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AMERICAN ENERGY INNOVATION REPORT

HEARING

BEFORE THE

COMMITTEE ON ENERGY AND NATURAL RESOURCES UNITED STATES SENATE

ONE HUNDRED TWELFTH CONGRESS

SECOND SESSION

TO

RECEIVE TESTIMONY ON REPORT PRODUCED BY THE AMERICAN ENERGY INNOVATION COUNCIL TITLED "CATALYZING AMERICAN INGENUITY: THE ROLE OF GOVERNMENT IN ENERGY INNOVATION" AND RELATED ISSUES

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CONTENTS

STATEMENTS

APPENDIX

AMERICAN ENERGY INNOVATION REPORT

TUESDAY, MAY 22, 2012

U.S. SENATE,
COMMITTEE ON ENERGY AND NATURAL RESOURCES,
Washington, DC.

The committee met, pursuant to notice, at 10:10 a.m. in room SD–366, Dirksen Senate Office Building, Hon. Jeff Bingaman, chairman, presiding.

OPENING STATEMENT OF HON. JEFF BINGAMAN, U.S. SENATOR FROM NEW MEXICO

The CHAIRMAN. Alright. Why don't we get started here?

Thank you all for coming. Today we are here to discuss the report of the American Energy Innovation Council on the role of government in developing innovative energy technologies. The business leaders of the Council have a long track record of commercial success building technology companies that compete in the global marketplace. They make a strong case in that report that with the government as a partner the United States can continue to lead in the clean energy sector.

As all of the witnesses today point out in their written testimony there is a global race on to produce the next generation of energy technologies. Though prices on our electricity bills or at the pump do not always reflect it, our current energy system is very expensive. The costs all of us pay in national energy and climate and economic insecurity are unacceptably high and it's likely the fast growing economies throughout the developing world will be looking to a new generation of technologies that avoid these costs.

It's not only a concern about costs and their effect on future generations. It's also a significant commercial opportunity for U.S. entrepreneurs. Fortunately developing new technologies has historically been a great strength of the United States. As the witnesses have pointed out, an area where the government has been an effective partner.

Although there has a broad consensus in Congress in the past in favor of investing in these emerging technologies, we've been sending much more uncertain signals recently. Important support programs have either already expired or appear to be in danger of expiring. Despite repeated calls to address the real problems of the so-called Valley of Death in initial technology deployment, instead of expanding on crucial current programs, some in Congress are looking to end these programs that we have in place.

Meanwhile our competitors and potential competitors in the developing world continue to press ahead aggressively to court new

energy companies and the talent that will develop the next innovations in this area. As these technologies continue to improve and become more cost competitive we should view this as an opportunity to take a global leadership position. We have some of the best minds in the world working on this problem.

It's very much in our national interest to show them a clear pathway toward developing and deploying these technologies here and exporting them abroad rather than forcing them to go overseas to find opportunities. I've said many times that I believe the only losers in the clean energy technology race will be those that fail to participate. I hope that the recent paralysis we've seen in Congress does not lead us to miss this opportunity.

The witnesses testifying today have given a great deal of thought to what leads to success in developing new technologies. I look forward to hearing about their conclusions and what we can do here to put American entrepreneurs in the best position to succeed in this vital area.

Let me call on Senator Murkowski and acknowledge that today is her birthday. We were delayed just a minute while we celebrated that in the back room.

But let me call on her for any comments she has before we turn to the witnesses.

STATEMENT OF HON. LISA MURKOWSKI, U.S. SENATOR FROM ALASKA

Senator MURKOWSKI. Thank you, Mr. Chairman. It would be, indeed, a fine birthday present if we could figure out, as a committee, how we really advance some good, strong energy policy for this Nation using the ingenuity, the, just the opportunity that we have as a Nation to really build on all of our strengths. So thank you for that recognition.

I'd like to welcome Mr. Augustine to the committee here this morning. Also, Mr. Jenkins, Mr. Zindler.

It was your report on competitiveness rising above the gathering swarm that served as a foundation for legislation that passed by an overwhelming margin back in 2007. It wouldn't surprise me if your work on energy innovation encapsulated in the report that we're going to hear about today ultimately could lead to a similar result.

I think most would agree that it's time for us to renew a coherent, long term approach to energy development, truly and all of the above approach. Innovation, of course, is absolutely at the core of that strategy. I think it's one of the few areas where the government can and should be providing greater funding. At the same time aware that if we do decide to spend more in energy innovation, we're going to have to make some very difficult choices about the amount of spending and the duration as well as what our priorities are for it.

A couple comments in each of these areas.

First, the obvious.

Investment is code for spending. That's going to require taxpayer dollars with our debt situation sitting at $15 trillion right now. Greater spending in this area is going to need to be offset. It's going to be challenging to find space in the budget.

But I think it also presents us an opportunity here to be financially creative. Let's figure out how we make this work. Let's assess the priorities and focus on them.

For years now I've suggested that a portion of the revenues from increased domestic energy production should be devoted to energy innovation. It's a key part of my ANWAR legislation which would raise an estimated $150 billion for the Federal Treasury at today's oil prices. Even a fraction of those revenues could go a long way toward developing the resources and the technologies that we'll rely on in the future. So I'm just glad to see the revenues from energy production listed as a possibility in the catalyzing American ingenuity report.

Now beyond how much we spend we also need to think carefully about our priorities. When we look back at where taxpayer dollars have been spent in recent years, I think it's clear that we haven't really gotten to that all of the above policy. We can see that in how much the Federal Government has spent on solar and wind as opposed to some of the other areas.

I'm always pointing out the opportunities that we have with methane hydrates. We can see that in the direction the Administration has taken in choosing to focus on electric vehicles perhaps as compared to other promising alternatives.

Finally a point about how long we should be involved here. It makes good sense to invest in energy R and D. That's clearly in our interests. But I think it's against our interests to keep subsidizing the same resources and technologies year after year without a clear path toward allowing those technologies to stand on their own in the market.

To strike the right balance will require reform of existing programs, possibly the phaseout of many of the subsidies that are currently in place. Some experts believe that Federal efforts should be oriented more toward basic research and away from deployment because in tight fiscal climate the government should spend on priorities that no other institution will fund. I tend to agree with that approach.

I think, though, when it comes to energy innovation we've got a lot of thinking to do, a lot of decisions to make. I hope that with the hearing this morning we'll have an opportunity to explore some of that.

Again, I appreciate the good work that has gone into the report.

Thank you, Mr. Chairman.

The CHAIRMAN. Our first panel is Norman Augustine, who is a Retired Chair and CEO of Lockheed Martin Corporation. He's been a witness before our committee many times in the past. We welcome him back and look forward to any comments he has about the report and what he thinks the Congress ought to do.

Go right ahead.

STATEMENT OF NORMAN R. AUGUSTINE, AMERICAN ENERGY INNOVATION COUNCIL

Mr. AUGUSTINE. Thank you, Mr. Chairman.

There we go.

Thank you, Mr. Chairman and members of the committee for this opportunity to share with you some thoughts on America's en-

ergy future. I'll be drawing, as was mentioned, on the work of the Energy Innovation Council. That's an informal group of 7 of us who came together because of our concern over the underinvestment in energy R and D in our Nation.

The names of the other 6 members are in the written statement that I would like to provide for the record.

The CHAIRMAN. Very good. We'll include the entire report*, in fact, in our record.

Mr. AUGUSTINE. Excellent. Thank you.

I also should acknowledge that we received excellent technical and administrative support from the Bipartisan Policy Council, an organization that was formed by 4 of your former colleagues.

I'm today not able to speak directly for my associates in this project because we are a highly informal group. On the other hand, I think that my comments will closely reflect the views of that entire group because there's very little difference among us on this issue.

We've prepared two reports.

The first of those had to do with the underfunding of research and development in the energy area in our country both by the government and by the private sector. We also came out very strongly for support in ARPA–E which I think has exceeded most of our expectations to date.

The second report we put out deals with the need for the government to involve itself in energy research and development. I will speak more to that in my remarks.

It's probably fair to note that we are not a group that in general welcomes government involvement in the private sector's business and industry. The reason being, of course, that it tends to form distortions in the way that people within business behave. It hurts our competitiveness globally.

On the other hand there are certain areas where there are programs that are of importance to the citizenry. But which the private sector can't or won't invest. Those, would seem to me to be, exactly the sort of thing that governments are designed to do. Indeed our government has done in the past.

There are two areas where the private sector is particularly reluctant to invest.

The first of these has become known as the Valley of Death. In the case of energy research I think there's a second valley also, a second Valley of Death, if you will.

The first of these describes a situation where basic research leads to a promising idea, but it has not yet been proven to be feasible in practice and is very risky because applying research or performing research is a long term proposition in terms of time. It often produces failure. Even when it succeeds the performer or the funder of the work may not be the beneficiary. Yet the work may well benefit society as a whole.

The second challenge indicates the energy field is a—energy is so capital intensive. That tends to discourage new entrants into the marketplace. It also discourages putting new ideas into the market-

*Report has been retained in committee files and can also be found at http://americanenergyinnovation.org/wp-content/uploads/2012/04/AEIC__Catalyzing__Ingenuity__2011.pdf

place because they are so disruptive to the investment that's in place.

The government, of course, has many options to support energy research and development and the advancement of energy in general. This goes all the way from contracts to grants to direct involvement in the marketplace to regulation to tax policy, in-kind support and more. The government has done many of these things in the past that we're all familiar with.

One thing that one certainly has to reflect upon and be aware of is that when performing research and also, the kind of development we deal with in energy where the second Valley of Death requires taking a proven concept and showing that it could be scaled, be economically competitive at scale. That's a very costly jump, usually more costly than the first threshold. It's a, the threshold, it's fairly unique to the energy field.

Innovation—oh, I was going to say that we certainly should be prepared to accept failures. That's a characteristic of research and development. I wouldn't for a moment excuse failure as due to incompetence or nefarious activity. But we're dealing with the unknown here. When you do that even the best intentions could lead to failure.

Finally I would just note that innovation really is the key to succeeding in this area. Fortunately Americans have been—America has been very good at innovation in the past. In fact it's one of the few non-diminishing advantages that we have today in the global marketplace.

In that regard, I believe that our ability to solve the energy challenge is really just a microcosm of—a very important microcosm, but America's position and the overall competitiveness arena in today's global marketplace.

So with those opening comments, Mr. Chairman, members of the committee, I'd be happy to address any questions you have.

[The prepared statement of Mr. Augustine follows:]

PREPARED STATEMENT OF NORMAN R. AUGUSTINE, THE AMERICAN ENERGY INNOVATION COUNCIL

Mr. Chairman and members of the Committee, thank you for this opportunity to share with you some thoughts on the challenge of providing safe, clean, affordable energy in sufficient amounts to power our nation in the years ahead.

My remarks today will be based upon the work of the American Energy Innovation Council, an independent and informal group of seven members who came together because of our common concern over what we consider to be America's insufficient response to one of the greater challenges facing our nation today; namely, the provision of energy. In this capacity we represent no other group. We speak simply as seven citizens who in the course of our careers have been called upon to meet various challenges and would like to share that experience as it relates to the energy challenge.

My colleagues in this endeavor are Ursula Burns, chairman and CEO of Xerox; John Doer, partner at Kleiner Perkins Caufield & Byers; Bill Gates, chairman and former CEO of Microsoft; Charles Holliday, chairman of Bank of America and former chairman and CEO of DuPont; Jeff Immelt, chairman and CEO of GE; and Tim Solso, chairman and CEO of Cummins, Inc.

Our work has been provided administrative and technical support by the Bipartisan Policy Council (of which I am a director). The Bipartisan Policy Council was founded by Senators Howard Baker, Tom Daschle, Bob Dole and George Mitchell as a non-profit organization seeking principled solutions to difficult public issues through analysis and respectful dialogue.

Your committee is well aware of the extent to which energy issues permeate of the challenges faced by our nation. These include the impact the uncertain availability and cost of energy has on our economy; the hazards of energy-related pollution on our planet's natural environment; and the role of constrained and manipulated energy supplies as a source of armed conflict. Thus, while fully recognizing the overall demands facing America today, the provision of safe, clean, affordable and sustainable energy is, by virtually any standard, one of the foremost challenges, particularly given its high leverage upon solutions to other problems.

While my testimony today is drawn from the work of the American Energy Innovation Council and while I am honored to have been invited by the Committee to appear before you, as in the case for all our members, I have no special authority to speak for the group as a whole. I do, however, believe that my testimony represents the general views of my colleagues.

Among its activities to date the Council has issued two reports. The first of these highlighted the need for a more vigorous public commitment to energy technology development. America's investment in energy innovation from the public and private sectors together is less than one-half of one percent of the nation's energy bill. This fraction is eclipsed by the innovation investment in most other sectors, particularly those in the high-tech arena. Meanwhile, we send one billion dollars abroad each day to pay our energy bill to foreign producers.

The Council's second report addressed the limited but important role the federal government will need to play in catalyzing American ingenuity as it seeks to meet the energy demands of the future.

While most of the current means of energy production are likely to be with us for a long time, each suffers from one or more shortcomings, whether it be cost, pollution, hazardous by-products, safety, limited scalability, or lack of domestic sources. If these liabilities are to be overcome the nation will need to depend more heavily on innovation; that is, utilize high quality research to create new knowledge, world-class engineering to convert that knowledge into new energy sources and delivery means, and enlightened entrepreneurship to translate those sources and delivery means into the marketplace. Fortunately, America has excelled in all three of these activities, which together make up innovation—although it should be noted that we are now losing our lead in at least two of these attributes.

In pursuing this process it is not uncommon to encounter what many innovators refer to as "The Valley of Death"—that period where an idea appears promising but has not yet been demonstrably shown to be workable in practice—and therefore is deemed too risky by most investors. To surmount the latter generally requires some form of convincing proof-of-principle demonstration. . .which in turn requires financial resources—thus the dilemma.

In many of the potential avenues for providing large quantities of energy there is also a second "Valley of Death." This latter valley is the gap that spans from proof-of-principle using, say, a prototype, to verification of market utility, including economic viability, with a near commercial-scale demonstrator. The latter valley, which also deters investors from participating, is a consequence of the characteristic that the steps in the process of developing new forms of energy often come in large quanta, making it very expensive to remove uncertainties as to ultimate scalability of an otherwise promising project.

Further complicating energy innovation is the capital intensiveness of most forms of energy production, delivery and storage, a characteristic that makes the economic threshold for replacing old plants with new ones very high.

In short, due to the risk entailed, private sector investment will often be unavailable to assist in crossing either of these important developmental gaps. In the case of basic research, market payoffs are usually well over a decade in the future, and may not exist at all. In the case of proving scalability, the size of the investment required is often large and the results uncertain. But in spite of these considerations, the development of new energy sources remains of critical importance to the nation. . .hence means of overcoming them must be found.

Although I must confess that I, and I believe my colleagues, are strong devotees of free enterprise as opposed to government involvement in markets to the extent practicable, the energy dilemma seems to be exactly the sort of issue which governments are designed to help solve, at least in democracies with free enterprise markets. That is, this is a case wherein there is an important benefit to be had by the citizenry as a whole but private resources cannot, or will not, provide that benefit because of financial risk, extensive delays in receiving returns, small or even negative returns and the possibility that the returns will not even accrue to the investor or performer. The latter is particularly true in the pursuit of basic research.

This circumstance is one that has long been recognized by our government in a number of areas, including many involving the application of technology. Commer-

cial nuclear power was the result of government investments in Naval reactors; commercial jet aircraft trace their origin to military transports; GPS to military positioning systems; the internet to packet-switched networks demonstrated by ARPA; and communication and weather satellites to military space programs. These achievements were in some cases by-products of the government's pursing other missions in the interest of its citizens—but the provision of energy is itself a mission of the utmost importance to the citizenry.

Looking further back in time there was the creation of land-grant colleges, agricultural research institutes, the federal highway program, and the air traffic control system. The key point is that the government advanced the state of the art in these areas to a point at which the private sector could responsibly undertake implementation and operation of the capability sought by the citizenry.

Principal objections to greater government participation in, and particularly in funding of, such developments are that (1) government involvement may favor one private entity over another, (2) foreign firms, not U.S. firms, may prove to be the ultimate beneficiary of the U.S. taxpayers' investments, (3) the government should not be in the business of "picking winners and losers," and (4) there are other important demands for the application of the government's financial resources.

In fact, the government's work in the early research phase can be, and generally is, made available to all interested parties. . .much as, say, NASA does with its aeronautics research. In the case of funding scalability demonstrations, the solution resides in maintaining fair and open competition. With respect to foreign firms being the principal beneficiaries, it is simply a fact of life in the globalized marketplace, permeated with instant communications, that the only way to prosper is to be quicker to the market with a better overall product that one's competitors. . .not to hope to hide information. With regard to picking "winners and losers," the government in effect does this every day at DARPA, ARPA-E, NSF, NIH, and elsewhere. The key to success under this circumstance is to maintain competition for ideas, transparency of results, and competent government employees who can weigh the options that are available—once having considered the private sector's perspective. Without these three ingredients failure will be assured irrespective of what foreign competitors might or might not choose to do. Finally, with regard to the other funding demands faced by the government, few issues have greater potential adverse impact on our nation than the availability of clean, affordable energy.

One technological development that has only recent occurred has the potential to profoundly impact the possibility of applying innovation across the energy spectrum. This is the marriage of horizontal drilling and hydraulic fracking to free trapped shale gas. This can provide America with the opportunity, if appropriately executed, to greatly reduce dependency upon foreign sources for its energy in the relatively near future and for many decades into the future. . .thereby providing the time needed to develop other energy sources including what may be the "ultimate" solution to the energy challenge, nuclear fusion. But the latter is yet another example of something that will never occur if we must wait for private investors to fund the needed research and development or if the government elects to under-invest in the relevant technology.

The members of the American Energy Innovation Council are aware of the intense fiscal problems facing the nation—and you as its leaders. But we are also aware that in our own business responsibilities that during difficult times it may be necessary and appropriate to increase spending in some areas while at the same time making overall reductions. There is an important distinction to be made between investment and spending for consumption.

Whatever the case, it is important to recognize that not all investments in innovation will "pay off". . .some, perhaps most, will fail. This is simply a fact of life. Supporting innovation is neither a short-term strategy nor a pursuit for the uncommitted.

Finally, it would be inappropriate for me to miss this opportunity to address briefly the precarious position in which America's overall innovation engine finds itself today. . .not just as it concerns energy needs but as it affects virtually all national issues. Our graduate schools of engineering now train mostly foreign engineers who increasingly say they will be returning home; our public primary and secondary schools are, on average, among the worst in the world; our great public research universities are challenged as never before by steep reductions in their funding; the consumer market is moving to the developing nations; our debt is so immense that it makes investment in the future particularly challenging; our corporate tax rates are now the highest in the world; our patent system is antiquated, as are our export controls and visa-granting systems; and U.S. corporations spend over twice as much on litigation as on research. This is not a formula for sustaining the success we have enjoyed in the past.

Fortunately, America still has a great deal remaining on the asset side, including high quality, albeit endangered, research universities; a culture of innovation and risk taking; the rule of law; the sanctity of contracts; use of the English language; and more. But today's trends are not in our favor, and when one considers the rapidity of advancement in technology it is apparent that a nation can lose its position in a technology driven, innovative economy very quickly. This has consequences that span from national security to health care and from the standard of living to the preservation of our planet's environment. The energy challenge we face today is, in my judgment, merely a reflection of this much broader challenge.

Thank you very much for the opportunity to share these rather candid thoughts with you.

The CHAIRMAN. Thank you very much. Thanks again for all the work that went into this and other reports that you've championed and been involved in.

Let me start with a couple of questions.

You know, whenever we get into this discussion it strikes me that a major change in the environment needs to be acknowledged as we talk about what role should our government play in working with industry in these areas. A major change in the environment is what's happening with other governmental support around the world. I think that, you know, for a lot of our history the involvement of the government in order to assist or work with industry, partner with industry, to be successful was not really required to a great extent. There are a lot of exceptions to that.

But it strikes me that when you look at what's happening in renewable energy, technology development, now, worldwide, you have very aggressive efforts going on by the Germans, by the Chinese, by various other countries, to not only further develop the technology, but also help with the commercialization of the technology and the capturing of the jobs that result from that technology. That puts a new importance on our own government finding the right level of involvement, the right type of involvement to have in this same area.

I don't know if you have thoughts about that?

Mr. AUGUSTINE. I would certainly agree with your conclusion that things have changed greatly. We do have foreign governments very much involved in their—supporting their so-called private sector. I've learned the hard way in my own experience that private companies can't compete with governments whether it be another government or our own.

So I think it's unfortunate thing that's taking place. On the other hand, I think it's a fact of life. My hope would be our government would have to involve itself only to the extent that one, helping preserve a level playing field so our field can compete fairly internationally.

Second, that our government would support those things that the private sector can't do or won't do and the government has done for many years all the way from building highways to putting the research in place to produce the internet or GPS or many of the other things we take for granted now.

So, yes, it is a changed world. Other governments are deeply involved. The first priority of our government should be to try to encourage other governments to limit their involvement to that second category I described and not to become active participants in the marketplace.

The, I guess the piece of good news for governments that become overly involved is that when they make a mistake it's usually a big one and carries throughout the economy. So I think they're good reasons for our government comporting itself as it has in the past. But we can't hide from the realities of today.

The CHAIRMAN. Yes. Sort of a follow up on that first question.

You know, we love to give speeches around the Congress here about how the government shouldn't pick winners and losers. Like most of these statements, it's a clear, simple formulation that H.L. Mencken pointed out is almost always wrong.

You pointed out that ARPA–E has been a great success so far. Of course, DARPA, which you were very intimately involved in, has been a great success over decades. They are, as I understand the way that DARPA has operated and the way that ARPA–E is now operating, it is in the business of trying to pick the winners.

Now it doesn't always do it. It doesn't make big bets by, in a relative sense. But it certainly tries to identify those areas of technology development that have great promise for the country. You mentioned some of them, the internet and GPS and some of the others that have proven to be very useful and have been winners.

So I'd be interested in any thoughts you've got on this concept of picking winners and losers.

Mr. AUGUSTINE. That certainly is the first accusation that usually is made is you don't want the government picking winners and losers. If you make it that simplistic, I guess I would agree with the comment.

The problem is that in the real world the government does and has to pick winners and losers every day. The government decides who is to win contracts, who gets grants for research, what projects are continued, which ones get canceled. That's, once again, a fact of life. I think not inappropriate.

I believe there are 3 guards that are very important if the government is going to have to make difficult choices which the government has to do.

The first of those is that the government appoint competition to the maximum possible extent so that everybody has a fair shot at contributing and being involved.

Second, whatever is done should be highly transparent.

The third thing I think that needs to be done is to assure that we have competent people in our government who are able to make sensible judgments without conflicts.

Given those 3 criteria, I believe, that the government not only can, but has to make choices, pick winners and losers.

You cited ARPA–E, ARPA. Many other parts of the government do this. I would also add In-Q Tel to your list. I should disclose I had involvement in it early on so I have a conflict here. But there's a certain parallel.

In-Q Tel was given a number of tools in its tool kit by the Congress. They go all the way from taking equity positions to giving grants, to contracts, to giving advice and in my view it's been quite successful at carrying out its missions. So it would be another example of they make choices every day.

The CHAIRMAN. Thank you very much.

Senator Murkowski.

Senator MURKOWSKI. Thank you, Mr. Chairman.

Mr. Augustine, in the report you have concluded that we can have the greatest impact if we focus on energy R and D. Others have said that the focus or the major impact should be on the deployment end. As we're trying to figure out how we allocate scarcer dollars and how we prioritize. What part of the technology chain do you figure we, here in the government, should be focusing on most?

Mr. AUGUSTINE. That's a difficult question. Certainly if you don't focus on research there will be nothing to deploy. On the other hand if you focus entirely on research they'll be nobody to deploy the benefits. So you need to do both.

As it happens research costs an awful lot less in general then the development deployment, the proof of principle, proof of scaling step. So maybe that much more money is required for the latter even though ideally I think the role of the government is more easily justified, focused on research. It used to be that the U.S. government—when I say used to I mean two, 3 decades ago, the U.S. Government provided about two-thirds of the research and development that was spent in this country. Today it spends about a third.

The problem is that industry which has picked up the two-thirds now, spends almost entirely on D and is getting out of the R business. The labs would be the classic example of what's happening in industry. I have my own experiences in that regard.

So my short answer is we need to do both.

Where do you focus, I think you focus on those two Valleys of Death.

How do you take just basic research ideas that get funded by a National Science Foundation and places like that?

How do you turn those into engineering projects? Then second how do you get across that Valley, and then the second valley, which is scalability?

In all cases I believe that industry should, that beneficiaries should involve some of their own investment. They should have some skin in the game.

Senator MURKOWSKI. It is. It's trying to find that balance and determining where you have those areas where the private sector just isn't willing or able to be involved. How we define all that is, of course, far more difficult than it might sound.

So let me ask you about the—how we pay for all of this innovation. In my opening statement I mentioned that one of the things that I think makes sense is to take the revenues from—take certain revenues from greater domestic energy production to help pay for our innovation.

Your report outlines that as one of the options. I appreciate that. Some of the other possibilities would include raising energy prices. But that's kind of tough for us all right now. I think we look at that.

But I'm reading your language that says that the AEIC does not advocate one revenue option over another. So that's probably your out there. But as one of the individuals on the committee here, do you think that there is one approach that is perhaps better than some of the others that you have outlined there for us?

Mr. AUGUSTINE. I suspect once again a mix of approaches is appropriate. Although I do have some that I think, personally, that are better than others. The reason we didn't try to make a choice is that we simply didn't get into enough detail to take a strong position.

Today, as you well know, we will send a billion dollars overseas today, to foreign countries to pay for the net cost of the oil we buy. For the last few years we've been averaging on the order of $2 billion dollars a year on energy R and D a year. That suggests to me that there's great opportunity to find the kind of money we need to triple the R and D which is what our little group has recommended.

The first sources of that certainly, I think back in my own case, probably 25 years ago or more, I was proposing that we add 3 or 4 cents to the cost of a gallon of gasoline back when gasoline costs 50 cents a gallon. I can even recall when it costs 19 cents a gallon. I said let's add two or 3 sets to it. Put that money in research and development.

My economist friend told me I would destroy the economy if we did that. Today we pay 4 and a half a gallon and the money goes to other nations with fuel would like to kill us with the money that we send to them. So there's clearly something wrong with that model.

I would hope that we would, in fact, provide a tax, if you will, on some of the energy sources, particularly those that are high polluting sources much along the lines you suggested. I personally don't have a problem with a modest tax at the gas pump. But that I realize is a very difficult issue today.

But the idea of having the industry that most benefits in the long term pay part of the costs. It seems appropriate to me particularly when you have an industry that's been spending maybe half a percent of its sales, revenues on R and D.

The industry I came from spent 10 percent.

The pharmaceutical industry spends 20 percent.

The electronics industry, I think, around 13.

It just seems not unreasonable to me that given the importance of R and D and the modest pain that would be added by some of these taxes. I'm not a tax guy. But in this case I think it's worth the price.

Senator MURKOWSKI. I appreciate your comments. I've long held that one of the ways to get to our energy future is, again, using those revenues from our fossil fuels to help build out the technology, the innovation, to advance us to the next generation of energy. But appreciate your comments.

Mr. AUGUSTINE. Thank you.

The CHAIRMAN. Senator Udall.

Senator UDALL. Thank you, Mr. Chairman.

Thank you to you and the ranking member for holding a very important hearing on innovation.

Always good to see you, Mr. Augustine.

Mr. AUGUSTINE. Thank you.

Senator UDALL. Thank you for your continued service to the country and your ideas are always spot on. The American Energy

Innovation Council has done yeoman's work here. I hope we will listen to and then implement your recommendations.

As you've pointed out we are in the midst of a clean energy revolution. By that I think we mean all energy sources and all energy technologies can have clean elements. We can't have, as you point out, inconsistent and uncertain innovation policies. That's what you've underscored here and why this hearing, again, is so important.

I said to myself, we need to be leaders in this field. We've always been a paragon of innovation. But, I think about the fact that we have been leaders in every energy technology. But I think about solar and wind, for example, in the 1970s. Now we're trying to play catch up with some countries that have seen the possibility here.

You know Colorado. I'm biased. I'm honored to represent the State of Colorado.

We are a national leader in many areas. We have a great, I think, model of how industry, entrepreneurs, universities, research institutions, like the National Renewable Energy Lab and the government are all encouraging energy innovation which then spurs job creation and economic growth. Then I would venture to say that that therefore means Coloradans and Americans have a more secure energy and economic future. So thank you for pointing out all these possibilities to us.

Let me move to ARPA–E. You talk about ARPA–E as a model program that we should prioritize. We can grow it going forward.

Do you recommend that other parts of the DOE could use the ARPA–E model? Would you speak to how this ARPA–E model could be applied in more specific and maybe, perhaps, some more broad ways, not just in the DOE, but as well in other agencies, other areas of activity?

Mr. AUGUSTINE. Senator, I'd be glad to do that.

Let me try to describe what I think are the essential facets of ARPA–E.

Let me say the ARPA model.

Senator UDALL. Yes.

Mr. AUGUSTINE. ARPA was always willing to take risks and realized that in some cases they would fail. ARPA did not devote itself to trying to do something we now do 20 percent better. They devoted themselves to try to do it 3 times better.

When they succeeded it was really an impactful event. So they were willing to take risks. They set high goals. They were very decisive in deciding what they would support. When they could see that something wasn't achieving what they expected, they stopped it and put the money elsewhere.

Very important to ARPA, I believe, is that they attracted extremely high quality talent. One of the ways they did that was by delegating a lot of authority to the program managers who oversaw these projects.

Another thing they did was they expected people to only stay there 4 or 5 years. They had a lot of rotation of people. Clearly the best way to freshen an organization is to rotate people through it. The best way to transfer knowledge to other organizations is by rotating people out and into those other organizations.

Then finally I would have to cite that in the case of ARPA, the government has been I don't like the word generous but because I think very constructive in supporting ARPA financially so that it has the resources it needs to pursue good ideas.

So those are the sorts of things. Also ARPA is very problem solving oriented. They're not organized by discipline as is DOE or our universities. They set out to solve a problem.

Senator UDALL. So in effect you're saying you have to be willing to risk failure, you need to provide a lot of space and a decentralized environment and turn people lose with a goal of not increasing the value of the product or the service 20 percent, but 3x. It's very helpful to hear all that, which isn't necessarily the way things are done in government nor in the private sector, as you well know. But I know under your tutelage in the private sector you would put teams together to do just what ARPA–E and DARPA still do today.

Let me, in the remaining time I have, talk about how we help American households transition to renewable energy systems. Those initial capital investments can be really cost prohibitive. We now see some creative ways in which residential renewable energy systems are leased.

Senator Whitehouse and Alexander have introduced a bill. The acronym is the REAL Act, Renewable Energy Access through Leasing. I've joined them in that, co-sponsoring that legislation.

What it does is it creates a secondary market by having the government ensure the leasee's value. The CBO scored this at no cost which is always great in this town today.

Can you speak to that model? Are there other areas you might have identified where we could help those who want to make the right investments, but who find the cost of capital prohibitive or difficult to embrace initially?

Mr. AUGUSTINE. Yes. I think the sort of thing you describe really addresses the other side of trying to encourage clean energy implementation.

One side is to encourage the research and development and so on.

The other side is the pull side. If we're to help the consumer afford it.

That can certainly be done by subsidizing. I don't like the word subsidizing. But I'll use it.

The cost of certain forms of energy helping people defray the costs of new buildings that are very energy efficient and then they can pay that back with the savings that they gain from being more energy efficient. I think in the grand scheme of things today we have a remarkable opportunity that bringing together the idea of horizontal drilling and hydraulic fracturing to recover shale gas could well buy us the time to pursue some of these really promising clean energy opportunities. Otherwise we just didn't have time to pursue given our dependency on oil and the lack of much we could do about it.

As you point out, it wasn't many years ago that we were No. 1 in photovoltaics and central thermal systems and wind power. Today we've lost our lead. I was recently in Japan and I was struck by how much we've lost our lead.

Senator UDALL. Thank you again for your leadership. Great to see you.

Mr. AUGUSTINE. Thank you. It was nice to see you, sir.

The CHAIRMAN. Senator Franken.

Senator FRANKEN. Thank you, Mr. Chairman. Thank you, Mr. Augustine.

We seem to have a debate here in this Senate over the very nature of the role of government in development of new technologies. Again, I appreciate the Ranking Member being here. But again, I don't see any of my colleagues from the other side.

We have these hearings a lot. We have either they don't show up at all or they come in and make a statement and leave and sometimes don't even want answers to their statement.

I mean, your report points to government support for development of all kinds of technologies that have led to all kinds of jobs. We talk about jobs.

Civilian nuclear reactors wouldn't have happened without the government.

GPS technology wouldn't of happened without the government.

Civilian aircrafts, the aircraft, the way they developed and that's your industry, without the government.

The internet, for goodness sakes. DARPA created the internet.

The long list of government support for all these industries just shows what the track record has been. I don't see any reason why the track record wouldn't continue to be where—is there anything about clean energy and renewable energy that was different by its nature, different than all these others that I've cited?

Mr. AUGUSTINE. I think, Senator, the things you cite have in common the fact that they were high risk undertakings offering high payoff. That's not an area that's particularly attractive to the private investor. I think energy fits this very well. Energy happens to have an additional characteristics that it comes in very costly quanta, if you will.

To go to nuclear power you would never get there with the private sector.

Senator FRANKEN. Many steps.

Mr. AUGUSTINE. It just won't happen. That's right.

Senator FRANKEN. Yes.

Mr. AUGUSTINE. If you talk about nuclear fusion that's a 60-year project. I happen to think a very important one.

Senator FRANKEN. I noticed that you mentioned fusion. That's something I've been interested in. They always say that, you know, nuclear fusion is the energy of the future and always will be. But I think that has a tremendous promise and we still continue to invest in that.

They're doing, you know, there's been, you know, support for industry for the development of shale fracturing and directional drilling. That's been done by the government support for industry. As well as 20 years of tax credits for production and subsidies. If we're going to pay for some of this stuff why not pay for it with some of the subsidies that we're already paying to this very mature industry?

So you know, it was government support that got shale gas to go from inaccessible to dominating much of our energy sector. So

I don't understand the unwillingness of my colleagues from the other side to even be present and to recognize what role the government has played.

You mentioned energy efficiency and about retrofitting. You touched on it a little bit. I was just and that means things like smart meters, better gauge energy use or efficient micro processors to make batteries last longer and innovation. I mean, and batteries or something that we've been doing in this latest round of government research, government funded research.

One thing we did in Minnesota that has helped create jobs in retrofitting and I'll get to it, this will be a question actually, is we have an energy efficiency standard that our utilities have to meet. Every year their customers have to improve their efficiency by 1.25 percent or something like that or 1.5 percent.

Do you think that's an area where if we did that nationally because it works in Minnesota. When we do that in Minnesota the utility companies go like, you know what, I think I'll invest in this retrofit of my customer. I'll lend them the money up front. It will pay for itself, the energy savings pays for itself.

If we did a national renewable energy standard, not renewable energy standard, but an efficiency standard for these utilities. Do you think that would have a good effect on our use of energy?

Mr. AUGUSTINE. Yes, I do believe that energy efficiency is an important part of the solution to this problem. I think there is no one thing that's going to solve it, nor did you suggest that. But if we can encourage the public either through the use of controllers in their power, the time of day they use energy or just using less energy that has to be a clear positive.

To encourage the public to do that, I think, is an important thing to do.

My bottom line, Senator, is that I spent 10 years in the government. I've traveled to 111 countries. Having seen all that, I'm a great believer in the private sector doing whatever it can.

There's one area where I think there's an exception to that. That is when the market itself fails. The energy market has failed.

Without government support, the type you describe, and of other types that have been described, we will not solve the energy problem in this country.

Senator FRANKEN. Thank you, sir. You've been a successful businessman, haven't you?

Mr. AUGUSTINE. I don't know. I've been a businessman.

[Laughter.]

Senator FRANKEN. OK. I think you've been successful, but that's on my, you know, my bar.

The CHAIRMAN. Senator Murkowski, did you have additional questions of Mr. Augustine?

Senator MURKOWSKI. I do, Mr. Chairman. But I also know we've got a second panel coming up.

But I have to have you fill in the blanks. Why do you think that the energy sector has failed? Above all the other sectors that are out there, what is it about energy that has made it more complicated?

Mr. AUGUSTINE. I think a number of things.

That one is the high capital cost and the long time that facilities remain in existence, 40, 50 years. But I think more importantly it's been a highly regulated industry. It's controlled, the oil industry, is controlled by cartels abroad.

The fair price system has generally not found its way into the energy market today. One of the things that you all could do is to help bring the fair price system into the market.

Senator MURKOWSKI. Thank you, Mr. Chairman.

The CHAIRMAN. Mr. Augustine, thank you very much for your testimony and the good work that's gone into these reports. We appreciate it very much.

Mr. AUGUSTINE. Thank you. It's always a privilege to appear before this committee.

The CHAIRMAN. Why don't we go to our second panel? We have two witnesses on our second panel.

Mr. Ethan Zindler, who is Head of Policy Analysis with Bloomberg New Energy Finance. He has testified to us before.

Mr. Jesse Jenkins is also here. He's the Director of Energy and Climate Policy with the Breakthrough Institute in Oakland, California.

We're told today is your birthday as well, Mr. Jenkins. Congratulations. This is a big day for birthdays.

Senator MURKOWSKI. Big day.

We do have cupcakes in the back here, Mr. Jenkins.

The CHAIRMAN. Yes, that's right.

Why don't we have the same procedure here that we did with Mr. Augustine and have each of you give us 5 or 6 minutes of summarizing what you think we should know from your testimony. We will include your full testimony in the record. Then we'll have some questions.

Mr. Zindler, did you want to be first?

STATEMENT OF ETHAN ZINDLER, HEAD OF POLICY FINANCE, BLOOMBERG NEW ENERGY FINANCE

Mr. ZINDLER. Sure, thank you.

So, good morning, Chairman Bingaman, Senators, ladies and gentlemen. Of course, happy birthday to my co-panelists and Senator Murkowski.

It's an honor and privilege to be here before the committee again. I join you in my role as analyst with Bloomberg New Energy Finance, a division of Bloomberg, focused on the clean energy sector. Our group provides accurate and actionable data and insight on investment, technology and policy trends in clean energy.

My remarks today represent my views alone and not the corporate positions of either Bloomberg LP or Bloomberg New Energy Finance. In addition, they do not represent specific investment advice and should not be construed as such.

That's what the lawyers told me to tell you.

In June 2010 my firm——

Senator FRANKEN [continuing]. By——

Mr. ZINDLER. In June 2010 my firm produced a study in partnership with the non-profit Clean Energy Group, entitled, "Crossing the Valley of Death: Solutions to the Next Generation of Clean Energy—to the Next Generation Clean Energy Project Financing

Gap." That report examined the various challenges facing energy technology companies looking to scale up while driving their costs down. It encompassed interviews with more than 5 dozen technologists, entrepreneurs and investors in the clean energy space.

Other studies have since explored this area in greater depth and advanced the discussion in important ways. The most notable has been the American Energy Innovation Council's work which examines the same Valley of Death conundrum, but with an explicit focus on American competitiveness. My fellow witness, Jesse Jenkins of Breakthrough Institute and others have also provided important insights in this area.

The clean energy sector has seen significant growth in recent years. New investment into the industry which total $54 billion in 2004 and $189 billion in 2009 rose to $263 billion last year. In fact in the fourth quarter of 2011, our firm counted the one trillionth new dollar invested in this sector.

Meanwhile we have seen clean energy technologies make important progress down their respective learning curves.

The price of a solar module at the factory gate has dropped by more than half in just the last 16 months.

The efficiency of wind turbines continues to improve.

Prices for lithium ion batteries used in electric vehicles are starting to take down.

A substantial part of this progress is a result of innovation, but much of it is due simply to economies of scale. As production of this equipment is ramped up per unit costs have come down.

Inevitably all this raises the question of whether or not the capital markets are today providing sufficient financing to address the Valley of Death conundrum. I would argue that they do not under closer examination of the investment trends reveals why. The vast majority of new capital entering the clean energy sector in any given year is actually directed toward well established, low risk technologies.

Just $5.1 billion of the $263 billion that we tracked last year came in the form of venture capital for new companies with the newest technologies. Within their portfolios VCs are now spending less money on the earliest stage companies and making fewer "A" round investments in new companies. So in short the so called Valley of Death for—at the technology stage for the earliest technology development has certainly not been bridged so far.

Similarly the riddle of later stage commercialization Valley of Death also remains unsolved. For a time it appeared the solution might come from the public stock exchanges where new biofuels, solar and electric vehicle companies raise billions via initial public offerings to support their growth. But public market fund raising has all but evaporated in recent quarters for clean energy.

Today, for instance, there are half a dozen, next generation biofuels firms looking to IPO. It remains to be seen if any of them will be able to float their shares. As an aside, I would note that last week, of course, Facebook managed to be valued at $100 billion and Linked In is currently valued at about $10 billion.

So there does seem to be an appetite for investors for dot com startups. Maybe not startups but certainly dot com companies.

What the risk appetite for clean energy companies is different at this particular moment.

Finally before concluding I'd like to take just a moment to address the question of where the U.S. stands in comparison to its peers in terms of clean energy technology development and deployment. I would emphasize that these two issues, development and deployment should be addressed separately.

In terms of deployment there can be little debate that the U.S. today trails nations such as Germany and Italy in terms of the installation of new, clean power generation. The same goes for the manufacturing of that conventional equipment with the U.S. often lagging behind China and others.

On the question of new technology development there remains much to play for however. The clean energy marketplace could not be sustained primarily by subsidies forever. Already we are seeing signs of declining support from governments around the world.

Rather, the industry must, and we think will, compete and beat its fossil rivals on price without government support. For some technologies in some parts of the world this is already occurring. But the day when that happens far and wide still lies ahead.

When it arrives will the U.S. be home to the most critical new energy technologies and the associated manufacturing capacity?

Will the U.S. be a market maker for these technologies or a price taker buying the equipment from companies overseas?

This remains very much to be seen, but there are hopeful signs for the U.S. despite the lack of investment.

The country is home to world class research institutions and laboratories.

It is the hub for venture investing with 3 out of 4 venture capital dollars for clean energy coming from the United States.

In short, in my view, no Nation may be better positioned to own the long term energy technology future than the United States. The only question is whether these resources can be coordinated to maximum advantage. That is where public policy inevitably must enter the picture.

Thank you very much for your time. I look forward to your questions.

[The prepared statement of Mr. Zindler follows:]

PREPARED STATEMENT OF ETHAN ZINDLER HEAD OF POLICY ANALYSIS, BLOOMBERG NEW ENERGY FINANCE

Good morning, Chairman Bingaman, Senators, ladies and gentlemen. Thank you very much for hosting me here today. It is an honor and privilege to be before this committee again.

I join you in my role as analyst with Bloomberg New Energy Finance, a division of Bloomberg focused on the clean energy sector. Our group provides accurate and actionable data and insight on investment, technology, and policy trends in clean energy. My remarks today represent my views alone and not the corporate positions of either Bloomberg LP or Bloomberg New Energy Finance. In addition, they do not represent specific investment advice and should not be construed as such.

In June 2010, my firm produced a study in partnership with the non-profit Clean Energy Group entitled Crossing the Valley of Death: Solutions to the Next Generation Clean Energy Project Financing Gap. That report examined the various challenges facing energy technology companies looking to scale up while driving their costs down. It encompassed interviews with more than five dozen technologists, entrepreneurs, and investors in the clean energy space.

Other studies have since explored this area in greater depth and advanced the discussion in important ways. The most notable has been the American Energy Innovation Council's work, which examines the same valley of death conundrum but with an explicit focus on American competitiveness. My fellow witness, Jesse Jenkins of the Breakthrough Institute, and others have also provided important insights in this area.

The clean energy sector has seen significant growth in recent years. New investment into the industry, which totaled $54bn in 2004 and $189bn in 2009, rose to $263bn last year. In fact, in the fourth quarter of 2011, our firm counted the one trillionth new dollar invested in this sector.

Meanwhile, we have seen clean energy technologies make important progress down their respective learning curves. The price of a solar module at the factory gate has dropped by more than half in the last 16 months. The efficiency of wind turbines continues to improve. Prices for lithium ion batteries used in electric vehicles are starting to tick down.

A substantial part of this progress is a result of innovation, but much of it is due to simple economies of scale. As production of this equipment has ramped up, per-unit costs have come down.

Inevitably, all of this raises the question of whether the capital markets are today providing sufficient financing to address the valley of death conundrums. I would argue that they do not, and a closer examination of the investment trends reveals why.

The vast majority of new capital entering the clean energy sector in any given year is actually directed toward well established, low-risk technologies. Just $5.1bn of the $263bn invested in 2011 came in the form of venture capital in support of new companies with the newest technologies. And within their portfolios VC's are today placing fewer bets on the very earliest stage companies. So, the so-called technology valley of death for embryonic research and development has by no means yet been bridged.

Similarly, the riddle of the later stage "commercialization" valley of death also remains unsolved. For a time, it appeared the solution might come from the public stock exchanges where new biofuels, solar, and electric vehicle companies raised billions via initial public offerings to support their growth. But public market fund raising has all but evaporated in recent quarters for clean energy. Today, for instance, there are half a dozen next-generation biofuels firms looking to IPO. It remains to be seen if any will ultimately float their shares.

Before concluding, I'd like to take just a moment to address the question of where the US stands in comparison to its peers in terms of clean energy technology development and deployment. And I would emphasize that these two issues—development and deployment—should be addressed separately.

In terms of deployment, there can be little debate that the US today trails nations such as Germany and Italy in terms of the installation of new clean energy power generation. The same goes for the manufacturing of that conventional equipment with the US often lagging behind China and others.

On the question of new technology development, there remains much to play for, however. The clean energy marketplace cannot be sustained primarily by subsidies forever, and already we are seeing signs of declining support from governments around the world. Rather, the industry must—and we think will—compete and beat its fossil rivals on price without government support.

For some technologies in some parts of the world, this is already occurring. But the day when it happens far and wide still lies ahead. When it arrives, will the US be home to the most critical new energy technologies and the associated manufacturing capacity? Will the US be a market maker for these technologies or a price taker, buying the equipment from companies overseas?

This remains very much to be seen, but there are hopeful signs for the US despite the lack of investment. The country is home to world class research institutions and laboratories. It is the hub of venture investing—three out of every four venture capital dollars for clean energy comes from US funds.

In short, in my view no nation may be better positioned to own the long-term energy technology future than the US. The only question is whether these resources can be coordinated to maximum advantage. That is where public policy inevitably enters the picture.

Thank you for your time and I look forward to your questions.

The CHAIRMAN. Thank you very much.

Mr. Jenkins.

STATEMENT OF JESSE D. JENKINS, DIRECTOR OF ENERGY AND CLIMATE POLICY, BREAKTHROUGH INSTITUTE, OAKLAND, CA

Mr. JENKINS. Thank you, Chairman Bingaman, Ranking Member Murkowski and distinguished members of the committee. I'm Jesse Jenkins. I direct the Energy and Climate Program at the Breakthrough Institute, an independent public policy think tank based in Oakland, California.

It's an honor to appear before you today to discuss the role of government in energy innovation, particularly on my birthday and Senator Murkowski's.

Advanced energy policy and markets in the United States are now at a key inflection point. In recent years U.S. advanced energy sectors have grown rapidly adding jobs even through the depth of the recession while reducing costs for many technologies including solar and wind power, batteries for electric vehicles and advanced biofuels.

Still all recent cost declines mark important industry maturation and progress. Nearly all advanced energy sectors currently rely on public policy support to gain an expanding foot hold in today's well established energy markets. That policy support is now poised to turn from boom to bust.

Total annual Federal spending supporting advanced energy industry surged to $44.3 billion in 2009. But it is now poised to decline 75 percent to $11 billion by 2014. That's according to original analysis of 92 Federal policies supporting advanced energy sectors conducted by the Breakthrough Institute and recently published with scholars at the Brookings Institution and World Resources Institute as "Beyond Boom and Bust", putting clean tech on a path to subsidy independence. Of the 92 programs we examined a full 70 percent are now scheduled to expire by 2014.

The topic of this hearing is thus very timely. With the U.S. advanced energy policy system set to be effectively wiped clean in the coming years, my "Beyond Boom and Bust" co-authors and I recommend smart energy policy reform along two key fronts.

First, energy deployment subsidies and policies should be reformed to better drive and reward innovation and move advanced energy sectors toward subsidy independence as soon as possible.

Second, we should strengthen our Federal energy R and D and commercialization institutions and investments.

Our recommendations on energy R and D and commercialization find much agreement with the recommendations of the American Energy Innovation Council and with some of Bloomberg New Energy Finance's thinking on policies to help private entrepreneurs and firms cross the so called clean energy Valleys of Death. I'm happy to discuss those topics in greater detail in the Q and A to follow. But I want to focus here on subsidy reform.

First, when discussing the role of government in energy innovation it is important to note that energy is a commodity. Like a bar of steel or a lump of copper, we don't care much about the qualities of the kilowatt hour of electricity or a gallon of fuel itself. What we care about are the products and services that we derive from those fuels.

As such while new pharmaceuticals or electronics command a price premium from customers by offering new value added features. New energy technologies must routinely compete on price alone right from the get go. This is an extremely challenging task, especially when facing competition from fossil fuels that have enjoyed over a century to mature and develop. It helps explain why the government must play a more proactive and extended role in driving energy innovation than in other sectors.

In light of this, the government's role is critical on at least two fronts.

First, policy is key to jump start market demand for nascent energy technologies that currently cost more than well entrenched conventional fuels and would thus otherwise not attract private sector investment.

Second and equally important, government policies must drive steady innovation, cost declines and technology improvements that can advance these maturing sectors toward full cost competitiveness with mature fossil fuels.

With Federal funds now poised to contract, my colleagues and I believe that now is the time to reform energy subsidies to ensure that they efficiently accomplish both of these key objectives, driving market demand and continual innovation. We should not abandon today's still maturing advanced energy sectors. But neither can we afford to perpetually subsidize these industries without making steady progress on price and performance.

In "Beyond Boom and Bust", we outlined a set of criteria for energy subsidy reform to ensure that these policies reward companies for developing, producing and continually improving advanced energy technologies. In brief, optimized deployment policies should establish competitive markets among technologies at similar stages of maturity.

They should avoid locking out new technologies to promote a diverse energy portfolio.

They should provide sufficient business certainty.

They should maximize the impact of taxpayer dollars by efficiently unlocking private investment.

Above all market creating deployment policies should provide only targeted and temporary support for technologies that are still maturing and improving.

They should be explicitly designed to drive and reward continually cost reductions and performance improvements.

They should steadily reduce subsidy levels and public support as these technologies improve.

Eventually these subsidies should fade away entirely as advanced energy sectors become fully competitive with conventional fuels.

The role of government in driving markets and innovation for advanced energy technologies should thus be limited and direct. The goal should be to help develop robust industries that can stand on their own and thrive without public subsidies as soon as possible. Several policy mechanisms may be designed to meet these criteria. I look forward to discussing those in more detail in the questions to follows.

I thank you for considering these recommendations.

Thank you.
[The prepared statement of Mr. Jenkins follows:]

PREPARED STATEMENT OF JESSE D. JENKINS, DIRECTOR OF ENERGY AND CLIMATE POLICY, BREAKTHROUGH INSTITUTE, OAKLAND, CA

Chairman Bingaman, Ranking Member Murkowski, distinguished members of the Committee, I thank you for the opportunity to appear before you today to discuss the role of the government in the process of energy innovation. It is an honor and a privilege to speak with you on a topic so critical to the nation's energy, economic, and environmental future.

I am the Director of the Energy and Climate Program at the Breakthrough Institute, an independent public policy research institute in Oakland, California (see http://thebreakthrough.org/energy.shtml). The Breakthrough Institute is non-partisan and accepts only charitable contributions from individuals and foundations without a direct economic interest in our research and analysis. The Institute's Energy and Climate Program focuses centrally on identifying and advancing the optimal policies to accelerate innovation to ensure that advanced energy technologies become affordable, reliable, and scalable. This objective is essential to securely and sustainably fueling the national economy, improving public health and environmental outcomes, and ensuring U.S. technological leadership in the multi-trillion dollar global energy markets of the 21st century.

I am here today to share key findings and recommendations derived from several recent reports and analyses published by the Breakthrough Institute, as this Committee takes a hard look at identifying a limited and direct role for the government in accelerating advanced energy innovation.

GOVERNMENT POLICY BUOYS RECENT ADVANCED ENERGY INDUSTRY PROGRESS

Driven by private innovation and entrepreneurship as well as critical public sector support in the form of tax credits, grants, and loan guarantees, several advanced energy technology segments (often referred to collectively as "clean tech") have grown robustly in recent years while making progress on cost and performance.[1]

Electricity generation from renewable sources (excluding hydropower) doubled from 2006 to 2011.[2] Construction is now under way on the nation's first new nuclear power plants in decades. And American manufacturers are regaining market share in advanced batteries and vehicles.[3] Private sector investment in U.S. clean tech sectors (excluding nuclear energy) grew 42 percent to $48 billion in 2011, the first year the United States has commanded the lead in global clean tech investing since 2008.[4] Meanwhile, employment across advanced energy sectors expanded by almost 12 percent from 2007 to 2010, adding more than 70,000 jobs even as overall U.S. employment stagnated during the height of the recession.[5]

Perhaps a more important measure of technological and industry maturation is that prices for solar, wind, and other advanced energy technologies fell in recent years, moving these technologies closer to cost competitiveness with conventional

[1] Advanced energy technology or "clean tech" industry segments are defined variously. Unless otherwise noted, this testimony refers to the following industry segments when discussing advanced energy technology or clean tech sectors: solar, wind, geothermal, biomass, and nuclear power technologies; fuel cells; combined heat and power (CHP); energy efficient technologies, appliances, and building practices; smart grid; carbon capture and sequestration (CCS); alternative fuels (alcohol fuels, biofuels, biodiesel); advanced batteries; hybrid and electric vehicles; and high speed rail.

[2] Non-hydro U.S. renewable electricity generation increased from 96 million megawatt-hours in 2006 to 195 million megawatt-hours in 2011. See: U.S. Energy Information Administration, "Electric Power Monthly," March 27, 2012, http://www.eia.gov/electricity/monthly/epm_table_grapher.cfm?t=epmt_1_1. Accessed April 4, 2012.

[3] Up from 2 percent in 2008, the United States is expected to make up 40 percent of the market for advanced batteries by 2014. See: "Transforming America's Transportation Sector: Batteries and Electric Vehicles," U.S. Department of Energy, July 2010.

[4] Investment figures include the following sectors: renewable energy, biofuels, energy efficiency, smart grid, energy storage, advanced transportation, carbon capture and storage, and clean energy services. See: "Who's Winning the Clean Energy Race? 2011 Edition," Pew Charitable Trusts, April 2012.

[5] Employment grew by a total of 71,633 jobs from 2007 to 2010 in the following sectors: renewable energy, nuclear energy, carbon storage and management, fuel cells, energy efficiency (including buildings, lighting, and consumer products and appliances), smart grid, and electric vehicle technologies and advanced vehicle batteries. See: Mark Muro, Jonathan Rothwell, and Devashree Saha, "Sizing the Clean Economy: A National and Regional Green Jobs Assessment," Brookings Institution and Battelle Technology Partnership Practice, 2011.

energy technologies. The global average cost of solar installations fell more than 50 percent between 2007 and 2011, while wind turbine costs fell 27 percent from 2008 to 2011.[6] The price of lithium-ion batteries used in electric vehicles also fell 30 percent since 2009 and dropped by 14 percent last year alone.[7] Finally, the cost of advanced "drop- in" biofuel replacements for petroleum-based military fuels (jet fuel, etc.) declined 82 percent from 2009 to 2011, as procurement by the U.S. Navy catalyzed a 10-fold increase in demand for these advanced fuels.[8]

The role of government policy has been crucial to recent advanced energy industry growth and progress. Advanced energy technology segments, from renewable and nuclear power plants to alternative transportation technologies and fuels, receive a variety of federal incentives, including direct grants, tax credits, financing guarantees, and other subsidy programs. Similarly, nearly all clean energy research and development benefits from some form of federal support. These federal incentives help clean energy segments gain a foothold in energy markets by overcoming the higher costs or risks these nascent technologies currently face relative to highly mature fossil fuels or vehicle technologies. We should acknowledge that this federal support is by no means unique to today's advanced energy sectors. Conventional fossil energy sources have enjoyed substantial public R&D funding, favorable tax and regulatory treatment, and production subsidies ongoing to this day.[9]

The recent growth of advanced energy sectors is due in large part to a parallel increase in federal investment via this range of public policy mechanisms. Cumulative federal support for advanced energy technology sectors totaled an estimated $44 billion over the 2002-2008 period.[10] That level compares to a cumulative $150 billion invested between 2009-2014 (see Figure 1)*, according to an original analysis of 92 distinct federal programs supporting advanced energy/clean tech sectors conducted by the Breakthrough Institute and published as the April 2012 report, "Beyond Boom and Bust: Putting Clean Tech on a Path to Subsidy Independence."[11] Furthermore, we estimate these initial public expenditures will leverage an overall cumulative public and private sector investment of $327 billion to $622 billion in U.S. advanced energy sectors from 2009-2014.

FROM CLEAN TECH BOOM TO FEDERAL SPENDING BUST

Despite recent cost declines, nearly all advanced energy sectors currently rely on public policy support and subsidy to gain an expanding foothold in well-established energy markets. That support is now poised to decline precipitously, presenting new challenges and raising the possibility of market turmoil ahead for several U.S. clean tech markets.

In summary, our research finds that annual federal clean tech spending peaked in 2009 at $44.3 billion and has already declined steadily through 2011 to $30.7 billion. Yet the sharpest reductions in federal support for these advanced energy sectors are still ahead: absent Congressional action, total federal clean tech expenditures will be cut nearly in half from 2011 to 2012 and will fall to just one-quarter of 2009 levels by 2014 (see Figure 2).

In the absence of legislative action to extend or replace current subsidies, America's system of policy support for nascent advanced energy sectors will have been largely dismantled by the end of 2014, a casualty of the scheduled expiration of 70 percent of all federal clean tech policies. Examples of expired or soon to expire policies include:

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[6] For solar cost trends, see: Ron Pernick, Clint Wilder, and Trevor Winnie, "Clean Energy Trends 2012," Clean Edge, March 2012. For wind cost trends, see: Mark Bolinger and Ryan Wiser, "Understanding Trends in Wind Turbine Prices Over the Past Decade," Lawrence Berkeley National Laboratory, October 2011.

[7] Justin Doom, "Battery Prices for Electric Vehicles Fall 14%, BNEF Says," Bloomberg, April 16, 2012.

[8] Breakthrough Institute analysis of data provided by the Office of the U.S. Secretary of the Navy, May 2012.

[9] See: "60 Years of Energy Incentives: Analysis of Federal Expenditures for Energy Development," Management Information Services Inc, October 2011; and Nancy Pfund and Ben Healey, "What Would Jefferson Do: The Historic Role of Federal Subsidies in Shaping America's Energy Future," DBL Investors, September 2011.

[10] Figure derived from "Estimating U.S. Government Subsidies to Energy Sources: 2002-2008," Environmental Law Institute, 2009 with RD&D data added from Information Technology and Innovation Foundation, "The Energy Innovation Tracker," www.energyinnovation.U.S. Accessed April 4, 2012.

* Figures 1–6 have been retained in committee files.

[11] The report was authored by Jesse Jenkins, Ted Nordhaus, Michael Shellenberger, and Alex Trembath of the Breakthrough Institute along with Mark Muro of the Brookings Institution and Letha Tawney of the World Resources Institute. See: http://thebreakthrough.org/blog/Beyond__Boom__and__Bust.pdf

- The Section 48C tax credit for manufacturers of advanced energy technologies and components (volumetric cap reached as of January 2010).
- The Section 1705 DOE Loan Guarantee Program for advanced energy technologies (expired September 2011).
- The Section 1603 Treasury Grants for renewable electricity projects (expired end of 2011).
- The Volumetric Ethanol Excise Tax Credit (expired end of 2011).
- The Production Tax Credit (PTC) enjoyed by wind power and other renewable electricity sources (expires at the end of 2012 for wind and at the end of 2013 for other technologies).
- A total of $51 billion in temporary clean energy expenditures under programs created or expanded by the Recovery Act (note that this total includes the Section 48C, 1705, and 1603 programs noted above).

Furthermore, many of the remaining programs will end shortly after 2014. The solar industry, for example, will be left with just two more years before the 30 percent federal Investment Tax Credit (ITC) buoying solar markets expires at the end of 2016. The only other ongoing programs left after 2014 include the nation's underfunded energy RD&D programs and a handful of tax credits and grant programs for energy efficiency and conservation.[12]

This impending mass-expiration of federal policy support comes at a time of corresponding subsidy declines in many European markets as well as heightened competition from both foreign clean tech manufacturers and record-low prices for natural gas—the chief domestic competitor to many clean electricity generation technologies, from wind and solar to nuclear power. Without action, the combination of these forces could see recent years of clean tech boom go bust—with significant effects to the economy and American competitiveness—and they will certainly present new challenges and headwinds for advanced energy sectors in the years ahead.

FEDERAL FUNDING CLIFF AND CHEAP GAS CHALLENGE ADVANCED ENERGY SEGMENTS

The expiration of key federal programs, including the Section 1603 renewable energy grant program and other ARRA-created programs, has already begun to impact advanced energy technology markets and investments. Furthermore, the scheduled expiration of other programs, including the wind PTC at the end of 2012 and the broader collapse in funding scheduled to unfold by 2014, are all well within the time horizon relevant to investment decisions being made today by advanced energy firms and financiers.

This policy uncertainty is thus already having a chilling effect on private sector investment in advanced energy sectors. After setting a record in 2011, global clean tech investment plunged in the first quarter of 2012, diving to the lowest levels since the depths of the global recession in 2009.[13]

With virtually all advanced energy segments dependent in one way or another on policy support, how this emerging industry will weather this policy collapse remains to be seen. Market impacts will certainly vary by industry segment, and "Beyond Boom and Bust" closely examines the outlook for wind, solar, and nuclear power, as well as corn and cellulosic biofuels, and plug-in hybrid/electric vehicles and advanced batteries.

To summarize our findings, we conclude that clean electricity sources competing directly with gas-fired power plants may face the most severe economic challenges, as low natural gas prices coincide with declining federal incentives (see Figure 3). Below I discuss the outlook for wind, nuclear, and solar markets.

Wind Power

Absent subsidy, the levelized cost of electricity from wind power facilities is now competitive with combined-cycle natural gas-fired power plants only at locations with the best wind speeds and ready access to existing transmission capacity. The PTC thus remains critical to ensure wind power is cost competitive and can expand in a broad range of locations. If the PTC expires without any replacement, market analysts expect annual wind energy installations to contract by as much as 85 percent from a projected peak of 8-10.5 gigawatts (GW) in 2012 to just 1.5-2 GW in 2013.[14]

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[12] See "Beyond Boom and Bust" for more detailed analysis of federal clean tech expenditures and programs.

[13] "Q1 2012 clean energy investment squeezed by policy uncertainty," Bloomberg New Energy Finance, April 12, 2012, http://www.bnef.com/PressReleases/view/208, accessed May 16, 2012.

[14] Felicity Carus, "Wind Rush: U.S. Industry Hurdles Towards a Cliff Without Production Tax Credit," AOL Energy, November 14 2011; "Impact of the Production Tax Credit on the U.S. Wind Market," Navigant Consulting, December 2011.

Nuclear Power

Given the expected construction costs of the two new nuclear reactors under construction by Georgia Power at Plant Vogtle, the levelized cost of electricity from new nuclear reactors may fall in the range of $95-130 per MWh, assuming amortization of capital costs over a 30-year period.

While financial incentives offered by the Energy Policy Act of 2005 will help reduce these costs somewhat for the first 6 GW of new nuclear builds, these unsubsidized cost estimates are roughly twice the current costs of electricity from new combined-cycle gas-fired plants, significantly dampening the interest of investors and utilities for new reactor construction.

It is worth noting however, that the levelized cost of electricity from nuclear power plants is very sensitive to the cost of financing. Furthermore, the new AP1000 reactors under construction at Vogtle are designed to operate for 60 years and may operate well into the 2080s if not beyond. Comparisons of such long- lived assets to the cost of gas-fired power plants at current gas prices thus unfairly value the longevity and price predictability of new nuclear power plants.

Solar Power

Finally, solar panels installed on residential and commercial rooftops do not have to compete directly with the wholesale cost of power from natural gas-fired plants. Given much higher retail electricity rates, more long-term federal incentives, and additional aid in several states, the outlook for solar power may be stronger. After significant recent cost reductions, rooftop solar installations on residential or commercial buildings have now reached unsubsidized prices that are competitive with retail electricity rates in Hawaii, where average residential electricity prices are quite high. Depending on the pace of innovation and cost reductions, rooftop solar is also within range of cost parity in certain U.S. retail markets with high average electricity prices and/or high solar irradiance, including California, Texas, Florida, and Nevada. Solar is approaching retail cost parity in a set of Northeastern states as well (Connecticut, New York, New Hampshire, and New Jersey), where retail rates exceed $160 per MWh and solar irradiance is modestly high (see Figure 4). The federal ITC for solar currently combines with numerous state and local inventive programs to open up wider opportunities for solar in select markets.

Large, utility-scale solar power plants must compete more directly with gas-fired generating units in wholesale power markets. While utility-scale solar installations typically achieve lower costs than rooftop installations due to greater economies of scale, solar power remains more costly (absent subsidies) than new gas-fired generation in wholesale power markets, except perhaps in regions with the highest solar resource (see Figure 3). Utility-scale solar installations thus currently rely on the federal ITC and other state incentives to be competitive in most U.S. markets.

FURTHER COST REDUCTIONS KEY TO MOVING CLEAN TECH BEYOND BOOM AND BUST

This is not the first time booming clean tech markets in America have been on the brink of a bust. U.S. markets for clean tech segments from wind, nuclear, and solar power to electric vehicles and alternative fuels have each surged and declined in the past. While a drawdown of federal subsidies is most often the immediate trigger of clean tech market turmoil, the root cause remains the same each time: the higher cost and risk of U.S. advanced energy technologies relative to either mature fossil energy technologies or lower-cost international competitors, which make U.S. clean tech sectors dependent on subsidy and policy support.

New industry sectors are often volatile, as innovative technology firms must challenge both established incumbents and competing upstarts. Advanced energy technologies are no exception.

Yet in energy, unlike biotechnology or information technology, price is king. Like steel or copper, energy is a commodity, principally valued not for its own qualities but for the services and products derived from it. As such, while new drugs, software, or consumer electronics command a price premium from customers by offering new value-added features, new energy technologies must routinely compete on price alone, even if they offer other long-term benefits.[15] It would be a difficult feat for any nascent technology to enter a commodity market and compete immediately on cost, but clean tech sectors face a particularly challenging rival: well-entrenched fos-

[15] For more on the challenges facing nascent advanced energy sectors, see: "Bridging the Clean Energy Valleys of Death." Full citation in references at end of this testimony. See also: Richard Lester and David Hart, Unlocking Energy Innovation: How America Can Build a Low-Cost, Low-Carbon Energy System (Cambridge: MIT Press 2011); Karsten Neuhoff, "Large-scale Deployment of Renewables for Electricity Generation," Oxford Review of Economic Policy, Vol 21, No 1, 2005.

sil fuel incumbents that have had more than a century to develop their supply chains—aided by government subsidies and support—and make incremental innovations to achieve high levels of efficiency.

The immediate cessation of advanced energy subsidies would not be in the national interest. These advanced energy sectors are still emerging and maturing and must compete against well- entrenched fossil energy sources. Supporting the development of a new portfolio of cost- competitive, scalable advanced energy technologies offers substantial opportunities for enhanced American energy security, economic growth, new technology exports, and improved public health. But this process will take time. Policy continuity, which provides assurance to the market and attracts private investment, is thus critical.

Fortunately, energy technology experts at the International Energy Agency point to numerous remaining technical opportunities to achieve significant cost reductions and performance improvements across a range of advanced energy technologies, from wind and solar power to enhanced geothermal energy systems, advanced nuclear designs, and improved vehicle technologies and fuels.[16] If costs continue to fall over the next several years, for example, rooftop solar PV installations will become fully cost competitive without subsidy in a growing number of retail electricity markets. Line-of-site innovations and improvements in both PV module and non- module costs could also bring utility-scale solar costs down to $40-102 per MWh by the end of the decade, making solar power subsidy independent in wholesale markets across much of the United States.[17] Analysts similarly project incremental turbine technology improvements have the potential to decrease wind energy costs by 10-30 percent in the 2015-2020 period, bringing the unsubsidized levelized cost into the $42-67 per MWh range and making wind power broadly competitive in that time frame.[18]

Full cost competitiveness with fossil fuels should be achievable in the near- to medium-term for a variety of advanced energy technologies. The steady process of innovation is the key.

As with prior energy innovations from gas turbines and nuclear reactors to shale gas extraction techniques,[19] sustained government policies will be critical to support private entrepreneurs and firms in driving further cost reductions and moving today's advanced energy technologies towards full maturity.

At the same time, the reality is that until technological innovation and cost declines can secure independence from ongoing subsidy, advanced energy technologies will remain continually imperiled by the threat of subsidy expiration and political uncertainty. Meanwhile, public tolerance for significant energy subsidies or the internalization of higher prices for energy is limited. If nascent energy technologies scale up without corresponding declines in price, this limited tolerance will eventually be expended, leading to another market bust. This means that the simple, perpetual extension of today's advanced energy subsidies and policies, with its passive approach to innovation, does not offer a sustainable path beyond a cycle of clean tech boom and bust.

The time has come then to craft a new energy policy framework specifically designed to accelerate technology improvements and cost reductions in advanced energy sectors, ensure scarce public resources are used wisely to drive technologies towards subsidy independence as soon as possible, and continue the growth and maturation of America's advanced energy industries.

With the U.S. advanced energy policy system set to be effectively wiped clean in the coming years, the time for smart reform is now, and this Committee will no doubt play a leading role in such efforts.

To these ends, my colleagues and I recommend policy reform on two critical fronts, detailed in "Beyond Boom and Bust" and summarized in the sections below.

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[16] See: Energy Technology Perspectives 2010, International Energy Agency, 2010.

[17] See: "Gas Boom Poses Challenges for Renewables and Nuclear." Full citation in references at end of this testimony. See also: D.M. Powell, et al., "Crystalline silicon photovoltaics: a cost framework for determining technology pathways to reach baseload electricity costs," Energy & Environmental Science, 2012, 5, 5874; and "SunShot Vision Study," United States Department of Energy SunShot Initiative, February 2012.

[18] See: "Gas Boom Poses Challenges for Renewables and Nuclear." See also: Ryan Wiser et al., "Wind Energy," in IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation, 2011, Cambridge University Press; and "2010 Wind Technologies Market Report," U.S. Department of Energy Office of Energy Efficiency and Renewable Energy, July 2011.

[19] See: "Where Good Technologies Come From" and "Where the Shale Gas Revolution Came From." Full citation in references at end of this testimony.

I. Reform Advanced Energy Deployment Subsidies to Reward Technology Improvement and Cost Declines

Expiring policies and programs are poised to wipe away the large bulk of today's advanced energy deployment regime. This creates a clear and urgent need for policy reforms that sustain market opportunities for advanced energy technologies, more effectively deploy limited public resources, and support innovative entrepreneurs and firms.

Whatever form it takes, a new suite of advanced energy deployment policies must simultaneously drive market demand and continual innovation.

By and large, today's energy subsidies do not do enough to support America's innovators, and they have not yet succeeded in driving down the costs of advanced energy technologies far enough to compete with conventional fuels. For example:

- Many of today's clean energy subsidies are focused primarily on supporting the deployment of existing energy technologies at current prices, and most provide no clear pathway to subsidy independence. The federal renewable electricity PTC, for example, has provided the same level of subsidy to wind power since initial enactment in 1992. Subsidy levels increase each year at the rate of inflation, keeping per MWh subsidy levels constant in real dollar terms and providing no clear incentive for continual cost declines or pathway to eventual subsidy independence.
- If not designed with care, deployment policies can also lock out more promising but higher risk technologies from markets, slowing their development. This is a challenge in particular for the renewable portfolio standard and clean energy standard policies given serious consideration by this Committee. These policies typically encourage deployment of the lowest-cost qualifying energy technology available—generally wind power or biomass, or in the case of a proposed CES, natural gas-fired plants. Yet if designed in this manner, RPS or CES policies may do little to drive down the price of other advanced energy technologies, such as solar or advanced nuclear reactor designs, that may have higher costs now but hold the potential to become much cheaper in the long-run.
- Intermittent and haphazard policy support can also wreak havoc with the business confidence necessary for the long-term investments required to develop new and improved products. The PTC for wind power, for example, was first enacted in 1992, but has since expired three times, and has been renewed a total of seven times, often with less than a month to spare before pending expiration. Other clean tech subsidies, including key tax credits for solar, biofuels, energy efficient products, and other segments have experienced similarly erratic expirations. The market effects are chilling, and many private firms are forced to focus principally on ramping-up production for subsidized markets while they last, rather than pioneering next-generation designs and manufacturing processes for the long-term. The intermittent nature of many advanced energy support policies thus slows the pace of innovation in these sectors and actually prolongs the amount of time these sectors remain reliant on public subsidy.

The United States can do better than this. Deployment subsidies and policies should be reformed and designed from the beginning to better support innovative U.S. firms and reward companies for developing, producing, and improving advanced technologies that can ultimately compete on price with both fossil fuels and international competitors alike. Each dollar of federal support today should be optimized to move maturing advanced energy technology sectors towards eventual subsidy independence as soon as possible.

Recognizing that investment horizons, technology development cycles, and market conditions vary across advanced energy technology segments, precise policy mechanisms will likely differ from sector to sector. Yet whether through production or investment subsidies, consumer rebates, market-creating regulations or standards, or other market incentives, we recommend that any advanced energy deployment subsidies meet the following policy design criteria. Reformed policies should:

1. Establish a Competitive Market.—Deployment policies should create market opportunities for advanced clean energy technologies while fostering competition between technology firms.

2. Drive Cost Reductions and Performance Improvements.—Deployment policies should create market incentives and structures that demand and reward continual improvement in technology performance and cost.

3. Provide Targeted and Temporary Support for Maturing Technologies.—Deployment policies must not operate in perpetuity, but rather should be terminated if technology segments either fail to improve in price and performance or become competitive without subsidy.

4. Reduce Subsidy Levels in Response to Changing Technology Costs.—Deployment incentives should decline as technologies improve in price and performance to both conserve limited taxpayer and consumer resources and provide clear incentives for continued technology improvement.

5. Avoid Technology Lock-Out and Promote a Diverse Energy Portfolio.—Deployment incentives should be structured to create market opportunities for energy technologies at different levels of maturity, including new market entrants, to ensure that each has a chance to mature while allowing technologies of similar maturity levels to compete amongst themselves.

6. Provide Sufficient Business Certainty.—While deployment incentives should be temporary, they must still provide sufficient certainty to support key business decisions by private firms and investors.

7. Maximize the Impact of Taxpayer Resources and Provide Ready Access to Affordable Private Capital.—Deployment incentives should be designed to avoid creating unnecessarily high transaction costs while opening up clean tech investment to broader private capital markets.

Several policies could be structured to meet these criteria, including:

- Competitive deployment incentives could be created for various clean tech segments of similar maturity, with incentives for each segment falling steadily over time to demand and reward continual innovation and price improvements.[20]
- Steadily improving performance-based standards could create both market demand and spur consistent technology improvement.[21]
- "Top-runner" programs competitively establish performance standards or financial incentive levels based on the leading industry performers in each market segment, forcing other firms to steadily innovate to stay competitive in the market.[22]
- Demanding federal procurement opportunities could be created to drive both market opportunities and ensure steady improvement of each successive generation of product, particularly when advanced energy technology products align with strategic military needs.[23]
- Reverse auction incentives could be established for varying technologies to drive industry competition and innovation.[24]

If structured to adhere to these criteria, a new era of advanced energy deployment policies will neither select "winners and losers" a priori, nor create permanently subsidized industries. Rather, these policies will provide opportunity for all emerging

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[20] See "Post-Partisan Power," page 22-23. Full citation in references at end of this testimony.

[21] Corporate Average Fuel Economy standards (CAFE) for passenger and freight vehicles or Emissions Performance Standards for new power plants each demand progressively improved technology performance. Similar standards could be designed to drive improvements in key factors determining technology costs or performance, such as the electric conversion efficiency of power plants.

[22] Japan's "top-runner" or "front-runner" energy efficiency program, for example, sets minimum standards for the energy efficiency of a variety of appliances, personal and freight vehicles, and lighting technologies. These standards are automatically revised on a periodic basis with new performance standards set based on the real performance of the most efficient products the market in each technology segment. Market leaders thus set the bar for the next performance standard, and competing firms must improve their technology performance to keep pace, driving market competition, innovation, and steady improvement in performance across each technology segment. See "Top Runner Program: Developing the World's Best Energy-Efficient Appliances," Ministry of Economy, Trade, and Industry of Japan, March 2010.

Environmental and air quality regulations requiring the implementation of "best available control technology" (i.e. certain New Source Review regulations implementing the Clean Air Act) operate on similar principles as well, requiring steady improvement in performance as available technologies improve.

[23] See "Post-Partisan Power," page 23-24. See also: Daniel Sarewitz and Sam Thernstrom, "Energy Innovation at the Department of Defense: Assessing the Opportunities," Consortium for Science, Policy, and Outcomes and Clean Air Task Force, March 2012.

[24] Reverse auction programs are now in place in California for utility procurement of rooftop solar power installations and have been used in India and China to determine accurate market prices for later feed-in tariff subsidies. These programs provide strong incentive for market competition and reward firms who set the bar for price and performance with expanded market opportunities. The reverse auction mechanism for solar in California have secured record low contract prices. See: "Update to RAM Contract—145 MW Total," Vote Solar Initiative," http://votesolar.org/2012/04/update-to-ram-contracts-145-mw-total/, accessed May 16, 2012.

For Congressional proposals establishing reverse auction mechanisms, see: H.R.909 (112th Congress), "A Roadmap for America's Energy Future," Title III, "Reverse Auction Mechanism for Renewable Energy Generation and for Renewable Fuel Production," sponsored by Representative Devin Nunes (R-CA-21); S.3434 (111th Congress), "Practical Energy and Climate Plan," Title I, Subtitle B, Sec. 111, "Production Incentives for Renewable Fuels," sponsored by Senator Richard Lugar (R-ID).

advanced energy technologies to demonstrate progress in price and performance, foster competitive markets within a diverse energy portfolio, and put these segments on track to full subsidy independence.

II. Strengthen the National Energy Innovation System

Subsidy reform by itself will not be sufficient to drive the needed technology innovation and subsequent adoption of affordable advanced energy technologies. For that reason, energy policy reform to secure an internationally competitive, subsidy-independent advanced energy technology sector must harness America's strengths as an innovator.

The United States is home to world-class universities, generations of trained scientists and engineers, potent centers of entrepreneurship, finance, and advanced manufacturing, and a creative culture capable of attracting talent from around the world. Yet when it comes to energy, America's innovation system falls short.[25] Policy makers must strengthen the U.S. energy innovation system to catalyze advanced energy breakthroughs and support continual technology improvement.

Along with the key reforms to deployment policies discussed above, the nation should pursue policy reform along three additional fronts:

Steadily Increase Investment in RD&D While Reforming and Strengthening the U.S. Energy Innovation System

Stepped up investment in energy RD&D is sorely needed to both invent new technologies and improve the cost and performance of existing ones to make them more competitive with conventional energy sources. Yet neither the private nor the public sector currently invests the resources required to accelerate energy innovation and drive down the cost of advanced energy technologies.

Multiple barriers prevent firms from adequately investing in the development of new, high-risk energy technologies. These include: knowledge spillover risks from private investment in research; the commodity nature of most energy markets, which prevent nascent, higher cost energy technologies from charging a premium; inherent technology and policy risks in energy markets; the financial scale and long time horizon of many clean energy projects; and a lack of wide-spread enabling infrastructure. As a result of these and other barriers, U.S. energy firms reinvest well below one percent of revenues in RD&D. This stands in stark contrast to firms in the information technology, semiconductor, and pharmaceuticals sectors, which typically reinvest 15 to 20 percent of their revenue in RD&D and new product development.[26]

This private sector gap is due in part to an analogous one in the public sector. Federal energy RD&D spending has stood in the $4-6 billion range in recent years.[27] By contrast, the United States invests almost $19 billion per year in the National Aeronautic and Space Administration (NASA) and $33.5 billion each year into health research (primarily through the National Institutes of Health), while defense related R&D now approaches $80 billion annually. At 10 percent of total economic activity, the vast size and critical importance of the energy sector to the U.S. economy and national security calls for investments in advanced energy innovation of a similar order of magnitude.

As such, a broad consensus has emerged among energy sector analysts—including the business leaders of the American Energy Innovation Council, the members of the Presidential Council of Advisors on Science and Technology, and a set of think tanks with diverse ideological backgrounds[28]—that energy RD&D investment should roughly triple over time to at least $15 billion annually.

At the same time, America's energy innovation system must also be modernized to leverage regional innovation opportunities and strengthen new institutional models at the federal level. Examples of recent institutional innovations at DOE include the creation of the Energy Frontier Research Centers (EFRCs), the Advanced Research Projects Agency-Energy (ARPA-E), and the Energy Innovation Hubs. Such efforts should be continued and expanded. Similarly, efforts to build public-private partnerships responsive to both industry needs and regional strengths should con-

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[25] See: "Post-Partisan Power," pages 13-16.

[26] See: "Bridging the Clean Energy Valleys of Death," pages 7-10. Full citation in references at the end of this testimony.

[27] See: "Energy Innovation Tracker," http://energyinnovation.us, Information Technology and Innovation Foundation.

[28] See for example: "A Business Plan for America's Energy Future" from the American Energy Innovation Council (AEIC); "Report to the President on Accelerating the Pace of Change in Energy Technologies Through an Integrated Federal Energy Policy" from the President's Council of Advisors on Science and Technology (PCAST)and "Post-Partisan Power," authored by scholars at the American Enterprise Institute, Breakthrough Institute, and Brookings Institution.

tinue to be encouraged across the DOE and particularly in the National Labs in order to ensure a maximum return on the federal investment in RD&D.[29]

Implement Effective Policies to Accelerate Commercialization of Advanced Energy Technologies

To ensure a fully competitive energy market, the federal government must also do more to speed the demonstration and commercialization of new advanced energy technologies. Due to multiple market barriers, private sector financing is typically insufficient to move new energy innovations from early-stage laboratory research on to proof-of-concept prototype and then to full commercial scale. There are two financing gaps, in particular, that kill off too many promising new technologies before they have a chance to develop. These are known as the early-stage "Technological Valley of Death" and the later- stage "Commercialization Valley of Death" (see Figure 5).[30]

The Technology Valley of Death occurs early in the development of a technology, as breakthrough research and technological concepts aim to develop commercially viable products. Investors are typically reluctant to fund early-stage research and product development, and many entrepreneurial start-ups fail to attract sufficient capital to see their research concepts translated into commercial products. New institutional arrangements for federal research support discussed above can help address this Technology Valley of Death, including ARPA-E and new regional innovation consortia.

The Commercialization Valley of Death exists between the pilot/demonstration and commercialization phases of the technological development cycle. This financial gap plagues advanced energy technologies that have already demonstrated proof of concept but still require large amounts of capital—often on the order of hundreds of millions of dollars—to demonstrate that their design and manufacturing processes can be brought to full commercial scale. This scale of funding exhausts the comparatively limited resources of typical venture capital-led financing rounds, and many VCs are beginning to eschew these nascent and capital-intensive energy technologies in favor of companies with more timely returns to investment.

Advanced energy policy reform should be extended to policies designed to address this Commercialization Valley of Death, including the DOE's Loan Programs Office. The LPO was created in part to help address this Valley of Death, yet the office was soon caught in a mix of competing objectives, including job creation, near-term economic stimulus, and long-term innovation. The LPO should now be replaced by a more flexible, independent, and sophisticated suite of financial tools and other mechanisms designed to draw private capital into advanced energy projects through a variety of investment, credit, securitization, insurance, and standardization activities. Whether delivered through a Clean Energy Deployment Administration (CEDA) or other entities or programs, the clear mission of these activities would be to accelerate the commercialization and deployment of critical advanced energy technologies.[31]

A National Clean Energy Testbeds program (N-CET) could also be established to take advantage of public lands to accelerate technology demonstration and commercialization. This new program would provide access to pre-approved, monitored, and grid-connected public lands and waters ideal for demonstration of innovative energy technologies, thereby reducing the cost, time, and permitting challenges associated with technology commercialization.[32]

The power of military procurement should also be leveraged to drive demanding early markets for advanced energy technologies that meet tactical and strategic military needs and may have later commercial applications. Energy technologies with dual-use military and commercial potential include advanced vehicle tech-

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[29] See: "Post-Partisan Power." Full citation in references at end of this testimony. See also: Duderstadt et al, Energy Discovery-Innovation Institutes: A Step Towards America's Energy Sustainability, Brookings Institution, February 2009; and Jesse Jenkins, Joshua Freed, and Avi Zevin, "Jumpstarting a Clean Energy Revolution with a National Institutes of Energy," Breakthrough Institute and Third Way, September 2009.

[30] See: "Bridging the Clean Energy Valleys of Death." Full citation in references at the end of this testimony.

[31] See: Jesse Jenkins and Sara Mansur, "A Clean Energy Deployment Administration: Unlocking Advanced Energy Innovation and Commercialization," November 2011. http://thebreakthrough.org/blog/CEDA.pdf

[32] See: Jesse Jenkins, Sara Mansur, Alexandra Tweedie, and Paul Sharfenberger, "A National Clean Energy Testbeds Program: Using Public Lands to Accelerate Advanced Energy Innovation and Commercialization," November 2011. http://thebreakthrough.org/blog/Testbeds.pdf

nologies, aviation biofuels, advanced solar power, improved batteries, and small modular nuclear reactors.[33]

Harness Advanced Manufacturing, Regional Industry Clusters, and a World-Class Energy Workforce to Enhance America's Innovative Edge

Advanced manufacturing is an integral part of the innovation system and a key area for cost reductions and performance improvements in emerging technologies. Innovation thus suffers when divorced from manufacturing activities. U.S. advanced manufacturing must play a key role in accelerating energy innovation. Technical support programs, public-private research consortia, and other strategic policies can help domestic manufacturers of advanced energy technologies remain at the cutting edge.[34]

Likewise, the nation needs to develop more potent, catalytic ways to leverage and enhance regional advanced energy industry clusters. Such industry clustering has been shown to accelerate growth by promoting innovation, entrepreneurship, and job creation. Policy makers should increase investment in competitive grants to support smart regional cluster initiatives, designed not in Washington but on the ground close to the "bottom up" innovation that has broken out in numerous states and metropolitan areas.[35]

Finally, American energy technology leadership will require a highly educated, globally competitive advanced energy workforce. The nation must make new investments in energy science, technology, engineering, and mathematics education and make smart reforms to immigration policies to ensure America remains the destination of choice for the world's best entrepreneurs and innovators.[36]

SHALE GAS REVOLUTION DEMONSTRATES IMPORTANCE OF GOVERNMENT ROLE IN ADVANCED ENERGY INNOVATION

As we consider policy reforms to accelerate energy innovation and move advanced energy technologies towards full maturity, we can look no further than the shale gas boom that has revolutionized U.S. energy markets for an important precedent for the key role of government in advanced energy innovation.

Shales now produce over 25 percent of domestic natural gas resources, up from 2 percent in 2001. The shale boom has also pushed natural gas's contribution to America's electricity generation portfolio from 20 percent to nearly 30 percent in the last few years alone. Natural gas resources in shale, once thought to be unrecoverable and until this past decade prohibitively expensive to extract on a full commercial scale, are now accessible and abundant. The shale boom has expanded domestic energy production, pushed down wholesale electricity prices to record lows, and accelerated the retirement of America's aging coal plant fleet, significantly improving public health. These advances were made possible by technological innovations resulting from a sustained partnership between the gas industry and the American federal government.

In a series of investigations and interviews with historians, gas industry executives, engineers, and federal researchers, the Breakthrough Institute uncovered the historical role of the federal government in the development of cost-effective shale gas extraction technologies.[37] We consistently found that innovation and progress in the development of hydraulic fracturing and other key gas recovery technologies arose from public-private research and commercialization efforts. From basic science to applied R&D to technological demonstration to tax policy support and cost-sharing partnerships with private industry, federal programs proved essential to gas industry engineers in figuring out how to map, drill, and recover shale gas—and, most importantly, how to do it cost effectively.

In summary, federal investments and involvement in the development of shale gas extraction technologies spanned three decades (see Figure 6) and were comprised of:

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[33] See "Post-Partisan Power," page 23-24. See also: Daniel Sarewitz and Sam Thernstrom 2012, op cit. note 21.

[34] See: Ryan McConaghy and Devon Swezey, "Manufacturing Growth: Advanced Manufacturing and the Future of the American Economy," Breakthrough Institute and Third Way, October 2011. http://thebreakthrough.org/blog/BTI__Third__Way__Idea__Brief__-__Manufacturing__Growth__.pdf

[35] See: Mark Muro and Bruce Katz, "The New 'Cluster Moment:' How Regional Innovation Clusters Can Foster the Next economy," Brookings Institution, 2010.

[36] See: "Post-Partisan Power," pages 18-20. Full citation in references at end of this testimony.

[37] See: "Where the Shale Gas Revolution Came From." Full citation in references at the end of this testimony.

- The Eastern Gas Shales Project, a series of public-private shale drilling demonstration projects in the 1970s;
- Collaboration with the Gas Research Institute (GRI), an industry research consortia that received partial funding and R&D oversight from the Federal Energy Regulatory Committee (FERC);
- Early shale fracturing and directional drilling technologies developed by the Energy Research & Development Administration (later the Department of Energy), the Bureau of Mines, and the Morgantown Energy Research Center (later the National Energy Technology Laboratory);
- The Section 29 production tax credit for unconventional gas, in effect from 1980-2002;
- Public subsidization and cost-sharing for demonstration projects, including the first successful multi- fracture horizontal drilling play in Wayne County, West Virginia in 1986, and Mitchell Energy's first horizontal well in the Texas Barnett shale in 1991;
- Three-dimensional microseismic imaging, a geologic mapping technology developed for applications in coal mines by Sandia National Laboratories.

It's clear that these government investment and research worked to drive innovations and cost declines in shale gas extraction technologies. Nevertheless, skeptics may wonder whether the private sector would have achieved these gains without any public support. Luckily, history puts this counterfactual to the test: there are plenty of countries with sizable shale deposits—including Russia, China, Poland, South Africa, Britain, and others—where active oil and gas industries did not make congruent investments in shale fracturing technologies. Instead, it was the United States that first cracked the shale gas challenge through decades of research and commercialization; shale fracturing operations in other countries are only now getting off the ground. The U.S. partnership between both public and private sectors was the key to America's shale gas leadership.

The importance of this government role should come as no surprise. Because private companies have difficulty monetizing and capturing all the benefits of energy technology research, it is consistently the case that federal coordination and investment is required to drive high-level technological innovation in the energy sector. As documented in the Breakthrough Institute's 2010 report "Where Good Technologies Come From," the American federal government has historically played a leading role in the development a broad range of other innovative technologies, including microchips, jet turbines, nuclear power reactors, and the Internet.[38]

The gas industry itself has spoken on behalf of the importance of federal research efforts. As Fred Julander, head of Julander Energy and member of the National Petroleum Council, notes: "The Department of Energy was there with research funding when no one else was interested and today we are all reaping the benefits. Early DOE R&D in tight gas sands, gas shales, and coalbed methane helped to catalyze the development of technologies that we [in the industry] are applying today."[39]

"The DOE started it, and other people took the ball and ran with it," Mitchell Energy's former Vice President Dan Steward told Breakthrough Institute. "You cannot diminish DOE's involvement."[40]

CONCLUSIONS

The American shale gas boom has brought bountiful new energy reserves, low prices, and thousands of new jobs. As we have seen, government policies—including federal R&D funding, public-private demonstration initiatives, and production incentives for maturing, pre-competitive energy technologies—played a critical role in advancing the key energy innovations required to unlock U.S. shale gas reserves.

Yet America's energy appetites are vast, and new uses for gas—from expanded chemicals production and gas-fired power generation to demand from new natural gas vehicles and export markets—will quickly take up new production. Rather than rest on our shale gas laurels, U.S. economic growth and energy security are best served by a diversified energy strategy that builds on the success of the shale boom to steadily expand—and make cleaner—domestic energy supplies.

As with government support for nascent unconventional gas technologies, the revamped U.S. energy strategy discussed in this testimony could establish a suite of

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[38] See: "Where Good Technologies Come From." Full citation in references at end of this testimony.

[39] See: "Shale Gas: Applying Technology to Solve America's Energy Challenges," US National Energy Technology Laboratory, http://www.netl.doe.gov/technologies/oilhgas/publica5ons/brochures/ Shale__Gas__March__2011.pdf

[40] See: "Where the Shale Gas Revolution Came From."

limited and targeted policies principally focused on driving innovation and cost declines to improve advanced energy technologies and unlock vast new domestic energy resources. These policies can accelerate technology improvements and cost reductions in advanced energy sectors, ensure scarce public resources are used wisely to drive technologies towards subsidy independence as soon as possible, and continue the growth and maturation of America's clean tech industries.

I thank you for considering these recommendations.

REFERENCES

This testimony relies centrally on the following publications, which may provide further resources and which may be read into the Hearing Report at the Committee's discretion:

- Alex Trembath, Jesse Jenkins, Ted Nordhaus, and Michael Shellenberger, "Where the Shale Gas Revolution Came From: The Role of Government in the Development of Hydraulic Fracturing in Shale," May 2012. http://thebreakthrough.org/blog/Where__the__Shale__Gas__Revolution__Came__From.pdf
- Jesse Jenkins, Mark Muro, Ted Nordhaus, Letha Tawney, and Alex Trembath. "Beyond Boom and Bust: Putting Clean Tech on a Path to Subsidy Independence," April 2012. http://thebreakthrough.org/blog/Beyond__Boom__and__Bust.pdf
- Alex Trembath and Jesse Jenkins, "Gas Boom Poses Challenges for Renewables and Nuclear," April 2012. http://thebreakthrough.org/blog/Gas__Boom__Challenges__Renewables__Nuclear.pdf
- Jesse Jenkins and Sara Mansur, "Bridging the Clean Energy Valleys of Death: Helping American Entrepreneurs Meet the Nation's Energy Innovation Imperative," November 2011. http://thebreakthrough.org/blog/Valleys__of__Death.pdf
- Jesse Jenkins, Devon Swezey, and Yael Borofsky (eds.), "Where Good Technologies Come From: Case Studies in American Innovation," December 2010. http://thebreakthrough.org/blog/Case%20Studies%20in%20American%20Innovation%20report.pdf
- Steven F. Hayward, Mark Muro, Ted Nordhaus, and Michael Shellenberger, "Post-Partisan Power; How a Limited and Direct Approach to Energy Innovation Can Deliver Clean, Cheap Energy, Economic Productivity, and National Prosperity," October 2010. http://thebreakthrough.org/blog/Post-Partisan%20Power.pdf

The CHAIRMAN. Thank you very much.

I believe Senator Murkowski wanted to make a statement.

Senator MURKOWSKI. If I may, Mr. Chairman. I've got to excuse myself and attend an Appropriations mark up, otherwise I would not be leaving. I'd be sitting and asking a series of questions.

I'm intrigued by some of your proposals, Mr. Jenkins, about how we really do get to reform of some of our subsidies and how we figure out what the ramping is. I think it is a key part to what we need to consider.

I do have a whole series of questions that I would like to submit to both of you for the record.

Perhaps we'd have an opportunity to visit outside of the committee hearing to follow up on some of the proposals.

This is an important topic. I think we all recognize that energy, the energy sector, is one where things are constantly evolving. How we appropriately integrate the Federal Government into the incentive process is an important one.

So, thank you, Mr. Chairman, appreciate it.

The CHAIRMAN. Thank you very much.

Let me go ahead with a couple of questions. First, let me ask Mr. Zindler.

One of the policies that some governments have pursued is to establish so called clean energy banks to help with deployment of

clean energy. I believe, the United Kingdom and Australia, in particular, have moved ahead with this.

Could you describe what this phenomenon is and what you think the benefits might be if we were to consider that or if you don't think it makes sense here, say that as well?

Go right ahead.

Mr. ZINDLER. As a quick update. So, you know, as obviously you're well aware here in the U.S. under your leadership and others there's been some attempt to establish a clean energy deployment administration. I think, as you know, and I think it's important to mention, this same idea is being pursued by other countries around the world right now.

Australia is close to finalizing a $10 billion green investment bank.

The UK is committing potentially 3 billion pounds.

India has made some announcements, but though I don't think that plan has moved forward to far.

The basic idea of all these institutions, more or less, is to create a separate, sort of quasi public entity that gets some seed funding from government. Then essentially can operate relatively autonomously in making investment in new technologies. Then as those technologies develop and hopefully are winners, they get a return on that investment that they can reinvest and continue on.

The idea is that it becomes—it does start with some—a nut of government money to begin with. But then it becomes self sustaining over time. I think one of the interesting, potential advantages of this model is that by kind of breaking it out of government infrastructure you can give it more leeway to make faster decisions and to operate in a more flexible manner and to make different kinds of bets, financial bets, than you might get through highly regulated government program.

So that's the idea generally speaking. It's certainly intriguing. What it really, I think what's potentially most interesting about it is its ability to address the so called demonstration Valley of Death. So that's the $100 to $200 million that might be needed to build a next generation biofuels plant or a plant that uses a new solar technology.

That kind of capital, banks won't, generally won't, lend because they have the money but they don't want to take that much risk. Venture capitalists like that much. They're willing to take that much risk but they don't have that much money to make on a single bet.

So it kind of falls into a black hole of sorts. An institution like that, that's willing to provide large amounts of capital at a higher risk rate, you know, really offers real potential.

The CHAIRMAN. Thanks.

Let me ask Mr. Jenkins a question. You list in your testimony here several policies that could be structured to accomplish some of the objectives you identify. One of the policies you mention is reverse auction incentives. You say that those could be established for varying technologies to drive industry competition in innovation.

I was wondering if you could elaborate on that a little bit and tell us what/how you think that might work and whether there are examples of that that we ought to look at.

Mr. JENKINS. Yes. Thank you, Senator.

Senator Franken earlier mentioned the role of government in a number of key technologies that have developed in the past. One of those is microchips where the government played an early demanding role or a role as an early demanding customer for virtually all of the market for microchips, in the 1960s and 1970s for the space program, the Minuteman missile program. That had the job of effectively driving down the cost of those technologies to the point where they could be more widely adopted by the private sector.

I think reverse auctions have the potential to play a similar kind of role as government procurement. In Southern California utilities are using reverse auction programs to procure solar panels at record low prices. To use the reverse auction mechanism to create a competitive market opportunity for firms to bid costs for their projects to meet a certain set of demand, a, you know, a number of megawatt hours or megawatts that utilities there need to procure from solar projects.

The winning bids then have strong penalties for non compliance which is a critical aspect of reverse auctions to ensure that people are providing accurate bids so they can actually meet. In the process the Southern California utilities are procuring several hundred megawatts of solar at close to or under $90 per megawatt hour which are significantly lower than prices we've seen even in the last quarter.

So it's a model that's been used in other markets, in India, in China, in Brazil, to varying degrees of success depending on how well they're able to police against non performance of contracts. But I think it's a model that meets many of the criteria that we outline.

It creates competitive markets.

It steadily drives down price because it's constantly driving competition.

Firms have an incentive to reduce costs, to expand on their market share.

So it's one of the policies we think we should look very closely at.

I should also note that some of the colleagues on the Republican side of the aisle have proposed similar reverse auction mechanisms in the past for biofuels, for deployment of wind or solar. So it seems like an idea that has been bouncing around the halls here as well. I think we should take a close look at it as we consider ways to drive both market opportunities but also continual cost reductions for these technologies.

The CHAIRMAN. Thank you very much.

Senator Franken.

Senator FRANKEN. Thank you, Mr. Chairman.

I just wanted to ask you, Mr. Jenkins. I spoke a little earlier about the government support for industry, for the oil industry, and gas industry and support for the industry in the development of shale fracturing and directional drilling.

Can you talk a little bit about that?

Mr. JENKINS. Yes. Thank you, Senator.

Yes, this is the result of an independent investigation the Breakthrough Institute conducted interviewing historians, industry, folks from the oil and gas sector as well as government researchers, to really piece together what was the process of development of the key technologies that enabled the shale gas revolution that is now sweeping across domestic energy markets in the United States.

What we found is that as with a number of other technologies the role of government in supporting innovation in the private sector was critical to the development of a number of the technologies that were needed to unlock previously unrecoverable shale resources.

So to summarize that includes the Eastern Gas Shale Project, a series of public/private shale drilling demonstration projects that were undertaken in the 1970s by the Energy Research and Development Agency and the Bureau of Minds, the collaboration with the Gas Research Institute, which is an interesting model of an industry research consortia that received partial funding in R and D oversight from the Federal Energy Regulatory Commission or Committee, FERC. To the discussion earlier of Senator Murkowski's questions about funding, GRI was funded by a user surtax on gas transmission fees. So we set aside a little bit of that funds in a way that Mr. Augustine mentioned, to drive further innovation in that sector. We think it's an intriguing model here.

Early shale fracturing and directional drilling technologies were also developed by ERTA and later the Department of Energy, the Bureau of Minds and the Morgantown Energy Research Center in West Virginia which is now the National Energy Technology Lab.

To Senator Bingaman's home State, Sandia National Laboratory has played a key role in developing micro seismic imaging technology initially to detect potential fractures and collapses in coal mines. That was a key technology that was later applied to understanding the geology of shale deposits and understanding where the fractures would occur so that private industry could figure out where to locate their drills, their drill bores and their fractures.

So there's—and beyond the initial demonstration of these technologies there was also a period of time when shale was technically recoverable but prohibitively expensive compared to more conventional extraction technologies. Once again this is the second key role that the government has to play.

The government instituted the section 29 Production Tax Credit for unconventional gases from shale, tight sands and coal bed methane. That was in place from 1980 to 2002. It made it profitable for the private sector to continue to develop and innovate upon that, those shale extractions.

Senator FRANKEN. That helped develop the market.

Mr. JENKINS. Without that conventional tax credit there would have been no profitable return for private sector innovators to invest in that sector.

Senator FRANKEN. That was the second Valley of Death.

So it really, the government, brought——

Mr. JENKINS. Across.

Senator FRANKEN. An industry—created the technology that made it possible which is, in one way, the first Valley of Death.

Mr. JENKINS. Yes.

Senator FRANKEN. Then created the market and subsidized it for the second Valley of Death. So that when my colleagues on the other side, who aren't here, when they sing the praises of fracturing and then demonize government involvement in picking winners and losers, it seems like they don't know the history of this industry.

Would that be a fair statement?

Mr. JENKINS. That may be the case. I do believe that the history has a clear record here that the government has played a substantial role in partnering with the private sector. We shouldn't diminish the private sector's role in driving innovation in these sectors.

But the risks, the capital requirements, the time horizons required to drive these new technologies forward are really prohibitive. This is where the private sector does fail. You needed the right kind of partnership between, you know, smart government policies in a limited and targeted way to address those barriers. That will unlock the private sector to do what it does best.

Senator FRANKEN. I'll take that as a yes.

Mr. Zindler, this is what the chairman was asking about. I think you spoke to it. But I just want to specifically talk about the Clean Energy Development Administration or CEDA.

Do you think that is a useful model as a way of helping get over the second Valley of Death?

Mr. ZINDLER. I mean potentially. It certainly has that opportunity. There is a short circuit in the market as I tried to sort of articulate. I don't know if I did earlier.

But basically, that there is not the right kind of money out there for this kind of task for large scale demonstration projects. So whether it's CEDA or maybe it's some other model or maybe you change the tax rules or whatever it is, you know, that that is a market disconnect that is sort of screaming out for some kind of a solution. I think, you know, that there are a number of interesting ideas out there. That's certainly one of them.

Senator FRANKEN. Thank you.

Thank you, Mr. Chairman.

The CHAIRMAN. Did you have any additional questions? If not, we can conclude the hearing at this point.

Senator FRANKEN. I don't want to, you know, put a crimp in your day, but.

The CHAIRMAN. No, go right ahead. That's what my day is for.

Senator FRANKEN. I wanted to ask about China. Sometimes we help, the U.S. Government helps U.S. companies come up with technologies. Then when these companies go to do something in China, China insists on their, you know, their intellectual property being—giving up their trade secrets in order to do business in China. I think this violates basic free trade principles.

Senator Webb has looked at this issue. I believe this committee ought to explore solutions to this problem. Do either of you have any opinions on how funding agencies can better protect taxpayer funded technologies?

Mr. ZINDLER. I'll take a crack at that. That's a tough question, obviously.

The U.S./China Clean Energy Trade relationship is at a very interesting juncture. In fact as you may have seen last week the Department of Commerce announced new, fairly substantial tariffs on Chinese goods, solar equipment, imported into the United States. So there's some tension there. I'll sure tread carefully in my remarks on this.

To some degree the Chinese government made some of the most important decisions about clean energy 3 or 4 years ago when it did make it difficult for outside companies to compete for contracts there. Now essentially and in the meantime, we saw a real scale up of domestic wind turbine manufacturing in China and really, in particular, for solar photovoltaics over that time. They've become, you know, really world leaders.

So, you know, on the one hand as you think about the politics of this, I understand the concerns about creating jobs and in protecting intellectual property. On the other, I do think it's important to note that in part because of that scale up the cost of solar, for instance, has never been cheaper than it's been. If you——

Senator FRANKEN. That actually undercut Solyndra. I mean that was part of the Solyndra story. Right?

Mr. ZINDLER. Yes, certainly part of the issue for Solyndra is that the—Solyndra is a very interesting example of a company that was trying to look longer range about driving down costs and literally got caught up, to some large degree, about what was going on at that very moment. So the conventional sector for solar has simply scaled faster and prices have come down faster.

Senator FRANKEN. So in an odd way they were undercut, Solyndra was actually undercut by the fact that the Chinese spent so much in promoting their own solar industry to make it so much cheaper that they were undercut and that their long term viability became longer term. Because they had a higher quality but more expensive product, right?

Mr. ZINDLER. What they were doing was looking further down the road. Basically the future arrived faster than I think that they had anticipated. That happened for a number of reasons. It frankly wasn't just the Chinese that scaled up. We've seen new capacity come online in Taiwan and other places as well.

But the solar market has very rapidly expanded and frankly gotten a little ahead of itself in the last couple of years. That's driven down prices very sharply.

Senator FRANKEN. Right.

Mr. Jenkins, did you?

Mr. JENKINS. Yes. Just one thing to add is that I mean, I think there are the current markets today for advanced energy technologies are substantial and but they are almost entirely government created markets. They are, you know, created by subsidies in Europe, in China and the United States or elsewhere.

I think we have to keep our eye on the ultimate prize which is the development of cost competitive, advanced energy technologies that can scale, you know, a $5 trillion global energy market without subsidies.

The game, I think, in the long term is who can develop the technologies that are cost competitive enough to export to global markets. Ninety plus percent of energy demand growth is coming from outside of the OECD countries, in the emerging economies. Those countries are going to be either unable or unwilling to substantially subsidize the deployment of cleaner energy technologies.

So one thing we can focus on both to drive competition, to enhance U.S. competition and to reduce the cost of taxpayer investments now is that the investments we level in creating these markets do have to continually drive down the cost of these technologies, support the right incentives for firms to continually innovate.

If we do that right and I think if we provide the right kind of continuity over the medium term and the right policy incentives and markets, we can succeed in out competing China. We can see firms in the United States take root that can deploy their technologies without subsidy and without the need for ongoing public support.

Senator FRANKEN. OK.

This is my last question/comment.

What we're basically doing is fighting for the future.

Mr. JENKINS. Yes, that's right.

Senator FRANKEN. Because what we're saying is is we know when these solar, wind, other renewables, other clean technologies become price effective. They will. They can, and they have to.

There's going to be an enormous world market and if we don't do this now we're not going to be part of it.

Mr. JENKINS. Yes.

Senator FRANKEN. Is that correct?

Mr. JENKINS. I think that's exactly correct. I think, again, we can look at the history of shale gas as a key example that we're not the only country in the world with large shale gas resources. China has even larger amounts of shale gas than we do, South Africa, many countries in Europe. But it was the United States that developed cost effective shale extraction technologies first.

That wasn't because we were the only country with an oil and gas sector either. It was because of the government partnership with that dynamic oil and gas sector that was able to develop those technologies. Now the United States enjoys a massive new source of domestic energy. We've created tens of thousands of jobs in that sector.

But if you go back and look, even in 2005 or 2006, not long ago, that sector was a tiny contributor to our national energy system. Those technologies were still cost ineffective. So you crossed that tipping point and all of a sudden you have a revolution in our American energy markets. We're exporting those technologies abroad, that expertise to China now and South Africa and other countries to help them develop those resources.

I think that's a parable for what we can and should do with other technologies, you know, energy demand in the United States is vast. So shale is great for expanding our energy supplies. We can't rest on those laurels.

We should continue to develop a diverse source of ever cleaner energy technologies. Those same kinds of polices are going to be

key to doing that and as you said, Senator Franken, winning the future.

Senator FRANKEN. I don't think we could end on a better note. Thank you, Mr. Chairman.

The CHAIRMAN. Thank you both very much. This was very useful testimony. We appreciate it.

That will conclude our hearing.

[Whereupon, at 11:27 a.m., the hearing was adjourned.]

APPENDIX

RESPONSES TO ADDITIONAL QUESTIONS

RESPONSES OF ETHAN ZINDLER TO QUESTIONS FROM SENATOR MURKOWSKI

CHINESE SOLAR TARIFFS

Question 1. Last week, the administration announced antidumping tariffs for Chinese solar panel producers. There's been conflicting media coverage about what this means—one article stated that "China unleashed a storm of protest across multiple outlets criticizing the U.S. decision" while another reported that "Chinese firms insisted US consumers would see only small price increases as a result." Have you been monitoring this issue? What do you think it means for the domestic solar market, and for our trade relations with China?

Answer. We have been monitoring this issue closely and reporting to our clients about it. We believe that a good deal of the rhetoric on all sides of this issue has been overblown and that the reality of the situation may be a good deal less dramatic than has been portrayed in the media to date.

Regarding the U.S. market for small-scale photovoltaic installations, we believe the duties are unlikely to have significant near-term impact on growth. A persistent global glut in photovoltaic cells and panels will continue to depress equipment prices though they could rise slightly from where they were before the tariffs in the US. Nevertheless, there is more than enough photovoltaic cell manufacturing capacity on line in other low-cost producing nations such as Taiwan to make up for any shortfall that might be created by the new tariffs. Cells and panels from these third party nations will not be subjected to the new tariffs.

Another reason for our outlook is that modules today account for only approximately a quarter of a typical installed watt of residential photovoltaic capacity in the US. That means US installers and developers could in many cases potentially cut their costs or trim their margins to accommodate the cost of these new duties.

For similar reasons, the new tariffs are unlikely to do much to help preserve jobs at US-based photovoltaic manufacturing plants. The cost advantages enjoyed by the Chinese in production are enjoyed by other nations who can now supply the US in their place. This largely leaves US-based manufacturing plants where they were before the tariffs were announced.

There clearly is a risk that the dispute with China can escalate and result in retaliation from the Chinese government that is either specific to the clean energy sector or involves other industries. Soon after the duties were imposed in May, the Chinese government said it was 'strongly dissatisfied' with the move. On May 25, 2012, China requested consultations with the United States before the World Trade Organization. China claims that the tariffs are inconsistent with several international trade conventions.

RESEARCH TRENDS

Question 2. In early May, it was reported that GM has decided to cut about 1/4 of its R&D workforce a technical center in Michigan—which surprised me, given the aggressive fuel economy standards the company has pledged to meet. Have you followed this story? Is it just a reshuffling on GM's part, or is it part of a larger trend in the industry?

Answer. While we are not closely familiar with the exact motives behind this move, our view from externally is that this most likely represents a reshuffle of resources within GM and is not emblematic of larger trends in the industry. Our understanding is that GM is cutting 190 employees, 100 in US and 90 in India as part of a restructure. Some 'R&D Division' staff will also be moving to other divisions—i.e. the fuel-cell research team will now become part of GM's powertrain division. GM has stated that a smaller workforce will focus on technologies that have a good

chance of being utilized on future vehicles/trucks rather than simply patenting innovations. By integrating some R&D into the relevant divisions, this does seem to make sense. We don't think this is part of a larger trend as we have not seen other automakers making similar moves.

It is worth noting that one key trend that we have seen emerge has been more partnerships between original equipment makers particularly surrounding electrification and fuel cell technologies. This has involved partnerships for technology sharing and development in a way that has not really been done with conventional powertrains. For example, Toyota and BMW began an agreement last December to cooperate on lithium ion battery cells and have just agreed to widen their cooperation to fields including lightweight construction, fuel cells and electric drive-trains. Essentially BMW is getting Toyota's strength in hybrid and battery technology and fuel cells, and Toyota is getting BMW's knowledge in diesel engines and sports cars. This splits the cost of R&D and allows the companies to play to their strengths. Similarly, BMW and PSA Peugeot Citroen have formed a joint venture to develop and manufacture components for electric drive-trains.

RESPONSES OF JESSE D. JENKINS TO QUESTIONS FROM SENATOR MURKOWSKI

SPENDING LEVELS

Question 1. The "Beyond Boom and Bust" report suggests that spending on clean tech will decline from $44 billion in 2009 to $11 billion in 2014. I think we all understand that 2009 was a stimulus year, and not representative of the amount the federal government has traditionally spent in this area. What do you think is an ideal level of spending on energy innovation? What would a realistic target be in 2020?

Answer. We have joined the broad consensus in advocating clean tech spending of at least $25 billion per year annually (see also PCAST, AAU/APLU, American Energy Innovation Council, Nobelists, Information Technology and Innovation Foundation). Federal spending on energy should at least match spending on health (NIH budgets run about $30 billion annually). In addition to the amount of funding, we have supported particular RD&D programs like ARPA-E and DOE's SunShot initiative, which prioritize breakthroughs for practical energy goals and improvement/commercialization of existing technology designs through partnership with private industries. Federal investments should be spread across RD&D and deployment, and these policies and programs should make innovation a top priority.

RD&D VS DEPLOYMENT

Question 2. Many observers believe that the federal government can have the greatest impact on energy R&D, but the vast majority of current spending goes to deployment. Do you think we need to improve—or perhaps reverse—that balance? In a time where our ability to spend money is greatly constrained, what part of the technology development chain should government focus on the most?

Answer. We have resisted the tendency to pin RD&D and deployment investments against one another. Our view has been that we should pursue strong and smart investments throughout the innovation pipeline, and that the amount of money spent on today's deployment subsidies is less important than the design of the policies. Today's deployment incentives prioritize output, not innovation. Scaling and market formation are important parts of maturation and cost declines, but policy needs design criteria explicitly directed towards these goals. This element hinges substantially upon an understanding of current market and technology realities. Clean energy technologies should be evaluated in terms of relative maturity and access to private financing; where these are less developed, more public support for innovation and deployment is called for. Where policies are not observed to drive regular and continuous cost declines and innovations, these policies in particular should be reevaluated or phased out.

TECHNOLOGIES VS OUTCOMES

Question 3. Something that bothers me is the federal government's habit of picking one technology, and plowing money into it at the expense of others. Then a new technology comes along, and we shift our focus and our spending. Do you think it would be more useful for the government to issue solicitations that focus on outcomes—with an example being, alternative fuel vehicles that can travel 300 miles without refueling—instead of focusing narrowly on individual technologies?

Answer. Our view is that the federal government should invest in a portfolio of technologies with the expectation that some may be more successful than others.

For instance, the 1980-2002 Section 29 tax credit for unconventional gas benefitted shale gas, tight sands gas, and coalbed methane; while all of these are now important contributors to domestic natural gas resources, shale has far outstripped tight gas and coalbed methane as a revolutionary new energy source.

The difficulty with a "one size fits all" approach to energy goals is that it inevitably ends up favoring certain winners at the expense of longer-term innovation and diversity of energy supply. An example is RPS's, which have largely been met by the most mature wind and biomass generation designs, without doing much in the way of fostering development of other less mature power technologies.

We have seen dynamic policy support for energy technologies in the past. In 1991 Mitchell Energy requested financial and technical assistance for their horizontal drill in the Texas Barnett shale, and the DOE and public-private Gas Research Institute provided that assistance. This was an example of a public commercialization investment, and an institution (the GRI) that teams taxpayer resources with industry expertise in the development of innovative technologies.

A prize or solicitation policy can be an important tool in a broad portfolio of federal clean tech innovation policies, but different technologies have different pathways to commercial maturity and are part of different markets with different needs. In some cases, innovation policies will incentivize performance and efficiency improvements; in other cases, financial or supply chain improvements are called for.

CLEAN ENERGY TEST BEDS

Question 4. I'm intrigued by your Institute's proposal for a "national clean energy test bed program," which would use public lands as dedicated demonstration sites. To take that concept a step further, I think about my home state of Alaska, and places like Hawaii, where energy is often tremendously expensive. Do you think it makes sense to focus on the areas where those costs are the highest—where new technologies make the most sense and are most likely to succeed—for demonstration and deployment?

Answer. This seems to us a desirable strategy. Solar power, for instance, is already at "grid parity" in Hawaii, where further test bed-style deployment might be appropriate. California and other states have developed financing models that allow residences and commercial businesses to enter into 20-year PPAs with power companies, which allows them to install solar panels on the residence or commercial rooftop with no upfront cost to the owner and typically a lower and constant electricity rate than the grid can provide. Early adoption policies should be targeted at these constituencies, where markets are allowed to grow, private finance enters the game, and technologies have the chance to achieve scale and maturity.

The test beds proposal was more for the high-impact demonstration on public lands of new energy technologies, including large-scale solar, wind, and (where applicable) hydro and tidal designs. If this proposal could be integrated into a strategy where local constituents can purchase power from test bed facilities, all the better.

INCENTIVIZING INNOVATION

Question 5. Your report recommends that federal policymakers "reform energy deployment subsidies and policies to reward technology improvement and cost declines." As we look at some of the subsidies that are expiring this year, including the wind tax credit, can you explain how you would begin that process? Assuming we come to a place where there's general agreement about renewing the credit—should we begin to phase it out, or limit eligibility to higher and higher efficiency turbines, or something else?

Answer. There are several ways we think clean tech existing deployment subsidies could be better designed that builds in a glide-path to their predictable closure. In the case of the PTC, it is clear that electricity generated by wind is close to competitive with wholesale natural gas-generated electricity, but also that the expiration of the PTC would do serious damage to the domestic generation and manufacturing market. This is because the wind industry has become accustomed to a particular type of project finance (tax equity markets) for wind energy projects.

An extension of the PTC could build in a gradual phasedown of the per-MWh subsidy, with the expectation that wind developers identify new sources of financing over the period of the phasedown (e.g., four years). Alternatively, the PTC could be re-oriented to provide a relatively higher subsidy rate to installations in lower wind-speed sites, and a lower subsidy rate in relatively higher wind resource zones.

Other smart deployment policies we've looked at include subsidies that scale down as deployment milestones are achieved (e.g., the California Solar Initiative). This guarantees a) that industry has an incentive to achieve cost declines and b) that the amount of public spending on the deployment policy is fixed.

There are also reverse-auction mechanisms (RAMs), which coupled with the appropriate enforcement protocols incent competition among project developers and reward those that promise the lowest-cost power generation with a utility contract or PPA.

Feed-in tariffs can fold in many of these criteria, and can also be ratepayer-financed as opposed to taxpayer-financed, which adds a layer of subsidiarity to the policy.

Wind turbines are a relatively mature power technology, and provided there remains a market for projects in the United States, turbine costs are projected to fall 10-30% in the next five years and wind electricity costs are projected to fall 20-40% by 2020. The phaseout of the credit will guarantee and accelerate these projections, while weaning the industry off its conventional form of project finance. For wind, a performance-based phaseout is less necessary than a scale-or time-based phaseout, both of which provide predictability and incentives for cost declines.

Federal energy policy should neither put all its eggs in one basket or assume a "one-size-fits-all approach," which will inherently favor today's most mature technologies over tomorrow's potential successes. As was the case with shale fracking commercialization, which relied on gas industry engineers and federal technology experts, technological development is a long path that often needs public investment at each successive step of the innovation pipeline (federal investments in shale gas included basic science, applied R&D, cost-sharing on demonstration projects, tax policy support for market pull). A successful energy policy will aim towards a broad portfolio of advanced technologies with a smart portfolio of investment and innovation policies.