almost every energy technology category, in both the public and private sectors, and at multiple stages in the innovation process. In each of these areas investment has been either been stagnant or declining. Moreover, the decline in investment in energy has occurred while overall U.S. R&D has grown by 6% per year, and federal R&D investments in health and defense have grown by 10 to 15% per year, respectively.

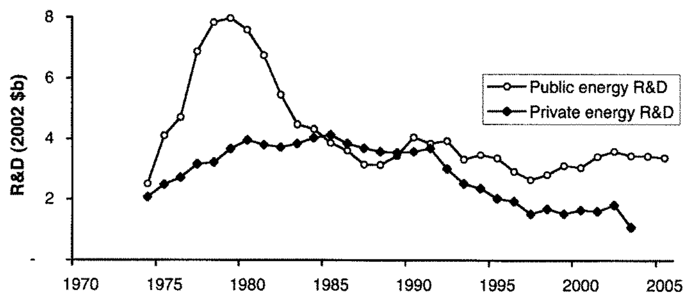


Figure 3 Declining energy R&D investment by both public and private sectors

Source: Kammen and Nemet (2005) *Issues in Science and Technology*, op cit.

By looking at individual energy technologies, we have found that in case after case, R&D investment spurs invention. For example, in the case of wind power patenting follows the wild swings in R&D budgets (Figure 4).

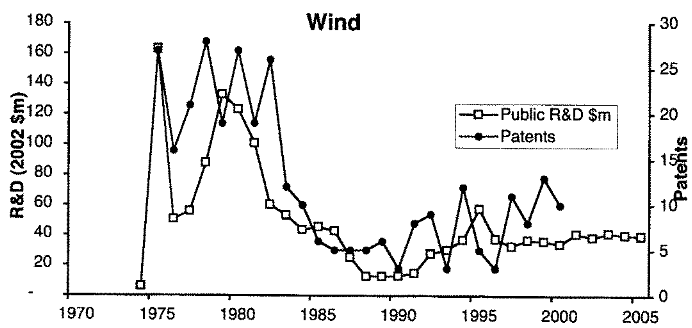


Figure 4 Federal R&D and U.S. wind power patents

A further concern regards U.S. competitiveness in these increasingly important technologies. For example, a glance at other nations' investments in new renewable energy technology shows the U.S. playing a secondary role (see Appendix C). Both Europe and Japan are investing more in R&D for renewable energy. Moreover, they have established leading companies in the fast growing wind and solar industries. Our economic competitiveness in these increasingly important sectors hinges on our commitment to investing in new technologies.

Finally, the drug and biotechnology industry provides a revealing contrast to the trends seen in energy. Although energy R&D exceeded that of the biotechnology industry 20 years ago, today R&D investment by biotechnology firms is an order of magnitude larger than that of energy firms (Figure 5). Today, total private sector energy R&D is less than the R&D budgets of individual biotech companies such as Amgen and Genentech.

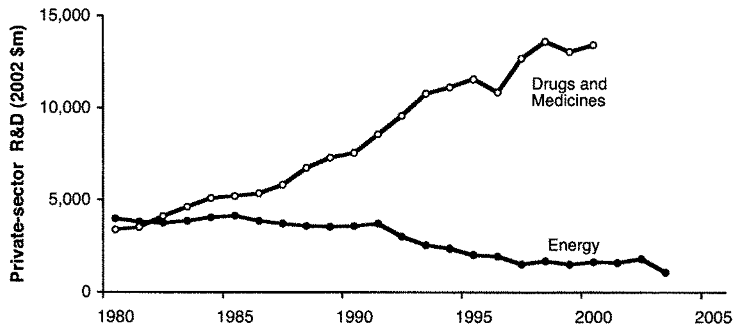


Figure 5 Private-sector R&D investment: energy vs. drugs and medicines

From Funding Levels to a Long-Term Energy Action Plan

To what extent will the draft strategic plan meet the Administration's goal of reducing U.S. greenhouse gas emission intensity (the amount of emissions per unit of production) by 18 percent by the year 2012?

In responding to this question, it is important to make clear how *small* a change is necessary for the nation to meet the Administration's GHG intensity goal for 2012. In Figure 6 we compare the President's climate change goal to the business-as-usual reference case established by the EIA. In order to achieve the President's goal, a reduction of 3.6%, or 66 million tons of carbon equivalent, would be required below the BAU projection. To put this amount in perspective, this change could be accomplished by switching about 100 of our nation's 1500 coal burning power plants to natural gas. New technology would make such a switch easier. But we could accomplish such a change with no research program at all with a relatively modest change in only one sector. If an array of changes were implemented throughout the energy sector, to include end-use and transportation, meeting the carbon intensity goal would be even easier. Meeting other goals such as the Kyoto Protocol or stabilization at levels of 450 or 550ppm would require much larger changes, including widespread deployment of technologies described in the Strategic Plan.

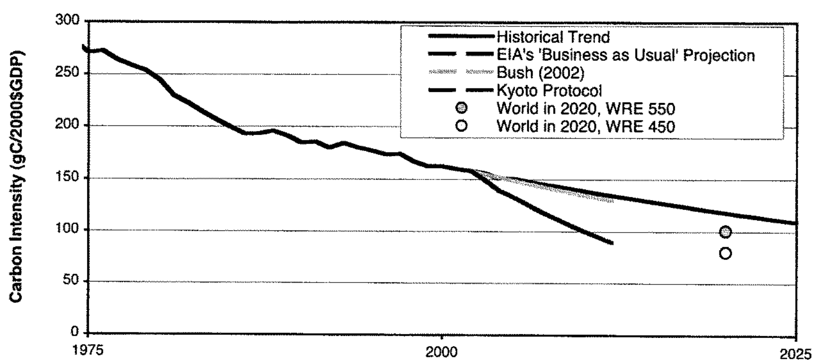


Figure 6 Carbon Intensity of the US Economy: Historical trend since 1975 and projection to 2025, with selected scenarios

Figure shows the carbon intensity of the US economy (in gC-equivalent/2000$GDP). The historical trend is shown from 1975 to 2002, with the EIA's "business as usual' (BAU) projection to 2025. Also shown are is the President's 2002 goal of an 18% reduction in carbon intensity below the 2002 level by 2012 and the Kyoto Protocol's goal of a 7% reduction in carbon emissions below 1990 levels by 2012. Additionally, the world "WRE stabilization pathways," named for the authors of a paper in Nature that has become a frequently used basis for carbon stabilization concentrations (see references), are used to calculate projected world average carbon intensity in 2020 for the 450 ppmv and 550 ppmv stabilization levels. In order to achieve Bush's goal, a reduction of 3.6%, or 66 million tons of carbon equivalent, would be required below the BAU projection. By contrast, in order to achieve the Kyoto Protocol's goal, a reduction of 33%, or 613 million tons of carbon equivalent, would be required. Note also that the WRE projections are world averages, which means that if enough other countries had carbon intensities higher than these values, it is possible that the US would have to reduce carbon intensity to below these values.

Does the Administration's strategic plan provide clear, unambiguous resource allocation guidance for the government's climate change technology R&D portfolio?

The plan's description of each technology program, including each program's overall strategy, current status, and future directions, does provide insight into the where resources will need to be allocated in order to bring programs toward commercially viable products. The broad array of technological options is an impressive feature of the plan. However, it is difficult to reconcile this rich and diverse technology portfolio with the budget summary in Appendix A.3. First, the plan does not clearly and unambiguously describe how each of the dozens of technology programs are to be funded. The budgets are listed at the level of the funding agency which gives little direction, for example, as to how much should be invested in biofuels versus carbon capture and sequestration. Second, it is difficult to imagine how a budget of slightly over three billion dollars per year can be used to fund the array of activities described in the plan at more than a trivial level. Real progress in programs such as fusion facilities and demonstrations of geological storage will require construction of facilities that will range in the tens to hundreds of millions of dollars. Funding a wide array of programs at relatively equal levels will ensure that these levels are low. A real danger exists that this funding will remain below critical thresholds for mobilizing needed technological improvements. If there is a prioritization of the programs that will allocate significant funds to a few key areas, it is not evident in the current public draft of the plan. Finally, a troubling omission is that the plan contains no budgets beyond 2006. This extremely short timeline for the budgets contained in the plan lies in stark contrast to the well-specified descriptions at the beginning of the document about the long term nature of the problem and the time it will take to develop the technological solutions to address it. The lack of clarity here is especially damaging because the absence of a longer term commitment sends an unnecessarily ambiguous signal to the private sector dampening the effect of the virtuous cycle that can emerge from government investment in R&D and subsequent investment by the private sectror.

Does the draft strategic plan appropriately balance the research needs that will enable the country to take short-, medium- and long-term actions to limit our greenhouse gas emissions and to adapt to any anticipated effects of climate change?

The strategic plan makes good use of emissions scenarios in its treatment of technology timing. On page 3-28, the plan makes the crucial point that the slow turnover of capital stock in the energy sector implies that technologies that need to achieve widespread deployment by mid-century will need to reach commercial readiness well before that, maybe even decades earlier. This infrastructural inertia combined with natural lags in the flows of GHG in the ocean, atmosphere, and biosphere creates an urgency that belies the long-time scales involved in the climate problem.

The "roadmap" in Figure 10-1 is a helpful visualization of the staged deployment of technology programs within the plan. Perhaps the most important text in Chapter 10 is the phrase "significant deployment." Offsetting GHG emissions with new technologies requires widespread deployment of low and zero-carbon technologies. This need for broad adoption of the technologies at issue really brings into question the adequacy of our near term response to the problem. For example, achieving widespread deployment of hydrogen fuel cell automobiles in the 2025 to 2045 period, as the plan recommends, means that a significant number of those vehicles would need to begin entering the market ten years from today when a viable hydrogen fueling infrastructure would need to be in place. Significant deployment by 2035 means almost all new vehicles would need to be fuel cell vehicles by 2025, which implies that a large number of commercially available models would be available by 2015. Yet the plan's goal for 2015 is merely to achieve reliability and cost targets in demonstration projects.

The roadmap is a succinct outline of the sequencing of the technology programs. What is missing is a clearer path for how these technologies emerge from modestly funded research programs, to demonstration, to early commercial applications, to rapid adoption, to the end goal, which is widespread deployment. As an example of what such a path might look lie, my students and I have produced a detailed analysis that shows how we can "decarbonize" the vehicles and electricity sectors through a small set of specific policies. We provide these illustrative scenarios in Appendix D, and note that work underway place in the Energy and Environment Division at Lawrence Livermore National Laboratory, under the leadership of Dr. Jane Long, is coming to similar conclusions.

What is the demonstrated value of investments in R&D?

One of the clearest findings from tracking actual investment histories, is that there is a very strong correlation between investment in innovation and demonstrated changes in performance and cost of technologies available in the market. In the case of solar photovoltaics, a 50% increase in PV efficiency occurred immediately after unprecedented $1 billion global investment in PV R&D (1978-85). From there, we observed significant efficiency improvements, which account for fully 30% of the cost reductions in PV over the past two decades.

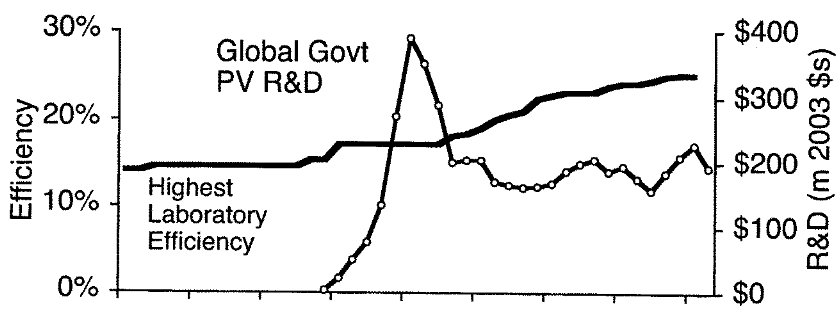


Figure 7: Clear Benefits of R&D Investments in Improving Products in the Market.
Source: G. Nemet, Nemet, G. F. (2006). "Beyond the learning curve: factors influencing cost reductions in photovoltaics,: Energy Policy 34(17): 3218 - 3232.

Two important considerations: incentives for high-payoff research and commercialization

I would like to emphasize two additional important aspects of a substantially enhanced climate technology program. First, special emphasis may be needed to create incentives for high risk, high payoff research. We refer to a section within a recent National Academies report on this topic. And second, development efforts to hasten commercialization need to be included as well so that research programs acknowledge the need for demand-side incentives too.

This past fall, the National Academy of Science released an important report that raised the issue of American technological competitiveness and provided recommendations for improving the country's capacity for innovation (Augustine, 2005). That report focused on the two fundamental issues that, in the opinion of its panel of experts, challenge our country's technical competence:

- Creating high quality jobs for Americans, and
- The need for clean, affordable, and reliable energy.

Setting energy-related challenges at the top of our country's science and technology agenda is an important step and fits well with the situation outlined in the rest of this testimony. The recommendations in this study are admirable for their breadth including suggestions for K-12 education, basic research, university training, and incentives for innovation. Of particular interest to this committee is the panel's vision of a Defense Advanced Research Projects Agency (DARPA) for energy, "ARPA-E." Such a program would fund "high-risk research to meet the nation's long-term energy challenges" including universities, existing firms, and start-up ventures. The flexibility and independence of the DARPA model are key attributes that such a program seeks to emulate. Establishing an adequately funded organization like this would be a powerful commitment to securing our nation's energy future much as the way DARPA has done for our military power.

Important details to consider in setting up such an agency include ensuring that the demand-side of the problem is addressed as well. The military is unique in that the technologies being developed are created for a single customer under public sector control. Decision-making and technology adoption in the energy sector are much more dispersed and are deeply impacted by market forces as well as regulation. As a result, an ARPA-E program would need to be more cognizant of the demand-side of the innovation process in order to bring high-risk, high-payoff energy technologies to widespread adoption. This may include more emphasis on collaboration and technology transfer activity between the government and the private sector. Prior work on federal energy R&D, such as the PCAST studies (PCAST, 1997, 1999), has emphasized the importance of designing programs and policies that provide pathways for technologies that emerge from R&D programs to find full-scale commercial applications. The notion of the "valley of death" is based on the observation that technologies that succeed in proceeding from research to development to demonstration face important new obstacles in becoming viable commercial products. Technologies at this stage are often one-of-a-kind demonstrations and have not been built at full scale, large volume manufacturing problems need to be solved, and reliability must be demonstrated to skeptical customers. Past experience shows that technological success is not sufficient to bring new energy technologies to market. The challenges of scaling up, investing in manufacturing and distribution, building institutional capacity, and customer education need to be addressed as well. Past energy R&D programs may have put too little emphasis on this critical stage and a large new initiative needs to address these issues as well if the United States is to take full advantage of the benefits that emerge from the research programs. For example, public funding may need to be allocated for demonstration projects that stimulate learning effects, prove the viability of unfamiliar technologies, and mediate the risks to early adopters.

Common misconceptions about an aggressive energy R&D program

Some have expressed skepticism about the need for a national program for high-payoff energy R&D. Here I'd like to point out important misconceptions behind five criticisms of such a program:

1. "*Energy research is already well funded by private firms.*" Our figures shown above show that this is clearly *not* the case, as R&D investment by private firms has fallen by 50% in the past decade and R&D intensity by energy firms is a factor of 10 below the U.S. average.

2. "*Public sector R&D will crowd-out private sector R&D*". For the economy as a whole, the evidence for this assertion is mixed at best (David et al., 2000). In the energy sector, there is so little private energy R&D that could be crowded out that this problem is small if it exists at all.

3. "*Venture capital will identify promising opportunities in the energy sector*". The emergence of VC investment in the energy sector has been encouraging. However, this is overwhelmingly for late-stage technologies with the potential for widespread adoption within 3 to 5 years.

4. "*Government programs would pick winners rather than let markets decide*". In early stage technologies, when uncertainty is high and risks are large, the best strategy is making a diverse set of uncorrelated investments. This strategy is best seen as placing multiple bets, not picking winners.

5. "*Emulating the success of DARPA for an ARPA-E program does not make sense because Department of Energy research programs are more productive than DARPA's.*" It is extremely difficult to measure the productivity of the early stage research that DARPA funds. R&D productivity measures that focus on the direct and easy-to-measure benefits

of new technologies, tend to underestimate the benefits of public R&D. For example, how would we assess the worthiness of DARPA's funding of research on semiconductors in the 1940s and 1950s and the internet in the 1970s?

Recommendations

- **Make Energy and the Environment a Core Area of Education in the United States.** Public interest and action on energy and environmental themes requires attention to make us 'eco-literate and economically savvy.' We must develop in both K-12 and college education a core of instruction in the linkages between energy and both our social and natural environment. The Upward Bound Math-Science Program and the Summer Science Program each serve as highly successful models that could be adapted to the theme of energy for a sustainable society at all educational levels. The launch of Sputnik in 1957 mobilized U. S. science and technology to an unprecedented extent, and should serve as a lesson in how powerful a use-inspired drive to educate and innovate can become. The Spring 2005 Yale Environment Survey found overwhelming interest in energy and environmental sustainability. Contrast that interest with the results of the Third International Mathematics and Science Study (TIMSS) where American secondary school students ranked 19th out of 21 countries surveyed in both math and science general knowledge. The United States can and should reverse this trend, and sustaining our natural heritage and greening the global energy system is the right place to begin.

- **Establish a Set of Energy Challenges Worthy of Federal Action.** Establish *SustainableEnergy USA* awards – modeled after the successful efforts of the Ashoka Innovators awards for social entrepreneurs and the Ansari X Prize initially given for space vehicle launch - that inspire and mobilize our remarkable resources of academia, industry, civil society, and government. These initiatives would support and encourage groups to take action on pressing challenges. An initial set of challenges include:

    - Buildings that cleanly generate significant portions of their own energy needs ('zero energy buildings');

    - Commercial production of 100 mile per gallon vehicles, as can be achieved today with prototype plug-in hybrids using a low-carbon generation technologies accessed over the power grid, or direct charging by renewably generated electricity, and efficient biofuel vehicles operating on ethanol derived from cellulosic feedstocks.

    - Zero Energy Appliances (Appliances that generate their own power)

    - 'Distributed Utilities'; challenges and milestones for utilities to act as markets for clean power generated at residences, businesses, and industries.

- **Make the Nation the Driver of Clean Vehicle Deployment.** As the Zero Emission Vehicle Mandate, the Pavley Bill (AB 1493), and the Pavley-Nuñez Bill (AB 32) have shown in California, dramatic improvements in vehicle energy efficiency and reductions in carbon emissions are eminently achievable, given political leadership. A clear message, as well as dramatic carbon and financial savings, would come from a decision to only purchase for state transportation needs vehicles meeting a *high* energy efficiency target, such as 40 miles per gallon for sedans and 30 miles per gallon for utility vehicles. These standards are now possible thanks to improvements in vehicle efficiencies and the wider range of hybrids (including SUV models) now available. A key aspect of such a policy is to announce from the outset that the standards will rise over time, and to issue a challenge to industry that a partnership to meet these targets will benefit their bottom line and our nation.

- **Expand International Collaborations that Benefit Developing Nations at a Carbon Benefit.** The needs of many developing nations are focused on the challenges meet fundamental economic and environment goals for their people. At the same time, these are our goals as well, both as a nation that must lead the charge to a sustainable and equitable world, and as citizens of a world where we share the rights and responsibilities to protect the atmosphere. Greenhouse gases emitted anywhere impact us all, not only today but for decades to come. In many cases, tremendous opportunities exist to offset future greenhouse gas emissions and to protect local ecosystems both at *very* low cost, but also to directly address critical development needs such as sustainable fuel sources, the provision of affordable electricity, health, and clean water. My laboratory has recently detailed the local development, health, *and* the global carbon benefits of research programs and partnerships on improved stoves and forestry practices (Bailis, Ezzati, and Kammen, 2005) across Africa. Far from an isolated example, such opportunities exist everywhere, with the recent wave of interest in 'sustainability science' (Jacobson and Kammen, 2005) a resource, aid, and business opportunity that the U. S. should embrace.

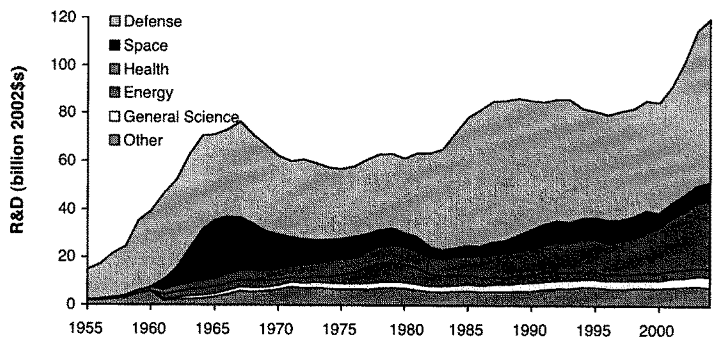
- **Recognize and Reflect Economically the Value of Energy Investment to the Economy.** Clean energy production – through investments in energy efficiency and renewable energy generation – has been shown to be a winner in terms of spurring innovation and job creation. This should be reflected in federal economic assessments of energy and infrastructure investment. Grants to states, particularly those taking the lead on clean energy systems, should be at heart of the federal role in fostering a new wave of 'cleantech' innovation in the energy sector.

- **Begin a Serious Federal Discussion of Market-Based Schemes to Make the Price of Carbon Emissions Reflect their Social Cost.** A carbon tax and a tradable permit program both provide simple, logical, and transparent methods to permit industries and households to reward clean energy systems and tax that which harms our economy and the environment. Cap and trade schemes have been used with great success in the US to reduce other pollutants and several northeastern states are experimenting with greenhouse gas emissions trading. Taxing carbon emissions to compensate for negative social and environmental impacts would offer the opportunity to simplify the national tax code while remaining, if so desired, essentially revenue neutral. A portion of the revenues from a carbon tax could also be used to offset any regressive aspects of the tax, for example by helping to compensate low-income individuals and communities reliant on jobs in fossil fuel extraction and production.

Acknowledgments
This testimony was prepared in collaboration with my students Gregory Nemet, Carla Peterman, Sam Arons, Jenn Baka, and Derek Lemoine, and with my post-doctoral research fellow Dr. Frank Ling. Additional collaboration has and continues to take place with Drs. Jane Long and Gene Berry of Lawrence Livermore National Laboratory. This work was supported by a grant from the Energy Foundation, the support of the Karsten Family Foundation endowment of the Renewable and Appropriate Energy Laboratory, and the support of the University of California Class of 1935.

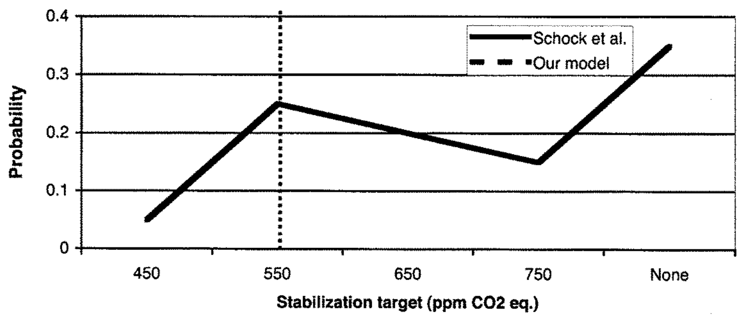
Appendix A: Previous federal R&D programs

This chart shows all U.S. federal R&D programs since 1955. Notice the thin strip showing how small the energy R&D program is relative to the others. The current budgets for energy R&D would continue this situation, or even reduce R&D investment (Kammen and Nemet, 2005).



Appendix B: Estimating energy R&D investments required for climate stabilization

This note describes the methodology used to arrive at the estimates for future energy R&D in Kammen and Nemet (2005). Schock et al. (1999) valued energy R&D by providing estimates of the insurance needed against oil price shocks, electricity supply disruptions, local air pollution, and climate change. By estimating the magnitude of the risks in each area and the probabilities of energy R&D programs to reduce them, they found that increasing energy R&D by a factor of four would be a 'conservative' estimate of its insurance value. We note that this estimate assumes a mean climate stabilization target of between 650 and 750 ppm CO_2 equivalent and incorporates a 35% probability that no stabilization at all will be needed. This possibility of no stabilization at all is especially concerning as it would potentially involve levels exceeding 1000 ppm CO_2 by the end of the century, with higher levels thereafter.



Probability density function for climate stabilization used by Schock *et al.* compared with the 550 ppm target used in Kammen and Nemet (2005).

A recalculation of their model to target the 550-ppm atmospheric level, scenario A1T ('rapid technological change') of the Intergovernmental Panel on Climate Change (Nakicenovic, Alcamo et al. 2000), increases the optimal R&D investment in energy R&D to $11 to $32 billion, 3 to 10 times the current level of investment.

Model Description

The model devised by Schock et al. establishes an "insurance value" of federal energy R&D. It is based on assessing risk mitigation due to R&D for four types of energy-related risks. The non-climate risks are discussed at the end of this appendix. The value of R&D for mitigating climate change is calculated according to the following:

The value of R&D for the U.S. (V_{US}) is the product of the climate mitigation savings derived from R&D programs (S), the assumed probability of R&D success (P), and the probability of needing to achieve each stabilization level (L). These values are summed for each stabilization level (i) and multiplied by the contribution to worldwide climate R&D by the U.S. (A).

$$V_{US} = A \sum_i (S_i P_i L_i)$$

Like Schock *et al.*, we assume that the contribution to worldwide R&D by the U.S. (A) is in proportion to its current share of worldwide greenhouse gas emissions, approximately 25%.

The subscript i represents 5 greenhouse-gas stabilization levels: 450 ppm, 550 ppm, 650 ppm, 750 ppm, and the case of no stabilization.

The probabilities (L) of needing to stabilize at each level i, are used as shown in the figure above. For the Schock et al. model these are: 0.05 at 450 ppm, 0.25 at 550 ppm, 0.2 at 650 ppm, 0.15 at 750 ppm, and 0.35 for the case of no stabilization. In contrast to the probability density function used by Schock et al., we select the doubling of pre-industrial levels as our target and thus assign the level i = 550ppm a "probability" of 1.

We use the values developed by Schock et al. for the assumed probability of R&D success (P). These probabilities decrease with stabilization levels, under the assumption that lower stabilization will require larger contributions from early-stage technologies whose ultimate viability is less likely than near-term options. The range for 550 ppm is 0.5 to 0.8. We use both ends of this range to bound our estimate.

For each stabilization level i, the climate mitigation savings derived from R&D programs (S) is the difference between the costs to stabilize using the outcomes of a successful R&D program (CRD) and the costs to stabilize without the R&D program (C).

$$S_i = C_i - CRD_i$$

We use the costs to stabilize (C) calculated by Schock et al., who used the MiniCAM 2.0 model applied to two sets of mitigation scenarios, those by Wigley et al. (1996) and the IPCC. The cost to stabilize at 550 ppm is in the range of $0.9 to $2.4 trillion. It is important to note that these scenarios already include technology improvement, although they do not specify how much R&D is implied to achieve this "autonomous" improvement. As Schock *et al.* point out, if any of this assumed improvement depends on higher levels of R&D, the estimates calculated in this model will then underestimate the R&D required.

The costs to stabilize using the outcomes of a successful R&D program (CRD) are lower because the energy technologies developed in the R&D program can be used to offset greenhouse gas emissions at lower costs than using existing technologies. We use the assumption by Schock et al. that a successful R&D program will enable us to deploy technologies that produce energy at costs similar to business-as-usual costs while reducing emissions sufficient to stabilize at the 550 ppm level.

Data comparison

The table below shows the values used in the model. In our version of the model we use the same values as Schock et al. for the 550 ppm level. The one exception is the probabilities assumed for the needing to achieve each stabilization level (L). Our model is conditional on a stabilization target of 550 ppm, because we are deriving the amount of R&D required to achieve a specific target. In contrast, Schock et al. treat the stabilization level as an uncertain parameter with a known probability density function.

Parameter values used in the model

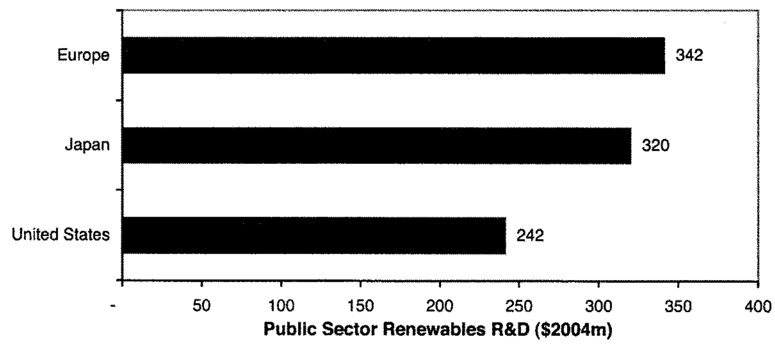
Study	Kammen and Nemet (2005)	Schock ***et al.*** (1999)				
Stabilization level CO_2 (ppmv)	550	550	450	650	750	*None*
Cost to stabilize without R&D (C) $trillions	0.9 to 2.4	0.9 - 2.4	3.7 - 4.5	0.3- 1.3	0.2 - 0.5	0
Cost to stabilize with R&D (CRD) $trillions	0	0	0.4	0	0	0
Savings from R&D (S) $trillions	0.9 to 2.4	0.9 - 2.4	3.3 - 4.1	0.3 - 1.3	0.2 - 0.5	0
Probability of R&D success (P)	0.5 to 0.8	0.5 - 0.8	0.1	1.0	1.0	--
Probability of needing to achieve stabilization level (L)	1.0	0.25	0.05	0.2	0.15	0.35
U.S. share of worldwide R&D (A)	0.25	0.25				
Discount rate	0.05	0.05				

Outcomes

In our model, the total required spending was discounted and annualized to arrive at estimates for the required amount of annual federal energy R&D to stabilize atmospheric concentrations of CO_2 at 550 ppm. We arrive at a range of $6 to $27 billion in 2005 dollars.

Finally, we note that in their model, Schock et al. show energy R&D can be used as insurance against other risks as well, such as oil price shocks, electricity outages, and air pollution. Using energy R&D to mitigate these risks has an annual value estimated to be $9 to $10 billion. The figures above are if anything, overly conservative in that they assume that the R&D programs launched to address climate stabilization perfectly overlap with the programs used to address these other risks. A less conservative estimate would be to assume that perhaps half of the other risks would be addressed by the climate R&D program and half would not. For example, investments to improve the reliability of the electricity grid would reduce damages due to power outages but would not necessarily be included in a large climate R&D program. In that case, optimal energy R&D would rise to $11 to $32 billion per year, or roughly 3 to 10 times current levels. In our paper, we use scenarios of increases of factors of 5 and 10 to compare this range to the large R&D programs of the past.

Appendix C: Investments in renewables R&D across countries.



Investments in Renewable Energy Research and Development by OECD countries in 2004 (Data: Kammen and Nemet, 2005; International Energy Agency, 2005).

Appendix D: Achieving a low-carbon economy

By committing to a program of feasible carbon reductions in electricity and transportation sectors, we find that emissions can be reduced by up to 75% from today's levels.

At the current rate of demand increase, the electricity market has and will likely continue to grow at an annualized rate of 1.5%. With current electricity use estimated at 4000 terawatt-hours (TWh) per year, it is poised to increase to 5500 TWh/yr by 2025 and 7500 TWh/yr by 2050. Today, the net carbon emissions from different fossil fuel sources is about 2400 million metric ton carbon equivalents (MMTCE) per year and is projected to go up to 3700 MMTCE by 2025 and 5100 MMTCE by 2050.

We examine alternative scenarios of supply and demand in the electricity market between now and the year 2050 (Figure 1). Deployment of efficiency along with the growth of renewables are examined for their impact on electricity consumption and greenhouse gas emissions (Table 1).

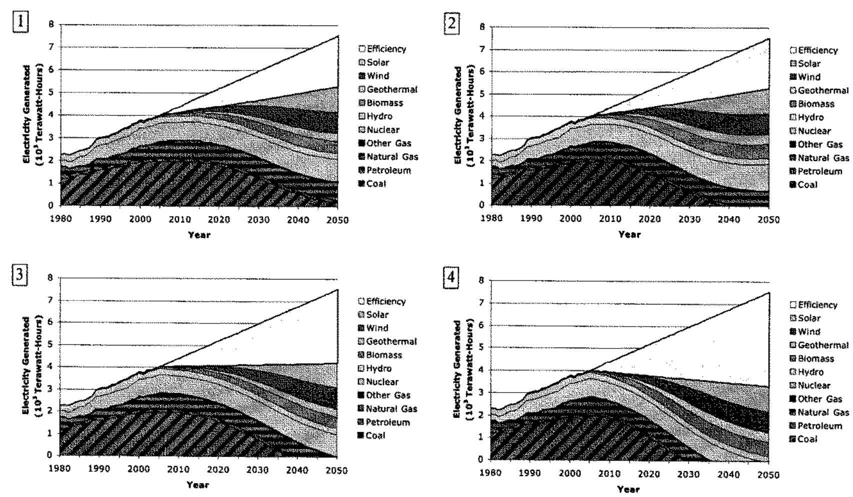


Figure 2. Alternative scenarios in the electricity market.

	Business-As-Usual	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Strategy	1.5% annual increase	1.0% Efficiency, Moderate	1.0% Efficiency, Aggressive	1.5% Efficiency, Moderate	2.0% Efficiency, Aggressive

		Renewables, Moderate Nuclear	Renewables, Aggressive Nuclear	Renewables, Moderate Nuclear	Renewables, No Nuclear
Electricity Consumed	7500 TWh	5300 TWh	5300 TWh	4200 TWh	3400 TWh
Carbon Emissions	5100 MMTCE	747 MMTCE	411 MMTCE	9 MMTCE	0 MMTCE
RPS [a]	5%	60%	64%	76%	100%

[a] Renewable Portfolio Standard (hydro, wind, solar, geothermal, and biomass)

Table 1. Description of scenario strategies and key findings for 2050 in the US electricity market.

The US currently uses 17 quads of primary energy for light duty fleet transportation. This figure is expected to grow to 24 quads in 2025 and 39 quads in 2050 under the current projected growth rate of 1.9% per year. Present emissions from light duty fleet transportation are 1,560 MMTCE and are projected to grow to 2,229 MMTCE by 2025 and 3,604 MMTCE by 2050. We examined potential reductions in CO_2 emissions from a business-as-usual approach by improving CAFÉ standards, increasing the market share of hybrid vehicles and meeting a larger portion of fuel demands with ethanol. We analyzed four scenarios based on moderate or aggressive paths of CAFÉ increases, hybrid market share increases and ethanol market share increases (Table 2).

Scenario	Description
BAU	BAU
Scenario 1	Moderate CAFE Moderate Hybrids Moderate Ethanol
Scenario 2	Moderate CAFE Aggressive Hybrids Aggressive Ethanol
Scenario 3	Aggressive CAFE Aggressive Hybrids Moderate Ethanol
Scenario 4	Aggressive CAFE Aggressive Hybrids Aggressive Ethanol

Table 2. Scenarios examined.

By 2025, light duty fleet carbon emissions can be reduced by approximately 29-45% from BAU and by 2050, carbon emissions can be reduced by approximately 58-72%.

	2025		2050	
	CO_2 Emissions	% Reduction from BAU	CO_2 Emissions	% Reduction from BAU
Strategy	MMTCE	%	MMTCE	%
BAU	2,229	-	3,604	-
Scenario 1	1,571	29.51	1,514	58.00
Scenario 2	1,508	32.34	1,242	65.54
Scenario 3	1,238	44.44	1,116	69.04
Scenario 4	1,218	45.36	1,010	71.98

Table 3. Potential reductions in light duty fleet CO_2 emissions.

Substantial savings from both the electricity and light vehicle sectors, which combined account for 65% of US emissions today, can be realized through a set of scenarios in both of these sectors (Figure 2). Nearly 75% from today's 4000 MMTCE can be saved under the most aggressive scenario.

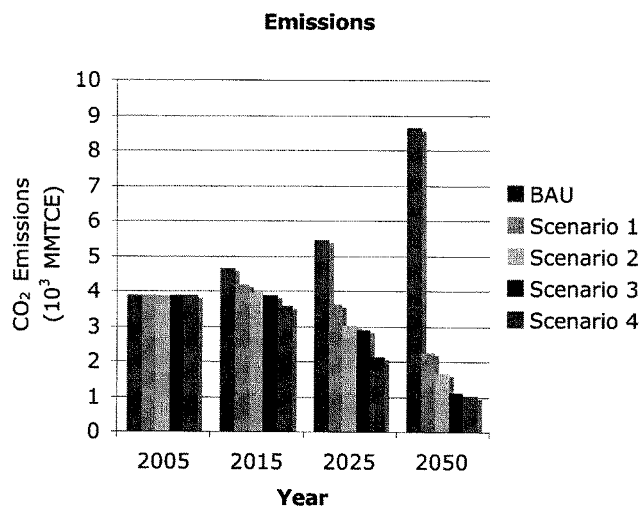


Figure 2. Carbon emissions from combined electricity and transportation sectors.

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A Clean Energy Roadmap for the United States

Daniel M. Kammen

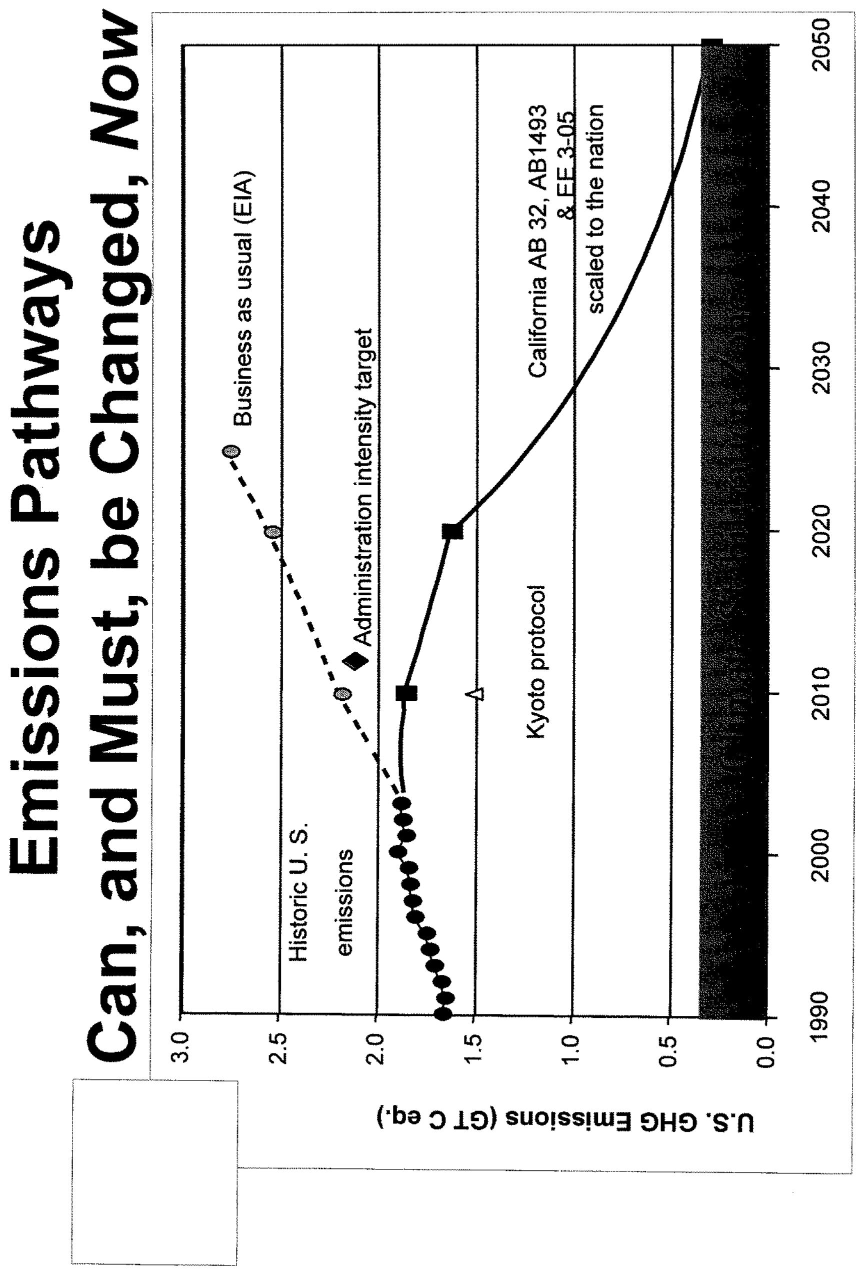
Co-Director, Berkeley Institute of the Environment
Director, Renewable and Appropriate Energy Laboratory (RAEL)
Energy and Resources Group, Goldman School of Public Policy, Nuclear Engineering
University of California, Berkeley

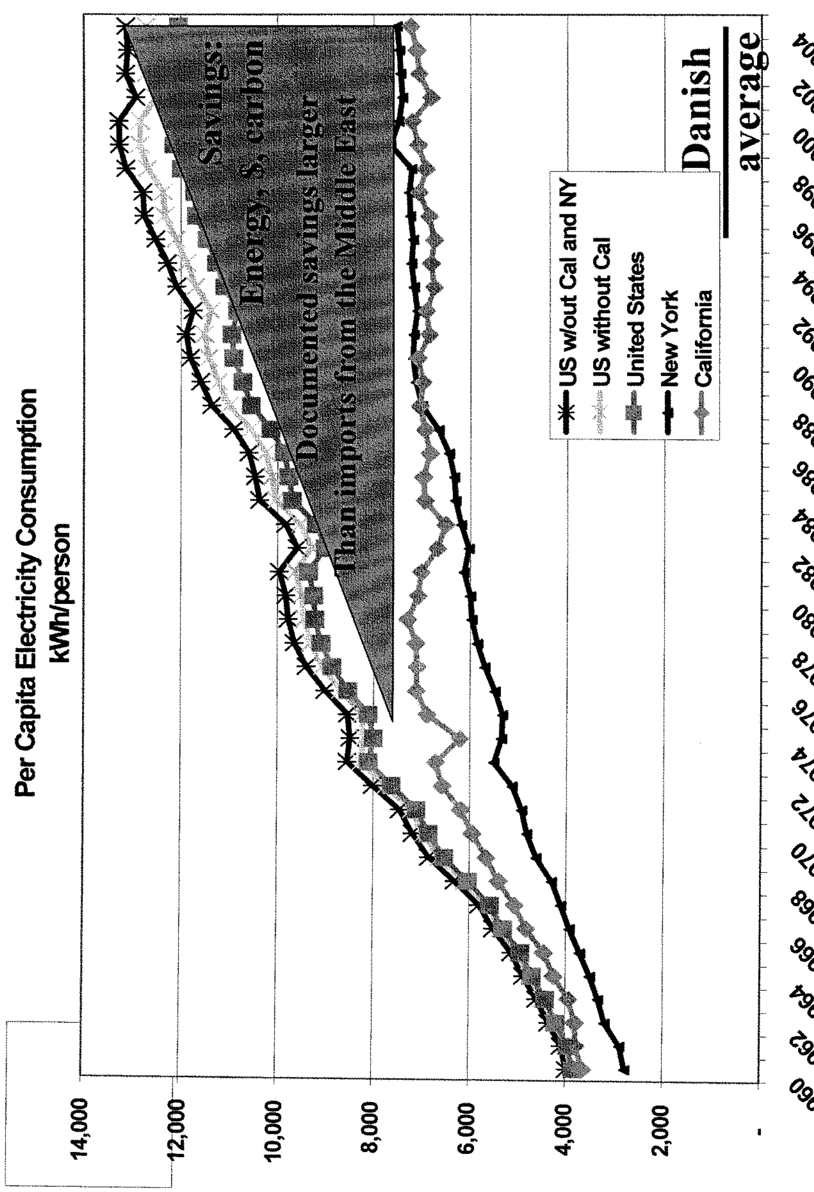
All materials online at: http://rael.berkeley.edu

Hearing:
Committee on Government Reform, U. S. House of Representatives - September 21, 2006
Climate Change Technology Research: Do We Need a 'Manhattan Project' for the Environment?

Do We Need a Manhattan Project for the Environment?

- A major commitment to energy leadership and sustainability is needed, and is long overdue
  - *Energy and environmental sustainability is a marathon, not a sprint*
- The the scientific and technological foundation exists, but a greatly increased commitment to innovation is necessary
  - *The benefits of investing in innovation are well documented*
  - *Clear signals result in significant, sustained, industry response & profit*
  - *Innovation leads to innovation; stagnation does not*
- Technologies do not adopt themselves
  - *While we have the tools, market forces must be employed in concert with sustained attention to innovation*
  - *Full use of market forces requires the introduction of carbon costs (and benefits of emissions reductions)*

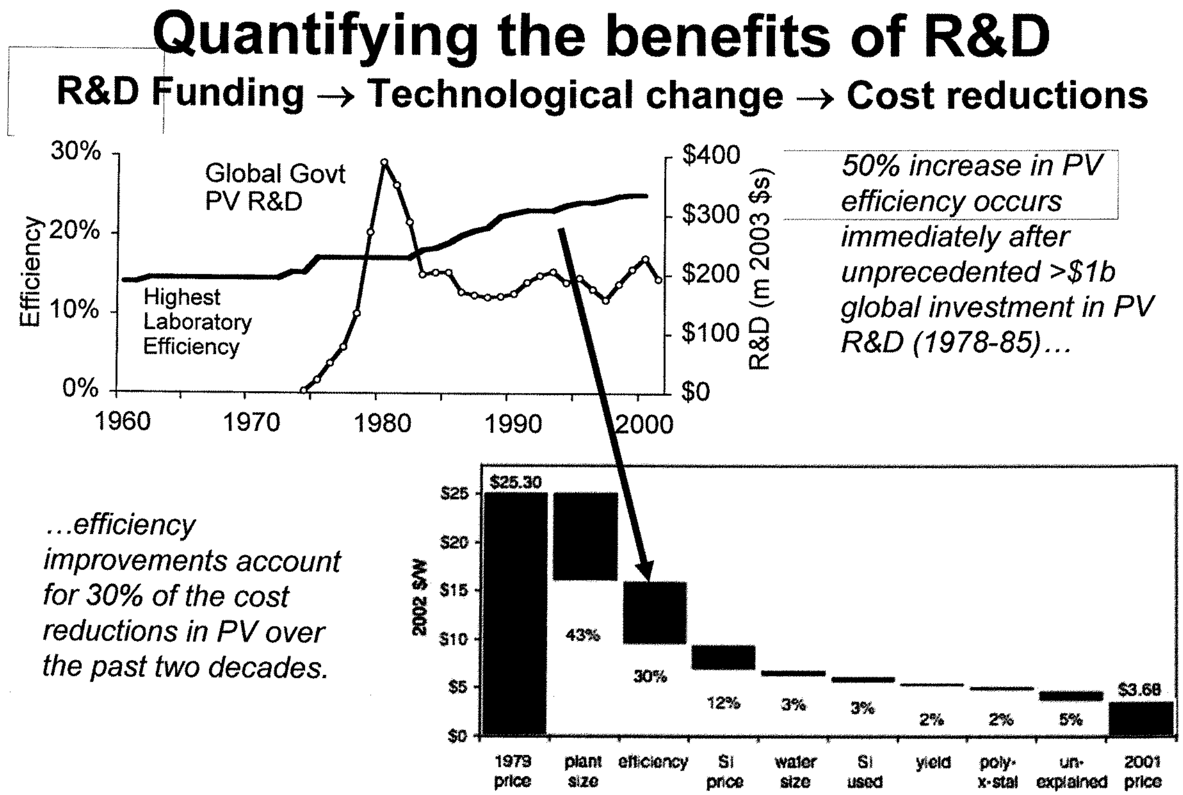

Emissions Pathways
Can, and Must, be Changed, Now
U.S. GHG Emissions (GT C eq.)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
1990
2000
2010
2020
2030
2040
2050
Historic U. S. emissions
Business as usual (EIA)
Administration intensity target
Kyoto protocol
California AB 32, AB1493 & EE 3-05 scaled to the nation


Per Capita Electricity Consumption
kWh/person
14,000
12,000
10,000
8,000
6,000
4,000
2,000
-
1960
1962
1964
1966
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
Savings:
Energy, $, carbon
Documented savings larger
Than imports from the Middle East
US w/out Cal and NY
US without Cal
United States
New York
California
Danish
average

Sustained Breakthroughs are Possible, *(yet U. S. analyses assume ~ 1.5%/year)*

	Metric	Interval	% Change/year
Energy Production			
Photovoltaic Cells	$/W installed	1955 – 2005	8.8
Wind turbine	$/W installed	1985 – 2000	3.6
Gas turbine	$/W installed	1958 – 1980	9.2
Ethanol fuel	$/m^3	1985 – 2002	6.0
Energy Use			
Refrigerators	Energy Use/Unit	1975 – 2001	5.0
Gas Furnaces	Energy Use/Unit	1972 – 2000	2.5
Central Air Conditioning	Energy Use/Unit	1972 – 2001	2.1
CFL ballasts	Cost/Unit	1986 – 1997	9.5
Economic			
US	Energy Use/GNP	1975 – 2001	2.9
US	Energy Use/GNP	1981 – 1986	3.4
US	Energy Use/GNP	1997 – 2001	2.7
California	Energy Use/GSP	1981 – 1986	4.5
California	Energy Use/GSP	1997 – 2001	3.9
China	Energy Use/GNP	1981 – 1986	4.8
China	Energy Use/GNP	1987 – 1996	5.0
China	Energy Use/GNP	1997 – 2001	5.3

Source: Kammen, *Ling & Baka,S cience,* in prep.



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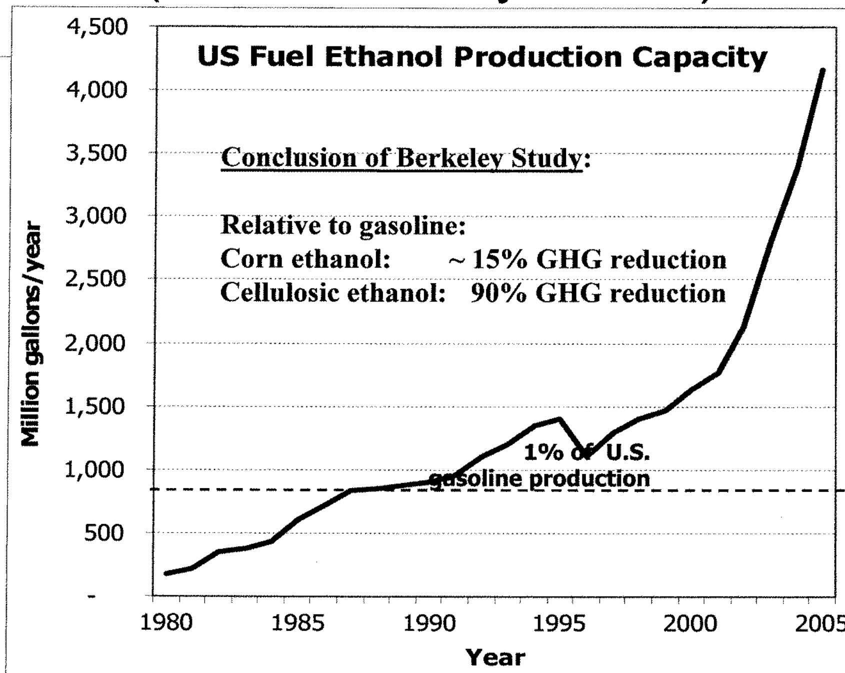
Biofuel Markets Growing Fast
(and can be very diverse)



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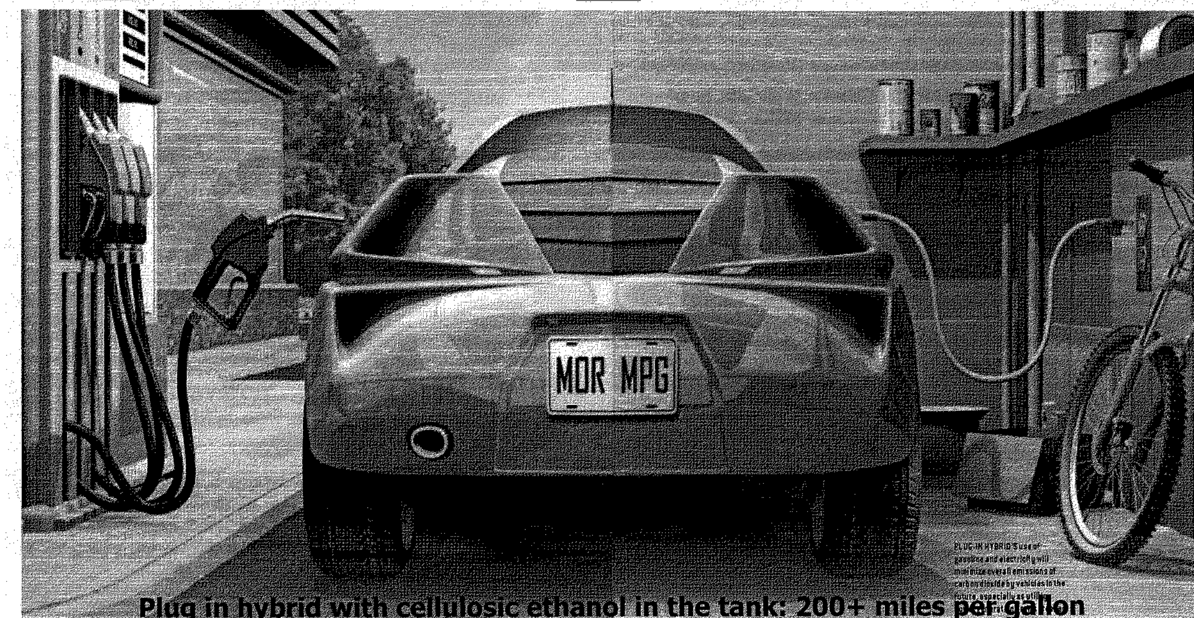
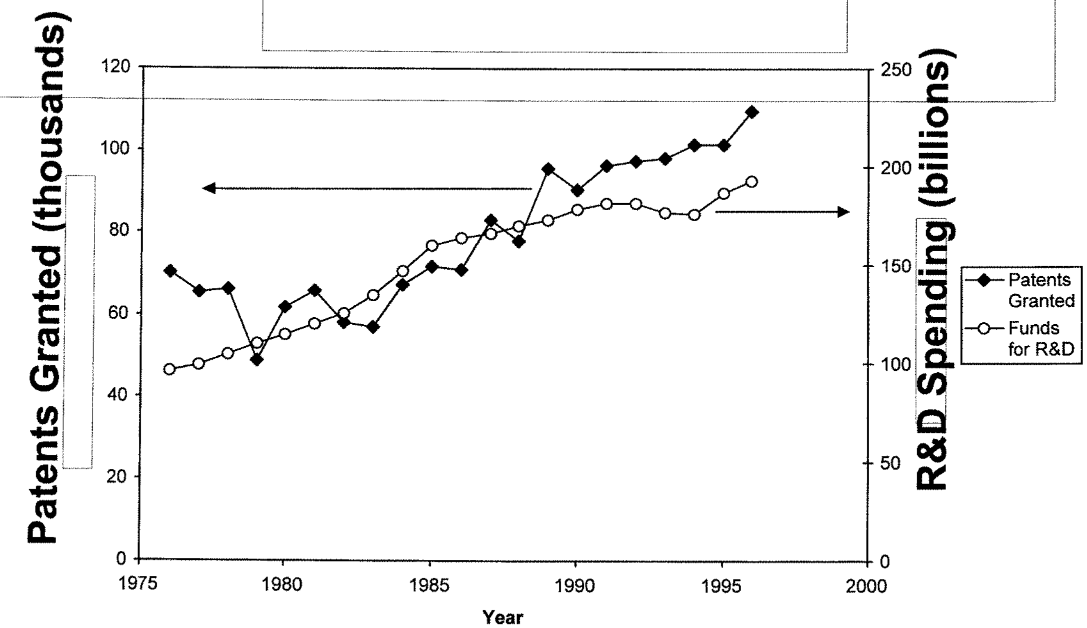
The PHEV concept

(HEV = electric range)



Breakthrough: stationary and mobile energy sources linked

Federal R&D Policy Can be Very Effective
(All sectors of the U. S. Economy)



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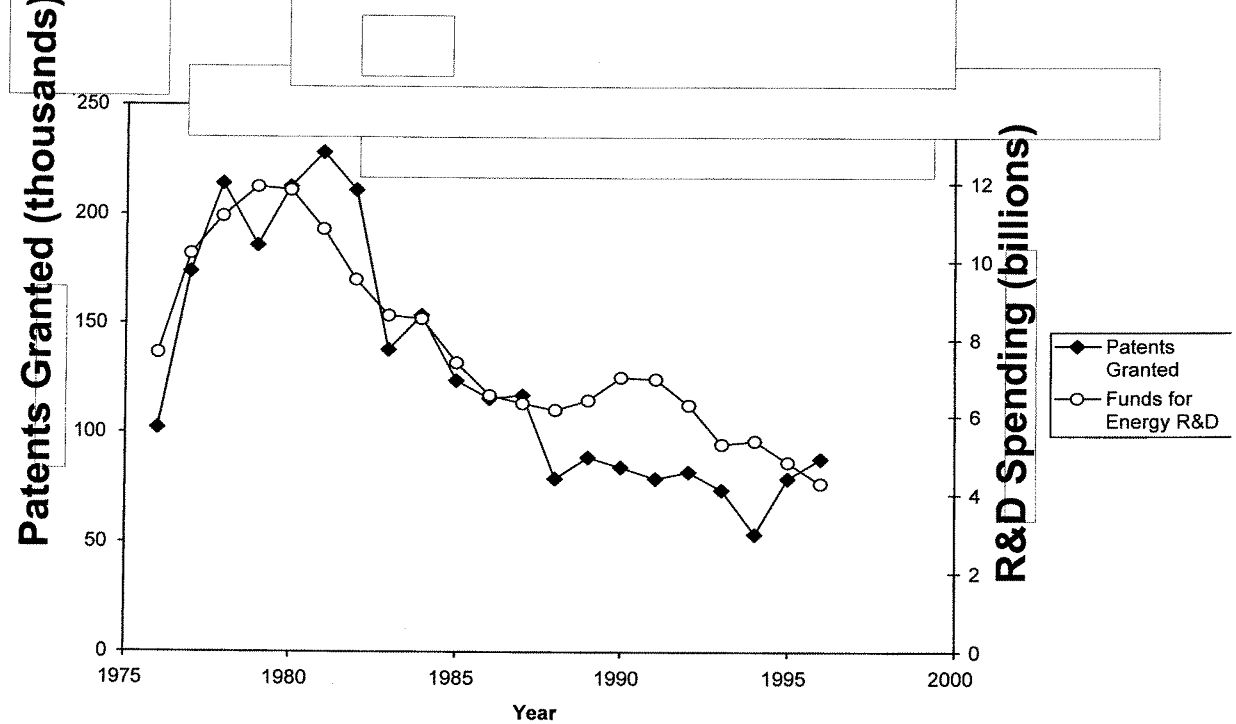
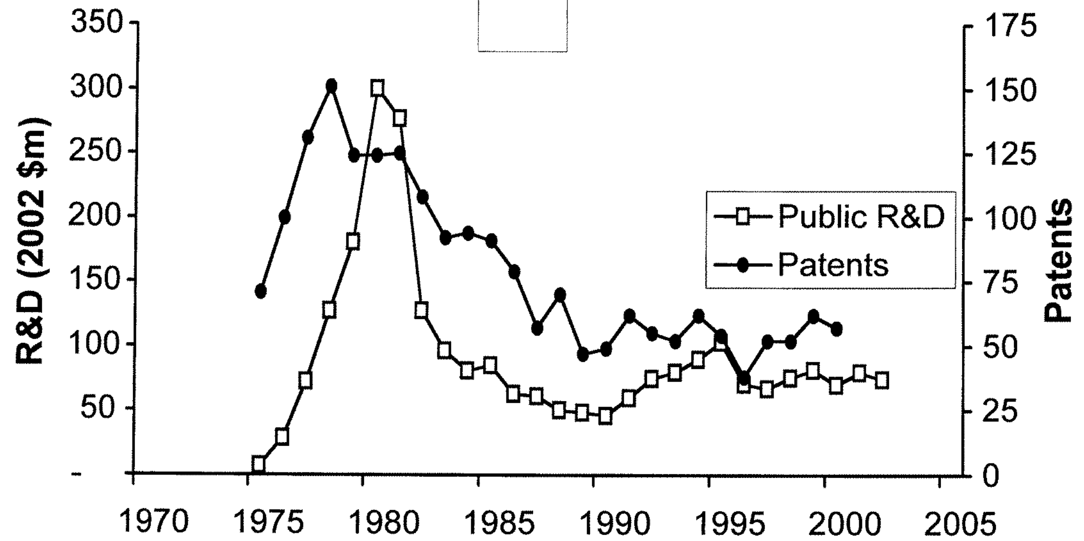
Investments and Energy Patents



Margolis and Kammen, *Science,* **285**, 690 - 692 (1999)

Federal Investment in Solar PV Has Been Insufficient



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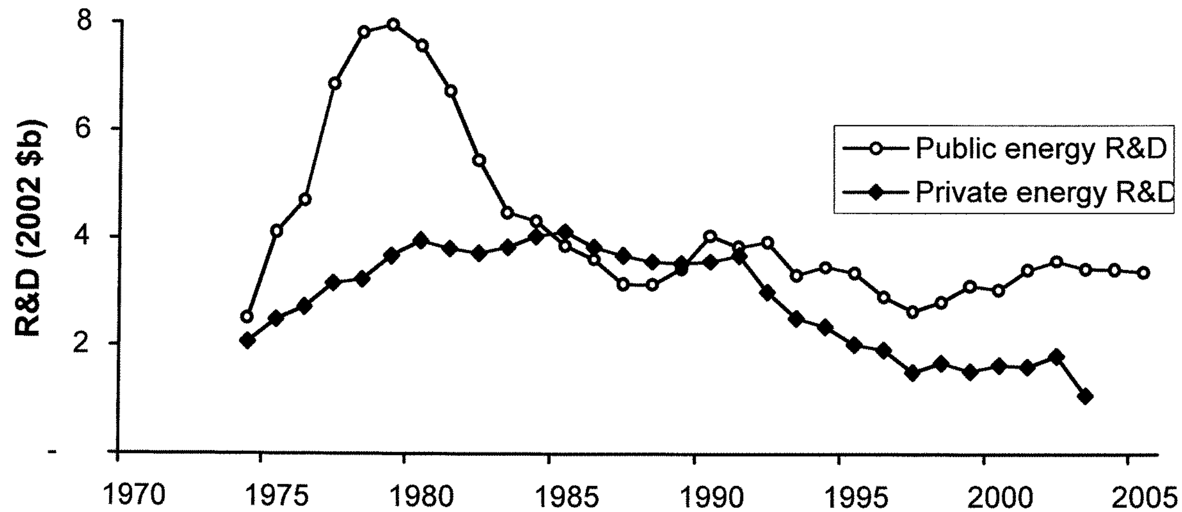
If you think US public sector energy R&D funding is doing poorly …



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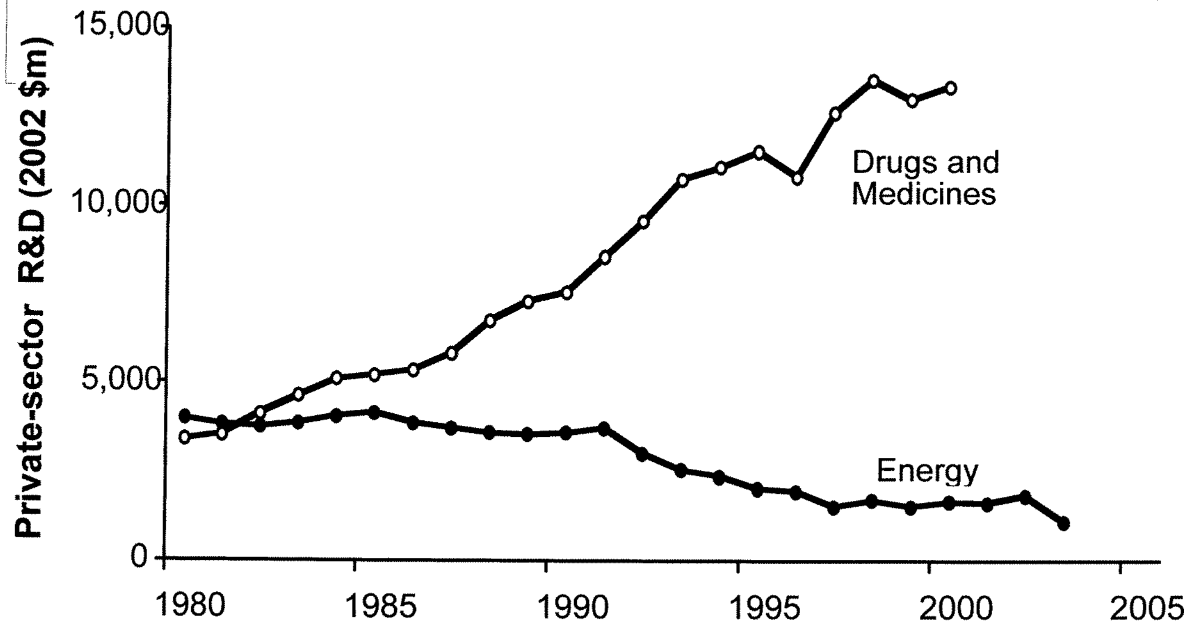
Private Sector R&D Investment in Health and Energy



Kammen and Nemet (2005)
"Reversing the incredible shrinking energy R&D budget," *Issues in Science & Technology,* **Fall**, 84 – 88.

Opportunities for Action

- Raise our expectations, and investments, in clean energy
- Support states that enact aggressive clean energy policies
- Recognize the benefits of clean, secure energy options
- Recognize the benefits of a carbon tax

  Oil in 2003 ($28/barrel), oil in 2003 ($60/barrel)
  This is equivalent to a $271/ton carbon tax

- Take advantage of the benefits of global energy and environmental leadership

Chairman TOM DAVIS. I want to thank all of you for your testimony.

The first question you always ask is, regardless of what California or the United States does, if everybody doesn't act together, particularly with the emerging nations, you know, you are penalizing yourself economically in not getting the same kind of results, but it starts here. I mean, all we can talk about in Congress is what we can do.

Mr. Van Atta, let me just ask you. You stated in your testimony that ARPA's success is dependent upon a galvanized structure and direct oversight. Where do you think a climate change ARPA could be housed?

Mr. VAN ATTA. Well, the most natural place would be the Department of Energy, but I would agree with others that probably not this Department of Energy. We have to find a way of having an imperative that is focusing on the energy and climate issues. If you chartered the Department of Energy to do that as its primary mission and the Secretary had that as the primary mission from the President, then an organization like this would be well housed there. If it is not that, then it would not succeed.

Chairman TOM DAVIS. And right now, I mean, the report right now, there are no lines of authority anywhere. You have all these task forces and everything else. You know, my experience in government is that this is not the way to get anything done.

Mr. Lane, what would a CCRPA be able to do that the CCTP doesn't have the capacity for right now?

Mr. LANE. Well, I think if you organized it the way that our paper proposed to organize it, which is to say as a not-for-profit government-financed but independent corporation, I think it would be insulated from the bureaucratic pressures for not very daring, not very breakthrough oriented technology that I fear characterizes part of the current DOE portfolio. I don't want to exaggerate that, but I think it all depends on insulating the entity doing the exploratory research to be able to operate the way Dr. Van Atta describes DARPA as operating. I don't think you can do that within the existing institution, so our proposal of a corporation was a way of trying to get around that.

Chairman TOM DAVIS. Let me ask this. I come at it from a more political perspective, because that is the way I have come up through the ranks. I don't have a Ph.D in physics. I am a lawyer by training. But we find out when you put FEMA in Homeland Security it is competing for dollars with prevention dollars in Homeland Security and it gets starved. We found this in other agencies. The Federal Information Security Management Act without information security gets starved when you put it in competing with everything else.

Making it a priority, that is one of the reasons, you know, you talk about Cabinet-level positions to make it priorities where it is not competing for precious dollars, discretionary dollars or anything. That is why I like the concept of an ARPA of some kind where you get the focus. I am just afraid, despite some good intentions of some people across the bureaucracy and even the administration, the way it is set up today I just don't see how we get from here to there. I guess that is the major concern.

Let me just ask if anybody else has any thoughts on that. Mr. Hoffert, do you have any thoughts on that?

Mr. HOFFERT. Well, I mean, there are things that you can do immediately in the exploratory R&D program that we proposed. There is not a lot of money. It is not a lot of money. I think we were asking on the order of $30 million. What it would do is it would be a first stage of analyzing what kind of ideas are out there that aren't really being captured by the present Department of Energy structure where you don't have a champion. It is something that could be done now.

Now, eventually, as I said in my statement, I really think the Department of Energy has to be restructured and given a mission. That is a very high-level decision. It is probably a Presidential decision. If you ask me what I would wish for, I would wish that, in time for the next Presidential elections, that both major political parties would realize that this is a vital interest of the United States, it is vitally important to U.S. policy and to the world. If you ask me, I think it is more important than terrorism and we would be having public debates about it and both parties, from whatever their ideological perspectives, would attempt to have a real energy policy, not just pork and reshuffling. I think that is important. That is something you guys can do.

Chairman TOM DAVIS. We can, but let me just tell you this place, once you get this thing to the mish-mash between the House and the Senate and Members with their employment opportunities in their State it gets bogged down. It really has to start at the top. I am just telling you. I mean, I think all of us here have good will in trying to tackle this, but trying to get it through the mish-mash makes it very, very difficult.

But you are right. I mean, I agree with you. It is a serious problem. We ought to be talking more about this. We ought to have an honest debate. There are differences of opinion about how we proceed, not just procedurally but what some of the functions are, and we don't even know scientifically everything we need to know in terms of what some of the options are. I think we agree it ought to be a priority.

Anyone else want to add anything on that?

Mr. KAMMEN. I agree that this needs to be a Cabinet-level position in time, but perhaps for a little bit different reasons, and that is that the benefits that would accrue to Commerce, to Agriculture, to Energy, to Defense come up in different settings in different conversations, and you discover that there is a security benefit by bringing down your oil.

Mr. Socolow and I sit on a Defense Science Board looking at these issues right now. Commerce discovers that there is an unmet international need for importing high-efficiency power plants, not because of greenhouse gas issues, because they are more efficient and less costly to operate in the long term. These are all technological areas where U.S. companies are well set up to innovate but they are not doing their share, A, because they don't see the Federal leadership on this; B, because the Federal dollars flowing in are simply too small to tickle enough of those interests, much different than we see, for example, in NIH, where private sector funding in the health field is far ahead of the public funding, so the public can fill a role and fill gaps. That is what a better mission would be here, and that would require the sort of inclination that the Cabinet-level would hold.

The benefits to our economy are very large. California is already adding up the tens of thousands of jobs that we expect to pull into the State because of the greenhouse gas requirements. Those are things that the United States could also capture as a peace or a green dividend by taking this on at that very highest Presidential cabinet level.

Chairman TOM DAVIS. You think it is helping the economy in California?

Mr. KAMMEN. It is documented. We have studies from universities, from private sectors——

Chairman TOM DAVIS. I would love to see that.

Mr. KAMMEN [continuing]. In and out of State. I would love to send the copies along. The estimates are that to meet the AB32 greenhouse gas standards California will generate about 50,000 new jobs, largely high-tech, in-State jobs.

Chairman TOM DAVIS. Because the general rap on California is it is a job killer. I will keep an open mind. I am interested to see it. I come from a District with a 2 percent unemployment rate out here in northern Virginia, but I would be eager to see that.

Mr. Waxman.

Thank you all very much.

Mr. WAXMAN. I also want to thank all of the panelists. One of the things you may not be aware of is that the hearings are carried on the internal television coverage within the House, so I was away but I was able to watch your testimony and to read it, of course, from the statements that you submitted.

Dr. Socolow, the administration's plan is to put off action on global warming for years to come. They continue to fund some research, but they would leave concrete action to address global warming to future administrations. They seem to think there is little meaningful action we can take now.

You have done considerable work examining what technologies are available today. Can you explain more about what you call stabilization wedges and give us some examples of available technologies that could be deployed to fight global warming?

Mr. SOCOLOW. I don't think there are many people in the administration who would agree with everything I am about to say, and it really infuses the climate change technology plan. I called it One Hand Clapping. The program there makes no sense unless, alongside it, there is a motivation for early action, for trying things out.

I will take the example of carbon capture and storage at coal plants. We shouldn't be building any coal plants from here on that don't further the goal of carbon capturing storage in all of them and keep as short as possible the transition from some of them to all of them. The DOE has a program on carbon capture and storage, a wonderful one, one of the best in the world. They, themselves, know that it makes no sense unless there is a carbon policy that goes with it, so we are not even going to get the taxpayers' benefit of the R&D without the associated program. This is widely understood. This is not a Democrat and Republican thing.

Inefficiency technologies, again, the DOE has had a perfectly simple program and substantially pushing the R&D element of efficiency, but we could have tougher appliance standards across so many sectors and move these things out. The R&D goes hand in hand with the policies.

In renewables, again, we have an incoherent renewables program as far as I can tell. If we had stronger signals that were broadly posed in terms of carbon price, for example, you would have better sorting out of the alternatives.

We listed 15 wedges, each of which is a gigantic challenge worldwide to reach a point where you are contributing 15 percent to the whole job 50 years from now. Each of these is a campaign. That is another word I like to use, a campaign or a strategy. It has to be globally coordinated. The United States is emitting one-quarter of the emissions today. We have technological leadership. We are slowing everybody else down by our inaction, which is another dangerous thing.

We will bring the world along if we join, and we will conjoin along renewables, efficiency, and fossil fuel technologies in a very important way.

Mr. WAXMAN. Thank you very much.

Dr. Kammen, we are proud of California for the leadership that our State has shown in this whole area. To me, I strongly believe in States experimenting, but this is an area where we need Federal leadership. Maybe California's actions will spur it.

You have testified that the administration's climate change technology program's strategic plan is seriously flawed. You state that the goal it seeks to attain is too modest. I would appreciate it if you could elaborate on that. And, moreover, if the administration were to achieve its so-called emission intensity target, would we have any confidence that we have meaningfully tackled global warming?

Mr. KAMMEN. Let me start with your second question first. The answer is absolutely not. The emissions intensity target, as I said before, has no basis in the natural world. It doesn't address the fundamental question that we are putting in too much carbon, so we have to have an absolute target here, one that is measurable and quantifiable. California, as you know, has set up a carbon registry so that companies and municipalities track their emissions and look at them not on an intensity basis, which is a sliding scale based on how much you are growing, but based on overall emissions levels.

And the most interesting first conclusion from that is that just by monitoring you discover some of the areas. I liken it to the frequent flyer effect. If you start to collect frequent flyer miles you want to spend them. Companies that tally up their numbers and discover they are saving this much, they could save more, want a market to sell those credits. That is what California's AB32 has in place. It has a market mechanism that extends across the economy and outside, because all electricity sold into California will be subject.

I know of six coal-fired power plant plans that were on the table to be built in the mountain States to sell to California that have now been shelved as a result of what California has done.

So the reach is impressive. You are right, we do need to have this go beyond not just California and the west but it has to extend to all countries.

I do not believe there is a benefit, however, in waiting to act until we get this. Those municipalities, countries that export and have developed the best technologies will have the opportunity to export them for a variety of efficiency gains, and that really is the benefit that we are seeing in Scandinavia. We see parts of Germany and Spain doing the same thing, and Japan and California and New England. The Reggie Coalition is also taking an aggressive role in that. That is where the economic benefit lies.

Mr. WAXMAN. Thank you very much.

Chairman TOM DAVIS. Mr. Van Hollen.

Mr. VAN HOLLEN. Thank you. Mr. Chairman, I want to thank all of the witnesses for your testimony. As Dr. Kammen said in his testimony, what we are measuring here against in terms of reductions is what has to be accomplished for the purpose of reducing the negative impacts of global warming, the human contribution to that to whatever level we feel is sustainable in terms of our own needs. The administration, when they talk about just reducing the rate of increase, that may not be enough if you are not reducing the rate of increase by the amount necessary to achieve the goals that we want.

I also, although I am from the State of Maryland, I want to commend the State of California for its leadership on this issue and moving forward. I think you have already spoken to some of the immediate economic consequences in terms of decisions that are being made by coal-fired plants not just in California but outside of California.

This is really a question for any of the witnesses. Because we have had testimony from various administration officials and you have heard their technology plan—there is no dispute about the need to invest in technology and renewable energy and energy efficiency. I mean, on a bipartisan basis people can agree and we should do it on an urgent basis and I think we should increase dramatically our investment in there. Where there seems to be disagreement, which is what Dr. Socolow really called the other hand for clapping, in other words, it is the need to invest in technology, but you really need that market forcing mechanism. You need to bring them both together. That is where there has been no political will. That is why the California legislation is important. That is where the administration has nothing to offer so far.

So I guess my question for any of the panelists here, if you just take the administration's plan with respect to what they want to invest in technology and renewable energy, what kind of reductions, if any, are we going to see? And what is the gap between the reductions we will achieve if we just do everything they say as compared to where we need to be?

Mr. HOFFERT. I just want to make a personal observation. I live on Long Island, on Great Neck Long Island in New York, a suburb of New York City. Our family has signed up for green energy. We get electric power from upstate New York. We don't actually get the electrons. It is basically an offset, but we have to pay extra for that.

Now, Long Island, where I live has a nuclear power plant called Shoreham that cost $6 billion. There are only 3 million people. That means every man, woman, and child is paying $2,000 for a power plant that is never going to produce any kilowatt hours. Most of the people don't even know that is happening, and that is one of the reasons we have a very high rate base. And then, when wind power becomes available, we have to pay in addition to that.

I think there is a really big problem of educating people so that they really understand where their utility bills go and how decisions that are made ultimately impact on them. I think there is also certainly a role for the Federal Government in making it financially desirable to do something like getting your power from green power, even though it means importing it.

There is also a lot that can be done with hybrid cars. I heard Dan talking about that earlier. Probably the most effective near-term thing that could be done to reduce our imported oil, in conjunction with biofuels like ethanol, which I might have some problems with, but the combination of plug-in hybrids and ethanol is very desirable. You can't buy a car like that.

I mean, I have a hybrid. I am not happy with it. It turns out I bought this Lexus hybrid before it was available on the market and the fuel economy is nowhere near what I was hoping it would be, but there are a lot of issues like that that I believe there is a role for incentives by the Federal Government that could really make a difference to the average person.

Mr. KAMMEN. I'd be happy to. I'd actually like to defend the Department of Energy here. I believe that the language in the mission statements that are in the CCTP were really a product of a little bit of an earlier era, and that the sense of that document is what are a set of individual stovepipe policies that are attractive. Many of the individual things in the report are quite interesting, but what I think we have heard broadly across the board here and what I heard actually from the Members and their comments is that an integrated strategy is needed.

Until you have the integrated strategy, in my opinion, with aggressive R&D, aggressive market policies, and a carbon tax you are not going to get the kind of document out of a tasked agency to do so, so I really think it is, and I would love to see a sense of the committee statement, a memo coming out saying we believe the following is in the national interest and this is what we should push for.

It is those sorts of sentiments coming back to a Department of Energy, a restructured one or not, that will allow us to say what is our goal. In my opinion the goal is the 80 percent reduction in greenhouse gases, but over a very manageable period of time—a big challenge, but a manageable period of time, five decades or so. When those political statements come out, I think that the DOE can actually move itself quite far in the direction they want.

Mr. VAN HOLLEN. Thank you.

Chairman TOM DAVIS. I think that the committee will try to work some bipartisan language on this. One of reasons we are holding the hearings is to establish a pretty solid link. Most Members understand there is a problem and are concerned about the way it is being addressed. It is not necessarily the goal, but just how you implement it. Where's the priorities?

Dr. Socolow, we have just a second because I have a Cabinet Secretary waiting in the back. Go ahead.

Mr. SOCOLOW. I just wanted to say that there is a time warp, I think, too, in the way in which we are all looking at this problem. The climate scientists have raised the level of the alarm. I live among them in my own office. They can't believe we are going to take the risks of going above doubling the CO_2 concentration. There isn't any urgency if we live with three times. So we have to keep reminding ourselves that there is a message coming from the science community, and as far as how much carbon we can put in for a given level, that is a completely agreed-upon area with very small uncertainties.

Chairman TOM DAVIS. Thank you.

Did you want to make one last comment?

Mr. VAN HOLLEN. I agree with you, Mr. Chairman. It would be important to get a sense of the Congress in terms of what goal we are trying to achieve, but the other half of that, of course, is how we get to the goal. I think, as I understand the testimony, just investment in R&D, alone, won't accomplish that. Is that fair?

Mr. SOCOLOW. Absolutely correct.

Chairman TOM DAVIS. We agree. That is one of the reasons we are doing it.

Thank you all very much. It has been very helpful for us.

The hearing is adjourned.

[Whereupon, at 1:20 p.m., the committee was adjourned.]

[The prepared statement of Hon. Elijah E. Cummings follows:]

U.S. House of Representatives
109th Congress

Opening Statement

Representative Elijah E. Cummings, D-Maryland

Full Committee Hearing: "Climate Change Technology Research: Do We Need a 'Manhattan Project' for the Environment?"
Committee on Government Reform

September 20, 2006

Mr. Chairman,

Thank you for holding this vitally important hearing to examine the administration's strategy to address the growing threat of global warming.

First let me say that I am encouraged by this administration's recent focus on global warming. There was a time when we did not all agree on the seriousness of this threat, and I appreciate that we are now all on the same page.

My only regret is that the situation had to become as dire as it currently is before we could agree to do something about it.

Make no mistake, Mr. Chairman, the threat is urgent.

It is reported by leading authorities that global warming here in the United States is responsible for unmanageable wildfires, severe dust storms, heavy floods, and thick snow accumulation. It has made hurricanes stronger and more dangerous—increasing the likelihood that another Hurricane Katrina-like disaster will occur.

In other parts of the world, heat waves tied to global warming caused more than 20,000 deaths in Europe and more than 1,500 deaths in India. And in what scientists regard as an alarming sign of events to come, the area of the Arctic's perennial polar ice cap is declining at the rate of 9 percent per decade.

In a worst-case scenario, researchers say that global warming could make large areas of the world uninhabitable and cause massive food and water shortages, sparking widespread migrations and war.

We have an obligation to our children, and to our children's children, to respond to this threat with great urgency.

That is why, while I am encouraged by the President's "Climate Change Technology Program Strategic Plan," I am concerned that it does not go far enough.

The President's plan invests in research and development to address the problem in the long-term—aiming to address its goals beginning in 2010.

While that is a worthwhile goal, I believe firmly that we must do everything we can to address this mounting threat now. I am not willing to wait until 2010 to address global warming when we have the technology available to do so in 2006.

In fact, we have the ability to reduce pollution from vehicles and power plants today. The question is whether we have the will.

Before 2010, with dedicated resources, we can put existing technologies for building cleaner cars and more modern electricity generators into widespread use. We can increase our reliance on renewable energy sources such as wind, sun and geothermal. And we can encourage companies to manufacture more efficient appliances and conserve energy.

But these changes will not take place if we do not take action now.

We must draft legislation that would drive necessary change—and we must work harder to enforce existing rules. I look forward to working with my colleagues on both sides of the aisle, and with this administration, towards that end.

I hope we can use our mutual understanding of the real threat presented by global warming as an opportunity to bring about change in a positive way.

We owe it to the American people—and to the world community—to do everything in our power to address the rising threat of global warming in an effective and efficient way.

I look forward to the testimonies of today's witnesses and yield back the balance of my time.