NEW ROADMAPS FOR WIND AND SOLAR RESEARCH AND DEVELOPMENT

HEARING

BEFORE THE

SUBCOMMITTEE ON ENERGY AND ENVIRONMENT

COMMITTEE ON SCIENCE AND TECHNOLOGY

HOUSE OF REPRESENTATIVES

ONE HUNDRED ELEVENTH CONGRESS

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NEW ROADMAPS FOR WIND AND SOLAR RESEARCH AND DEVELOPMENT

TUESDAY, JULY 14, 2009

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

The Subcommittee met, pursuant to call, at 2:19 p.m., in Room 2318 of the Rayburn House Office Building, Hon. Brian Baird [Chairman of the Subcommittee] presiding.

BART GORDON, TENNESSEE
CHAIRMAN

RALPH M. HALL, TEXAS
RANKING MEMBER

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Committee on Science and Technology
Subcommittee on Energy and Environment

Hearing on

New Roadmaps for Wind and Solar Research and Development

Tuesday, July 14, 2009
2:00 p.m. – 4:00 p.m.
2318 Rayburn House Office Building

Witness List

Mr. Steve Lockard
Chief Executive Officer
TPI Composites
Co-Chair of the American Wind Energy Association (AWEA)
Research & Development Committee

Mr. John Saintcross
Energy and Environmental Markets Program Manager
New York State Energy Research and Development Authority

Professor Andrew Swift
Director
Wind Science and Engineering Research Center
Texas Tech University

Mr. Ken Zweibel
Director
George Washington University Solar Institute

Ms. Nancy Bacon
Senior Advisor
United Solar Ovonic and Energy Conversion Devices, Inc.

HEARING CHARTER

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

New Roadmaps for Wind and Solar Research and Development

TUESDAY, JULY 14, 2009
2:00 P.M.–4:00 P.M.
2318 RAYBURN HOUSE OFFICE BUILDING

Purpose

On Tuesday, July 14, 2009 the House Committee on Science and Technology, Subcommittee on Energy and Environment will hold a hearing entitled *"New Roadmaps for Wind and Solar Research and Development."*

The Subcommittee's hearing will receive testimony on H.R. 3165 sponsored by Rep. Tonko to authorize a comprehensive research, development, and demonstration program to advance wind energy technologies. The hearing also will examine the status of solar energy research and development programs and the need for a comprehensive plan to guide future solar R&D, including advanced manufacturing techniques for solar equipment.

Witnesses

- **Mr. Steve Lockard** is CEO of TPI Composites and Co-Chairman of the American Wind Energy Association (AWEA) Research & Development Committee. Mr. Lockard will testify on the findings of a recent AWEA report on wind energy research and development needs.
- **Mr. John Saintcross** is an Energy and Environmental Markets Program Manager at the New York State Energy Research and Development Authority. Mr. Saintcross will discuss the current challenges associated with using wind energy systems to meet New York State's renewable portfolio standard.
- **Dr. Andrew Swift** is Director of the Wind Science and Engineering Research Center at Texas Tech University. Dr. Swift will testify on ways to best integrate academic, governmental, and private sector resources to advance wind energy and wind forecasting technologies.
- **Mr. Ken Zweibel** is the Director of the George Washington University Solar Institute. Mr. Zweibel will testify on the current status of solar energy technology and the potential for this resource to have a much larger impact in the Nation's energy portfolio.
- **Ms. Nancy Bacon** is a Senior Advisor for United Solar Ovonic and Energy Conversion Devices, Inc. Ms. Bacon will testify on the private sector's view of the federal role for solar energy research and development in manufacturing and materials.

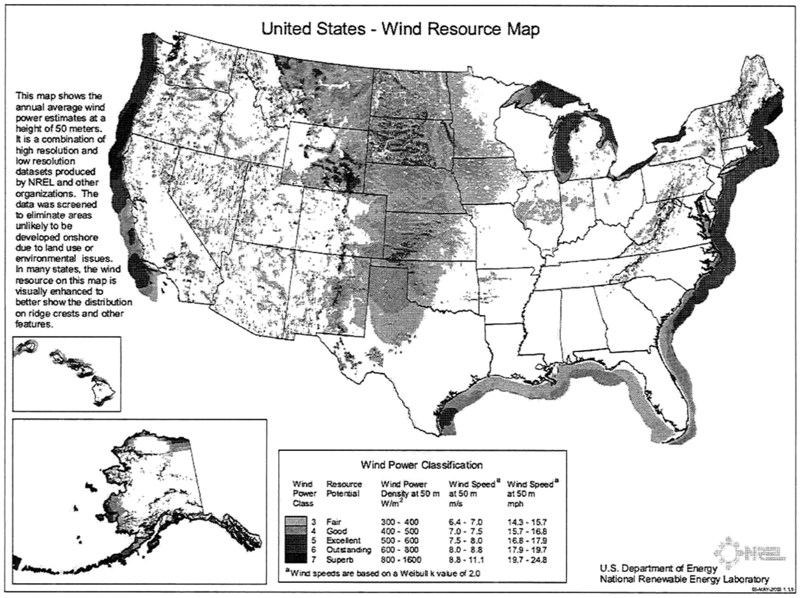

Figure 1: United States Wind Resource Map at an elevation of 50 meters. Produced by the National Renewable Energy Laboratory in May 2009.

Background

Wind Energy Research and Development Needs

Current U.S. land-based and offshore wind resources are sufficient to supply the electrical energy needs of the entire country several times over according to a Department of Energy report published in May 2008 entitled: *20% Wind Energy by 2030.* A map of these resources produced by the National Renewable Energy Laboratory (NREL) can be found in Figure 1. A further illustration of the large wind resource potential in the U.S. can be found in Table 1. Factoring in environmental and other relevant land use exclusions, Pacific Northwest National Laboratory determined that the top 12 states in wind energy potential (in order: North Dakota, Texas, Kansas, South Dakota, Montana, Nebraska, Wyoming, Oklahoma, Minnesota, Iowa, Colorado, and New Mexico) could theoretically produce more than double the U.S.'s current annual generation of electricity.

Top Twenty States for Wind Energy Potential in billion kWh/year

1.	North Dakota	1,210	11.	Colorado	481
2.	Texas	1,190	12.	New Mexico	435
3.	Kansas	1,070	13.	Idaho	73
4.	South Dakota	1,030	14.	Michigan	65
5.	Montana	1,020	15.	New York	62
6.	Nebraska	868	16.	Illinois	61
7.	Wyoming	747	17.	California	59
8.	Oklahoma	725	18.	Wisconsin	58
9.	Minnesota	657	19.	Maine	56
10.	Iowa	551	20.	Missouri	52

Table 1: Top 20 states for wind energy potential as measured by annual energy resource in billions of kWhs, factoring in environmental and land use exclusions for wind class 3 and higher. For comparison, total U.S. electric generation in 2007 was 4,157 billion kWh. ***Sources: DOE Energy Information Administration and "An Assessment of the Available Windy Land Area and Wind Energy Potential in the Contiguous United States", Pacific Northwest National Laboratory, 1991.***

However to expand from today's proportion of electric generation from wind (less than two percent) to a scenario where the U.S. generates 20 percent or more of its power from wind energy would require several significant advances including: improved wind turbine technology, improved wind forecasting capability, improved energy storage, and expansion of transmission systems to deliver wind power from resource centers to centers of population. In turn, these changes in the power generation and delivery process may involve changes in manufacturing, policy development, and environmental regulation.

Overall performance of wind energy systems can be substantially improved to become more efficient, cost-effective, and reliable. Fundamental technical issues remain even while wind power is competitive with coal and other conventional forms of energy in some markets. As a follow-up to DOE's wind energy report the AWEA Research and Development Committee produced a detailed *Action Plan to 20% Wind Energy by 2030* in March 2009. This plan proposed $217 million in annual federal funding combined with a $224 million industry/state cost share to support specific research and development programs which the AWEA Committee believes are necessary to meet a goal of providing 20 percent of America's electricity from wind by 2030.

This would be a significant increase from the DOE wind program's current annual budget of roughly $50 million, notwithstanding the one-time expenditure of $118 million currently identified by the Department for additional wind research and development activities from the *American Recovery and Reinvestment Act of 2009.* In recent years much of the federal wind program has focused on testing and evaluation of commercial turbines rather than advanced research, leading to gaps in our national wind R&D portfolio. There is broad consensus among government, academic, and industry leaders that research areas in which greater federal support could have a considerable impact include:

- new materials and designs to make larger, lighter, less expensive, and more reliable rotor blades;
- advanced generators to improve the efficiency of converting blade rotation to electric power;

- automation, production materials, and assembly of large-scale components to reduce manufacturing costs;
- low-cost transportable towers greater than 100 meters in height to capitalize on improved wind conditions at higher elevations;
- advanced computational tools to improve the reliability of aeroelastic simulations of wind energy systems; and
- advanced control systems and blade sensors to improve performance and reliability under a wide variety of wind conditions.

Wind energy forecasting is another important area of concern identified in the AWEA plan and by producers and users of relevant data provided by the National Weather Service. Current observational networks in the U.S. are relatively sparse and widely spaced for the purposes of forecasting for wind energy activities. These networks emphasize data collection at a height of 10m or less above the surface compared to today's typical wind turbine hub height of roughly 80m. This makes it difficult to detect and forecast weather events such as large wind speeds over short time periods. In addition, collaborative field and computational modeling research is considered necessary in strategic areas of the country to better detect and forecast complex flow regimes that lead to unexpected turbine outages, long-term turbine performance issues, and wind forecasting errors.

New Directions for Solar Technology Development

Solar energy constitutes the largest global energy resource. Currently the Bureau of Land Management (BLM) has 158 active solar applications, covering 1.8 million acres with a projected capacity to generate 97,000 megawatts of electricity on the public lands that have been fast-tracked for renewable energy development in six western states. These BLM solar projects could provide the equivalent of 29 percent of the Nation's household electricity use. In addition, the United States Geological Survey (USGS) estimates that 48 percent of freshwater withdrawals in 2000 were used for electric power generation. The combination of life-cycle analysis of carbon emissions with this land and water usage data has resulted in a boom in the growth of applications for solar energy projects on public and private lands and on residential, commercial, and municipal sites. An array of solar technologies are currently available for use in lighting, heating, and cooling (air or water) as well as to generate electricity on a wide range of scales from the residential level to utility-scale installations.

The solar industry faces a number of challenges to achieving a significant, stable domestic energy supply for U.S. consumers while meeting greenhouse gas emission reduction targets. Reaching these goals will require the coordination of the solar research and manufacturing supply chains. The U.S. solar industry faces a number of barriers to entry in energy markets. Utilities are justifiably risk-averse and need access to best practices and expertise in order to efficiently integrate solar loads especially in urban areas. Some examples of this were identified in the April 2009 NREL publication: *Photovoltaic Systems Interconnected onto Secondary Network Distribution Systems—Success Stories.* In addition, there are additional opportunities for the solar manufacturing industry to make large gains through technological advancement.

The United States has a long history of leadership in solar energy technology, in part due to development of photovoltaic technologies for space applications. However, in recent years other nations have come to dominate the solar market through aggressive policy and favorable market conditions. Spain and Germany installed the largest amounts of solar energy capacity in 2007 and 2008. And China, Korea, and Taiwan continue to show significant growth in photovoltaic manufacturing capacity.

To help accelerate the widespread deployment of solar technologies in the U.S., the Administration recently dedicated $117 million in Recovery Act funds to projects administered by the DOE solar program. This program currently has a base annual budget of roughly $200 million.

In reviewing ways to support the long-term growth of a domestic solar manufacturing industry the semiconductor industry may provide a model for partnership on R&D between government and the private sector.

In the case of semiconductors, in the mid-1980s the U.S.—and the Department of Defense in particular—became concerned that Japanese semiconductor manufacturers were limiting access to semiconductor chips for two years or longer, delaying or halting the progress of technological advancement. In order to protect its strategic interest in advancing electronics the U.S. opted to support the growth of a domestic semiconductor industry through support for a semiconductor manufacturing technology research consortium. Sematech which still exists today was created along with a National Technology Roadmap for Semiconductors.

These two activities brought together key players within the industry, from semiconductor manufacturers to manufacturing equipment builders and members of the semiconductor materials supply chain. This model of coordination and collaboration helped to keep the technology moving forward at a quick pace, encouraged the industry to adopt cost and time-saving standards, and helped to eliminate the duplication of research efforts on pre-competitive technologies through communication and coordination. The U.S. continues to host some of the world's most prominent semiconductor companies including Intel, AMD, National Semiconductor, and Texas Instruments.

By 1994, the U.S. semiconductor industry had grown considerably and expanded its share of the world market for these products. The membership of Sematech voted to end federal matching funds for its activities in that same year and all federal funding for Sematech ended in 1996. During that same time period, Sematech expanded its membership to include non-U.S. manufacturers and it continues to serve the industry as a global consortium supporting collaborative research.

In late April 2009, the National Academies organized a meeting on "The Future of Photovoltaic Manufacturing in the U.S." At this meeting a large number of industry players including DuPont, Dow Corning, FirstSolar, SunPower, Applied Materials, and IBM expressed the view that the photovoltaic industry needed to develop a comprehensive R&D agenda in order to grow the industry. They also suggested the government could facilitate these activities.

While there are American solar companies that have emerged as strong players in the world solar market, they do not have the resources to individually support long-term research, development, and commercial application of new solar technologies while sustaining rapid growth and expanding production capacity. A jointly-developed comprehensive solar technology plan with public and private support may provide a framework for strengthening U.S. leadership in renewable energy technology.

Chairman BAIRD. I think our witnesses will be joined shortly by additional Members who will be coming from the vote. Our hearing will now come to order. I want to welcome everyone to today's hearing on *New Roadmaps for Wind and Solar Research and Development.* One moment, please. I heard Mr. Inglis was coming, and I had to pause because I know he hates to miss opening statements, they being so important.

Today's hearing will explore research and development needs for both wind and solar energy technologies. The U.S. has great potential for expanding the use of both renewable energy resources. According to a study by the Pacific Northwest National Laboratory, accessible wind potential in just 12 states could power the entire country twice over. Lawrence Berkeley National Lab has also shown that if we covered just one-fourth of one percent of the total U.S. land area with currently available solar panels, we could meet all of our nation's energy needs.

In order to realize this potential, however, considerable investments are required. We need a significant upgrade to our transmission grid and to move beyond fossil fuels and address the growing threat of climate disruption, our overheating and ocean acidification, these domestic energy options must receive additional support. Wind and solar technologies have progressed over the last several decades to a point where cost-competitiveness with fossil fuels is considered achievable, and paths toward this goal can be laid out in detail.

Today we will hear from an excellent panel of witnesses on the concrete steps government and the private sector can take to overcome the technical and economic barriers that wind and solar still face in the U.S. We will also receive testimony on H.R. 3165, the *Wind Energy Research and Development Act of 2009.* The bill was recently introduced by our friend and colleague, Mr. Tonko, to establish a more comprehensive research, development, and demonstration program at the Department of Energy. I believe this bill goes a long way toward helping wind power reach its full potential.

I thank the witnesses for appearing before the Subcommittee this afternoon.

With that I yield to our distinguished Ranking Member, Mr. Inglis.

[The prepared statement of Chairman Baird follows:]

PREPARED STATEMENT OF CHAIRMAN BRIAN BAIRD

Today's hearing will explore research and development needs for both wind and solar energy technologies. The U.S. has great potential for expanding the use of renewable energy resources. According to a study by the Pacific Northwest National Laboratory, the accessible wind potential in just 12 states could power the entire country twice over. Lawrence Berkeley National Lab has also shown that if we covered just one quarter of one percent of total U.S. land area with currently available solar panels, we could meet all of our energy needs.

In order to realize this potential, considerable investments are required. We need a significant upgrade to our transmission grid and substantial investments in new generation equipment. However, if we are to move beyond fossil fuels and address the growing threat of climate disruption and ocean acidification, these domestic energy options must receive additional support. Wind and solar technologies have progressed over the last several decades to a point where cost-competitiveness with fossil fuels is considered achievable and paths toward this goal can be laid out in detail.

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I thank the witnesses for appearing before the Subcommittee this afternoon. With that I yield to our distinguished Ranking Member, Mr. Inglis.

Mr. INGLIS. Thank you, Mr. Chairman, and thank you for holding this hearing. South Carolina, like much of the country, is suffering in this economic downturn. Our unemployment rate is at an all-time high of 12.1 percent. Thankfully though, General Electric's turbine facility is helping to cushion the impact in the upstate of South Carolina where about 1,500 engineers and 1,500 production employees are designing and building wind turbines and advanced gas turbines.

Doubling worldwide production of wind energy will generate $100 billion in sales for the wind industry. So I am very excited about improving the domestic wind energy industry.

The United States was an early leader in photovoltaic power in large part due to our robust space technology. Government policy and strong market signals have since increased solar energy installation and manufacturing capacity in other nations, and we have fallen behind. American companies are poised, though, to reclaim leadership in renewable energy technology and revitalize our economy through innovation. Well-focused research dollars can support long-term research to keep us ahead of the development curve and can spur opportunity and growth in the private sector.

The renewable electricity industry faces a number of important research topics. Wind energy in particular will improve through wind forecasting capacities, increased turbine efficiency and reduced capital costs, all of which will make wind farms easier to site and cheaper to build and operate.

Both wind and solar energy face a hurdle in terms of reliability. Energy storage systems that convert intermittent renewable capacity into base-load power source will be necessary to move beyond our dependence on fossil fuel energy.

Once we have addressed these obstacles, we are still left with the aging and inefficient electricity grid geared to centralized generation of conventional power plants. I am glad we will have a chance to address that critical challenge in our next Subcommittee hearing.

I am looking forward to hearing from these witnesses, Mr. Chairman, about ways to reshape and properly focus our renewable energy research dollars, and I thank you again for holding the hearing.

[The prepared statement of Mr. Inglis follows:]

PREPARED STATEMENT OF REPRESENTATIVE BOB INGLIS

Good morning and thank you for holding this hearing, Mr. Chairman.

South Carolina is suffering a great deal in this economic downturn. Our unemployment rate is at an all time high of 12.1 percent. Thankfully, General Electric's turbine facility is helping to cushion the impact in Greenville where about 1,500 engineers and 1,500 production employees are designing and building advanced gas and wind turbines. Doubling worldwide production of wind energy will generate

$100 billion in sales for the industry, so I'm very excited about improving the domestic wind energy industry.

The U.S. was an early leader in photovoltaic power, in large part due to our robust space technology industry. Government policy and strong market signals have since increased solar energy installation and manufacturing capacity in other nations, as we fall behind.

American companies are poised to reclaim leadership in renewable energy technology and revitalize our economy through innovation. Well focused research dollars can support long-term research to keep us ahead of the development curve, and can spur opportunity and growth in the private sector.

The renewable electricity industry faces a number of important research topics. Wind energy in particular will improve through wind forecasting capability, increased; turbine efficiency, and reduced capital costs, all of which will make wind farms easier to site and cheaper to build and operate. Both wind and solar energy face a hurdle in terms of reliability; energy storage solutions that convert intermittent renewable capacity into a base load power source will be necessary to move beyond our dependence on fossil fuel energy.

Once we've addressed these obstacles, we're still left with an aging and inefficient electricity grid geared to centralized generation at conventional power plants. I'm glad we'll have a chance to address critical challenges in electricity delivery at our next Subcommittee hearing.

I'm looking forward to hearing from the witnesses about ways to reshape and properly focus our renewable energy research dollars. Thank you again for holding this hearing, Mr. Chairman.

Chairman BAIRD. I thank Mr. Inglis. If there are other Members who wish to submit additional opening statements, your statements will be added to the record at this point.

[The prepared statement of Mr. Costello follows:]

PREPARED STATEMENT OF REPRESENTATIVE JERRY F. COSTELLO

Good afternoon. Thank you, Mr. Chairman, for holding today's hearing to examine research and development programs in wind and solar energy and to receive testimony on H.R. 3165, a bill to develop a wind energy research, development, and demonstration program.

Wind and solar energy have potential to provide abundant, clean energy for the country and increase our energy independence. The Department of Energy (DOE) estimates wind energy has the potential to provide two times our energy needs, and the Bureau of Land Management estimates that 29 percent of household energy needs could be met by solar projects. There still remain research, development, and demonstration efforts to guide the next steps to reach the full potential of these energy sources. For example, Illinois is the 16th largest sources of wind energy in the country. Technology to utilize this resource would provide substantial energy to the state and the region. I look forward to hearing from our witnesses on how the DOE and other agencies can collaborate with the private sector, academic institutions, and State and local governments to support wind and solar energy projects.

In particular, I am interested in hearing how the U.S. can retain its position as the leading producer of wind and solar energy. Though the U.S. once led the world in the development and deployment of solar technology, our international counterparts have made substantial investments in photovoltaic technology. The DOE solar program received $117 million in Recovery Act funding for deployment of solar energy technology. While this funding will go a long way towards improving our solar energy research efforts, I would like to hear from our witnesses today how Congress can continue to support their efforts to return the U.S. to its leadership role in solar technology and to maintain our leadership position in wind energy technology.

I welcome our panel of witnesses, and I look forward to their testimony. Thank you again, Mr. Chairman.

Chairman BAIRD. It is my pleasure to introduce our witnesses at this time. Mr. Steve Lockard is CEO of TPI Composites and Co-Chairman of the American Wind Energy Association, AWEA, Research and Development Committee. Mr. Ken Zweibel, I am reminded here by my staff, rhymes with Bible. Thank you, staff. He is the Director of George Washington University's Solar Institute. Ms. Nancy Bacon, a famous name in science—Francis Bacon, of course, would be an apt quote to put up on one side or the other, probably that side would be safer—is a Senior Advisor for United Solar Ovonic and Energy Conversion Devices, Inc. I will at this point yield to my distinguished colleague, Mr. Tonko, to introduce our witness from Albany, New York.

Mr. TONKO. Thank you, Mr. Chairman. It is a pleasure to introduce a constituent from the capital region of New York, John Saintcross. John is the Program Manager of Energy and Environmental Markets at New York State's Energy Research and Development Authority, or NYSERDA. He is currently responsible for managing the centralized procurement of renewable resources under the renewable portfolio standard in New York and the auctions and sales of allowances under the Regional Greenhouse Gas Initiative and Clean Air Interstate Rule programs. Mr. Saintcross is a member of New York State's Nuclear Assessment and Evaluation Team which is responsible for conducting evaluations of physical reactor plant conditions and plant personnel responses to unusual or emergency reactor and other plant system events.

Before assuming these current responsibilities at NYSERDA, John managed various renewable technology product development and deployment activities including those associated with the development of green power markets. He was the Director of Resource Portfolio Management for Green Mountain Power Corporation where his responsibilities included the development of renewable and distributed power technologies, integrated generation and demand planning, and power contract delivery and trading.

He also led the effort working with Electric Power Research Institute and the Department of Energy to develop one of the Nation's first utility-owned wind projects for the testing of large-scale, pre-commercial turbines located in Searsburg, Vermont, and I do want to welcome him here today and also speak to the issues of character because he's a great volunteer for Habitat for Humanity which I think says volumes for the crew at NYSERDA. Welcome, John.

Chairman BAIRD. Thank you, Mr. Tonko. I will yield to our other colleague, Mr. Neugebauer, to introduce his fellow Texan and our final witness.

Mr. NEUGEBAUER. Well, thank you, Mr. Chairman. It is my honor to be able to introduce a great educator, researcher, and leader in science and engineering, Dr. Andy Swift, who is the Director of the Wind Science and Engineering Research Center at Texas Tech which is home to America's only doctoral granting program in wind science engineering located in my District as well.

His previous employment included more than 20 years as Professor of Mechanical Engineering at University of Texas, El Paso, the last seven of which was the Dean of the College of Engineering. He completed his engineering graduate work obtaining a Doctor of Science Degree at Washington University at St. Louis where he began conducting research in wind turbine engineering with a focus on dynamics and aerodynamics of wind turbine rotors. Dr. Swift has worked in wind energy for over 25 years and has over 100 published articles and books and chapters in the area of wind turbine engineering and renewable energy. And in 1995, he received the American Wind Energy Society Academic Award for continuing contributions to wind energy technology as teacher, researcher and author. It is my privilege to welcome a true pioneer in renewable energy and a recognized leader in engineering of wind energy development, and I thank you, Mr. Chairman, for holding this hearing.

Chairman BAIRD. Thank you, Mr. Neugebauer. I should mention that we also are joined today by Dr. Bartlett and Dr. Ehlers. Dr. Ehlers?

Mr. EHLERS. Thank you, Mr. Chairman. Even though she doesn't live in my District, she does have a plant very close to my District, and I have to recognize Nancy Bacon. And the firm she represents has been far and away the leader in solar electric panels in the Nation. And they hired her because she can bring the bacon home. And so we are pleased to have her here, too. Thank you.

Chairman BAIRD. Thank you, Dr. Ehlers. We also have Ms. Edwards and Ms. Giffords, both outstanding Members of this committee as well. Thank you both for being here.

And with that, as our witnesses should know, you will have five minutes for your spoken testimony. Please do your best to keep around that. We try to be fairly rigorous on that. Your written testimony will be included in the record for the hearing. When you have completed your spoken testimony, we will begin with questions. Each Member will have five minutes to question the witnesses after that point. We will start with Mr. Lockard. Please proceed.

STATEMENT OF MR. STEVEN C. LOCKARD, PRESIDENT AND CHIEF EXECUTIVE OFFICER, TPI COMPOSITES, INC.; CO-CHAIR, AMERICAN WIND ENERGY ASSOCIATION, RESEARCH & DEVELOPMENT COMMITTEE

Mr. LOCKARD. Good afternoon. Chairman Baird, Ranking Member Inglis, distinguished Members of this subcommittee, I appreciate the opportunity to testify before you today.

Our company, TPI Composites, is a manufacturer of large wind turbine blades for leading turbine makers including GE and Mitsubishi. We are headquartered in Scottsdale, Arizona. TPI operates wind-related factories in Rhode Island, Mexico, China, and most recently, Newton, Iowa.

In addition to my role with TPI, I also Co-Chairman the R&D Committee of the American Wind Energy Association, on whose behalf I am testifying today.

Before proceeding I would like to thank Congressman Tonko for sponsoring legislation to authorize a comprehensive research, development and demonstration program for wind energy. AWEA and TPI endorse this legislation and urge Members to support its passage. Representative Tonko's legislation authorizes wind energy R&D at a level that will allow the wind industry to significantly improve turbine reliability and reduce capital costs.

Combined with a strong national Renewable Electricity Standard and broader transmission cost-allocation, planning, and siting policies, greater R&D funding will increase wind energy production and lead to the creation of more high-paying jobs across our country.

Last year, at a time when most U.S. industries were shedding jobs, the wind industry added 35,000 jobs and deployed over 8,500 megawatts. This record growth amounted to more than 40 percent of the country's new electricity generating capacity in that year.

However, our job is far from complete. Wind power is still constrained by difficulties in market acceptance and needed improvements in cost, performance and reliability.

The $70 million approved by the House Appropriations Committee for wind energy R&D, combined with funds that will be provided through the *American Recovery and Reinvestment Act,* will finance a number of key wind industry priorities.

However, in order to fully address all of the key wind energy R&D and deployment challenges, a sustained annual budget of at least $200 million is needed.

The Department of Energy's 20 percent by 2030 wind report was released in 2008. The report assumes that capital costs be decreased by 10 percent and turbine efficiency increase by 15 percent to reach this achievable goal of providing 20 percent of our nation's electricity from wind.

Meeting this goal will require increased R&D funding. Meeting the 20 percent goal will provide a host of benefits, including supporting 500,000 jobs and generating over $1 trillion in economic impact by 2030, decreasing natural gas prices by approximately 12 percent, avoiding 825 million tons of CO_2 emissions in 2030, equivalent to 25 percent of the electric sector emissions, and reducing cumulative water consumption in the electric sector by 17 percent in 2030.

Increased R&D funding will bring down capital costs and increase turbine efficiency to help realize these benefits and keep America's wind industry competitive with other electric generation sources and the wind industries of other countries.

Last year, as part of an AWEA R&D Committee effort, a team of over 80 AWEA members and advisors from industry, government, and academic institutions worked over several months to develop a specific action plan and funding proposal to meet our 20 percent goal.

Participants determined that $217 million in annual federal funding, combined with $224 million annual industry and State cost share, would be necessary to support the R&D and related programs. The group determined that $201 million of the $217 million should be directed toward the DOE.

AWEA and the wind industry support funding for this action plan. AWEA also recognizes the need to reduce the cost of offshore energy, offshore energy technology to provide the estimated 54 gigawatts of the 300 gigawatts needed to meet the 20 percent goal by 2030.

AWEA recommends funding for programs that focus on the power system operations issues of integrating variable power sources, such as wind, into the electric grid. An important component of such integration includes developing and promoting advanced forecasting methods.

Another important research area is wind project siting including better understanding the impact of wind turbines on wildlife and radar installations and mitigating these impacts.

While the wind industry is continuing to add new electric generation capacity, a number of challenges still exist. Continued support for wind energy R&D is vital to helping wind become a more prominent energy source that leads to a host of benefits.

Continued investments in wind energy R&D are delivering value for taxpayers by fostering the development of a domestic energy source that strengthens our national security, provides economic development, spurs new high-tech jobs, and helps protect the environment.

Thank you, again, for the opportunity to testify. I'd welcome any questions.

[The prepared statement of Mr. Lockard follows:]

PREPARED STATEMENT OF STEVEN C. LOCKARD

Introduction

Good Afternoon. Chairman Baird, Ranking Member Inglis, and distinguished Members of the Subcommittee, I appreciate the opportunity to testify before you today.

My name is Steve Lockard. I am the CEO of TPI Composites. TPI is a manufacturer of rotor blades for leading wind turbine makers including GE Energy and Mitsubishi Power Systems. TPI operates wind-related factories in Rhode Island, Mexico, China, and Newton, Iowa.

In addition to my role with TPI, I also Co-Chairman the Research and Development Committee of the American Wind Energy Association, on whose behalf I am testifying.

Before proceeding I would like to thank Congressman Tonko for sponsoring legislation to authorize a comprehensive research, development, and demonstration program for wind energy.

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Combined with a strong national Renewable Electricity Standard; and broader transmission cost-allocation, planning, and siting policies; greater research and development funding for wind energy will increase wind energy production and lead to the creation of more high-paying jobs across the country.

The American Wind Industry Today

Last year, at a time when most U.S. industries were shedding jobs, the wind industry added 35,000 jobs and deployed over 8,500 megawatts (enough to serve the equivalent of more than 2.5 million homes nationwide).

This record growth amounted to more than 40 percent of the country's new electricity generating capacity.

Our job is far from complete. Wind power is still constrained by difficulties in market acceptance and needed improvements in cost, performance, and reliability.

In addition, research and development funding for wind energy has lagged behind funding levels for other energy technologies over the past few decades, which held back the growth of wind energy in the United States.

The $70 million approved by the House Appropriations Committee for wind energy R&D, combined with funds that will be provided through the *American Recovery and Reinvestment Act,* will finance a number of key wind industry priorities to help overcome the challenges to meet the 20 percent by 2030 vision.

However, in order to fully address all of the key wind energy research, development, and deployment challenges, a sustained annual budget of at least $200 million is needed.

Importance and Benefits of Wind Energy Research and Development

The Department of Energy's *20% Wind Energy by 2030* report was released in 2008. The report assumes that capital costs decrease by 10 percent and that turbine efficiency increases by 15 percent to reach the achievable goal of providing 20 percent of our nation's electricity from wind by 2030. That will require increased R&D funding.

Meeting the 20 percent goal will provide a host of benefits, including:

- Supporting 500,000 jobs and generating over $1 trillion in economic impact by 2030;
- Decreasing natural gas prices by approximately 12 percent;
- Avoiding 825 million tons of carbon dioxide emissions in 2030, equivalent to 25 percent of expected electric sector emissions, and;
- Reducing cumulative water consumption in the electric sector by 17 percent in 2030.

Increased research, development, and deployment funding will bring down capital costs and increase turbine efficiency to help realize these benefits and keep America's wind industry competitive with other electric generation sources and the wind industries in other countries.

Needed Funding Levels for Wind R&D

Last year, as part of an AWEA Research and Development Committee effort, a team of over 80 AWEA members and advisors from industry, government, and academic institutions worked over several months to develop a specific action plan and funding proposal to meet the goal of providing 20 percent of our nation's electricity from wind energy by 2030.

Participants determined that $217 million in annual federal funding, combined with a $224 million annual industry/state cost share, would be necessary to support the research, development, and related programs needed to meet the 20 percent goal. The group determined that $201 million should be directed to DOE.

AWEA and the wind industry support funding for wind turbine technology and reliability to develop wind turbine components that will reduce capital costs, improve performance, and enhance reliability.

AWEA also recognizes the need to reduce the cost of offshore wind energy technology to provide the estimated 54 gigawatts (GW) of the 300 GW needed to meet the 20 percent goal by 2030.

In addition, AWEA recommends greater federal funding for programs that focus on the power system operations issues of integrating variable power sources, such as wind, into the electric grid.

An important component of such integration includes developing and promoting advanced forecasting methods.

Another important research area is wind project siting. In general, increased funding in this area should be targeted toward better understanding the impact of wind turbines on wildlife and radar installations and mitigating these impacts.

Conclusion

While the wind industry is continuing to add new electric generation capacity, a number of challenges still exist. Continued support for wind energy R&D is vital to helping wind become a more prominent energy source that leads to a host of benefits.

Continued investments in wind energy R&D are delivering value for taxpayers by fostering the development of a domestic energy source that strengthens our national security, provides economic development, spurs new high-tech jobs, and helps protect the environment.

Thank you, again, for the opportunity to testify. I welcome any questions you may have.

BIOGRAPHY FOR STEVEN C. LOCKARD

Mr. Lockard joined TPI Composites in 1999 to lead their growth strategy and has transformed the Company from a recreational boat builder into a leading manufacturer of wind turbine blades. The Company is also a composites innovator in military and transportation markets. Mr. Lockard has 25 years of experience building high-growth, manufacturing companies. Prior to TPI, Mr. Lockard served as Vice President of Satloc, a supplier of precision GPS equipment. Prior to Satloc, Mr. Lockard served as Vice President and a founding officer of ADFlex Solutions, a leading international manufacturer of interconnect products for the electronics industry. Mr. Lockard holds a BS degree in Electrical Engineering from Arizona State University. He serves as Co-Chairman of the R&D committee for the American Wind Energy Association (AWEA) and has testified in front of Congress and the National Governor's Association on behalf of the wind industry.

Over the last seven years, TPI has created five composites manufacturing plants and over 2,800 jobs worldwide. With over one million square feet of manufacturing floor space, TPI operates factories in Rhode Island, Iowa, Ohio, Mexico and China.

The company is headquartered in Arizona. TPI wind customers include Mitsubishi Power Systems and GE Energy.

TPI's most recent wind blade factory opened in September, 2008 in Newton, Iowa. This town of 15,800 was the home of Maytag for over 100 years. TPI has already replaced 350 of the 1,800 lost Maytag manufacturing jobs.

Chairman BAIRD. Thank you, Mr. Lockard. Mr. Saintcross, please.

STATEMENT OF MR. JOHN SAINTCROSS, PROGRAM MANAGER, ENERGY AND ENVIRONMENTAL MARKETS, NEW YORK STATE ENERGY RESEARCH AND DEVELOPMENT AUTHORITY (NYSERDA)

Mr. SAINTCROSS. Chairman Baird, distinguished Members of the Subcommittee, good afternoon. My name is John Saintcross. I am the Program Manager, Energy and Environmental Markets, at the New York State Energy Research and Development Authority (NYSERDA).

Before I begin, I would also like to recognize Congressman Tonko on behalf of Governor David A. Paterson for his tireless efforts toward the advancement of clean energy.

NYSERDA is a public benefit corporation whose mission is to help grow the State's economy and improve its environment by partnering with business, industries and residents to invest in innovative and environmentally friendly renewable energy and energy efficient technologies.

Its annual budget of approximately $600 million is funded through multiple sources. NYSERDA currently administers a systems benefits charge based on a small surcharge on utility bills which is allocated toward energy efficiency programs and R&D development initiatives. Funding from the renewable portfolio standard (RPS) is also a critical part of what we do to lessen our heavy dependence in New York on fossil fuels and reduce harmful air emissions.

In addition, NYSERDA expects to realize additional funding for related research through its participation in the regional greenhouse gas initiative carbon cap-and-trade program. NYSERDA will also be implementing Governor Paterson's "45 by '15" initiative, the most ambitious clean energy program in the Nation which requires that by 2015, 30 percent of New York's energy will be supplied by renewable resources and 15 percent from energy efficiency.

NYSERDA commends this committee for taking up the issue of wind technology performance and improvement to apply in transformational research and demonstration. NYSERDA is here today to speak to the promise of wind energy and related technology challenges from two perspectives, the first as a user of the technology to satisfy State policy goals and second as an entity committed to the pursuit of technological advancement for clean energy resources.

As an administrator of the RPS program in New York, NYSERDA acts as a user of the technology by centrally procuring on a competitive basis the generation of electric energy and qualified renewable resources such as wind power. On the State's installed wind generation of 1,275 megawatts, about 1,100 megawatts are supported through the RPS program. By the end of 2009, the state is expected to have satisfied 30 percent of its renewable energy targets. Wind energy represents over 90 percent of the energy associated with this program. The State of New York is counting on wind project performance and reliability to satisfy statewide goals.

The American Wind Energy Association (AWEA) has clearly identified gaps in research that, left unattended, could prevent the Nation from realizing the full potential of its abundant wind resources. NYSERDA believes these challenges are manageable and not unlike challenges other technologies face. The evolution from scientific research and analysis progressing to product and material development, product demonstration and validation, analysis of commercial feasibility, and ultimately to operating practices and codes remains a continuum of integrated activities. It is along this continuum where NYSERDA makes its home. NYSERDA is committed to working with the private sector and institutions of higher learning and the Federal Government to characterize challenges along this continuum and collaborating where appropriate to overcome them.

New York is unique in that wind technology will be asked to perform capably on two frontiers, on land and offshore. NYSERDA believes in a research agenda that addresses technology needs on both frontiers yet sees a pressing need to increase the focus of collective energies toward offshore development. NYSERDA believes increased sophistication and computational modeling of wind resources, fluid flow and turbulence within turbine arrays will be of near-term benefit to New York and the Nation as they pursue ambitious environmental goals, and as such models are extended offshore, such benefits will only grow.

For offshore application, current wind fluid dynamic modeling will need to be extended to the simulation of water and wave motion so that turbines can be designed accordingly and operate reliably. Advances in the development of energy storage technologies that could store wind energy and release it to the electric grid when demanded would help the state offer similar benefits to other regions in the Nation. New York has made a great stride forward in this regard by spearheading a battery energy storage technology consortium that will capitalize on the state's existing technical and industrial capabilities and advance New York's clean energy and storage technology industries.

The predominant turbine design in use in the United States is not suited for application offshore. It is widely accepted that turbines for offshore use will be larger, on the order of two to four times the scale now in use for land-based turbines. To migrate to such scale and develop a turbine designed specifically for the offshore operating environment will require a bold effort in engineering, prototyping, testing and manufacturing.

In closing, NYSERDA, as a user of wind technology to satisfy New York climate goals, and as a science-based research organization focused on the development and commercialization of clean energy technologies, strongly encourages the Committee to consider substantially increasing federal funding for wind technology research and development.

I thank you again for the opportunity to share our views on this important subject. I would be pleased to answer any questions you have.

[The prepared statement of Mr. Saintcross follows:]

PREPARED STATEMENT OF JOHN SAINTCROSS

Good afternoon, my name is John Saintcross. I am the Program Manager, Energy and Environmental Markets at the New York State Energy Research and Development Authority (NYSERDA). In this position, I am responsible for the centralized procurement of renewable resources under the Renewable Portfolio Standard in New York and the auction/sale of allowances under the Regional Greenhouse Gas Initiative and Clean Air Interstate Rule Program. There is the potential in my program area for launching a new Advanced Renewable Energy Program aimed at building a pipeline of diverse, promising renewable energy technologies that will enable achievement of New York State's long-term climate protection objectives. The legislation we are discussing today is highly relevant to the types of activities such a program might support.

The Energy and Environmental Markets Program is one of four program areas managed under NYSERDA's Clean Energy Research and Market Development organization. Some other program activities relevant to today's discussion include an environmental evaluation and monitoring program engaged with the industry in the objective measurement and analysis of the impacts on wildlife from wind energy and competing power generating resources, a clean energy technology manufacturing incentive program that supports manufacturing process development, product manufacturing, and ongoing product innovation, and the development of a new university/industry research collaborative to expand New York State capabilities in the clean energy sector. With respect to this later initiative, our initial focus will be split between the development of financially sustainable test centers in New York that will provide testing services for photovoltaics and small wind turbines during product development, final system testing for certification purposes and the creation of a battery storage consortium that will capitalize on the state's existing technical and industrial capabilities to advance New York's clean energy and storage technology industries. Because a trained workforce is essential to ensure New York has the capacity to implement and sustain the state's renewable energy initiatives, NYSERDA, in partnership with other State agencies, is developing a network of renewable energy training facilities across the state that will better prepare the state's workforce to analyze, design, sell, install, service, and maintain renewable energy technologies and systems. Currently, one institution of higher learning is offering curricula specific to wind turbine technology and similar programs are under development at another six facilities.

NYSERDA is a public benefit corporation created in 1975 through the reconstitution of the New York State Atomic and Space Development Authority. NYSERDA's earliest efforts focused solely on research and development with the goal of reducing the state's petroleum consumption. Subsequent research and development projects focused on topics including environmental effects of energy consumption, development of renewable resources, and advancement of innovative technologies. NYSERDA strives to facilitate change through the widespread development and use of innovative technologies to improve the state's energy, economic, and environmental well-being. NYSERDA's workforce reflects its public service orientation, placing a premium on objective analysis and collaboration, as well as reaching out to solicit multiple perspectives and share information. NYSERDA is committed to public service, striving to be a model of efficiency and effectiveness, while remaining flexible and responsive to its customers' needs.

NYSERDA's programs and services provide a vehicle for the State of New York to work collaboratively with businesses, academia, industry, the Federal Government, environmental community, public interest groups, and energy market participants. Through these collaborations, NYSERDA seeks to develop a diversified energy supply portfolio, improve energy market mechanisms, and facilitate the introduction and adoption of advanced energy and environmental technologies.

The NYSERDA annual budget of approximately $600,000,000 is funded through multiple sources. NYSERDA currently administers the System Benefits Charge (SBC) from a small surcharge on an electricity customers' utility bill that is allocated toward energy-efficiency programs, research and development initiatives and other energy programs. Funding for the Renewable Portfolio Standard (RPS) is also a critical part of what we do to lessen our heavy dependence on fossil fuels and reduce harmful air emissions.

NYSERDA commends the Committee for taking up the issue of wind technology development, performance and improvement through applied and transformational research and demonstration. Recent passage in the House of the *American Clean Energy and Security Act* (H.R. 2454) and the recent movement of Senate bill S. 433 out of the Senate Committee on Energy and Natural Resources signal an increasing awareness that national energy policy is approaching a crossroads. A strong federal commitment to renewable energy, energy efficiency and other climate protection strategies could become common practice. NYSERDA recognizes the significance of this legislation and respects the debate ensuing over how the Nation should best migrate toward a cleaner future.

NYSERDA is here before you today to speak to the promise of wind energy and related technology challenges from two perspectives; the first, as a user of the technology to satisfy State policy goals and second, as an entity committed to the pursuit of technological advancement and maturity for clean energy resources. NYSERDA, as the administrator of the New York Renewable Portfolio Standard (RPS) program on behalf of the New York State Public Service Commission, acts as a user of the technology. In this role, NYSERDA centrally procures, on a competitive basis, the economic and environmental improvements associated with the generation of electric energy from qualified renewable resources, such as wind power. The current program goal established in 2004 is to increase the percentage of renewable electric energy sold to New York consumers to at least 25 percent by 2013. However, Governor Paterson's 2009 State-of-the-State message to the New York State Legislature pledged to meet 45 percent of New York's electricity needs through expanded energy efficiency and clean renewable energy goals by 2015, the most ambitious clean energy program in the Nation. As part of this initiative, the Governor requested that the Public Service Commission consider increasing the percentage of renewable electric energy sold in New York to 30 percent by 2015.

NYSERDA has conducted three procurements for large scale, grid-connected generation under the RPS program. Of the state's installed wind generation of 1,275 megawatts, approximately 1,100 megawatts are being delivered to consumers through RPS program contracts with NYSERDA. Currently, there are over 8,000 megawatts of wind capacity awaiting interconnection agreements with the New York Independent System Operator. Interestingly, according to the Department of Energy (DOE) Study, *20% Wind Energy by 2030,* New York's contribution to the national goal would translate into 1,000 to 5,000 megawatts of installed wind capacity in the state by 2030. Clearly, New York's goals are quite ambitious, as the state has already installed over a quarter of the maximum expected by the study. The RPS program has been in effect for only a few years and to meet State goals, additional installed wind capacity is highly probable. Administration of that segment of the RPS program aimed at supporting smaller distributed renewable technologies such as small wind, photovoltaics and farm waste digester gas-to-electric resources, all located behind the retail meter, is expected to result in about 30 MW of installed photovoltaic capacity alone. In total, by the end of 2009 the state is expected to have satisfied 30 percent of its renewable energy targets and expects to realize direct economic benefits approaching two billion dollars over the lifetime of the affected technologies. Wind energy represents over 90 percent of the energy associated with program activity to date and the State of New York is counting on wind project performance and reliability to satisfy statewide program goals. Noting recent activity in the House and in the Senate with respect to a federal renewable energy standard, it becomes clear that New York will not be alone in its reliance on increased performance and reliability of wind technology.

The progress this technology has made in the last decade should be recognized. However, any vision that has wind power playing a more prominent role in the Nation's energy mix must include a plan for increased support that would encompass applied wind research, development and demonstration to ensure continued improvement in technology performance and reliability.

NYSERDA, in administering the RPS program pays only for performance that translates into energy delivered and no funds are expended if energy is not produced. However, there is no comfort in under-performance. Lagging performance translates into deferred progress in meeting New York State environmental and energy security goals and potentially reduced consumer confidence in the technology. While New York has seen its success as described earlier in this testimony, progress toward renewable energy goals has been deferred as well. If it were not for under-performance by one large wind farm, New York would be at 32 percent of its RPS targets rather than at 30 percent. I would like to say unambiguously why this particular project under-performed but it is difficult to identify the root cause for less than expected production. NYSERDA is generally aware that the industry is earnestly working to understand completely why overall capacity factors have lagged expectations. In competitive energy markets such as that employed in New York where generators of all types vie to sell their energy to end-users, information on turbine failure or under-performance in general is considered sensitive. This complicates the process of learning of the specific challenges the turbine(s) may be facing and targeting research accordingly. In the case of newer wind projects, component failures are covered by warranty guarantees, and only the manufacturer has knowledge of root causes during the warranty period.

For the past couple of years, the industry has debated the underlying reasons for under-performance and as the hearing charter makes clear, the American Wind Energy Association has identified gaps in research that could prevent the Nation from realizing the value from its abundant wind resources. While experience with the technology is limited in New York because of the early stage of deployment under the RPS program, NYSERDA is no stranger to these issues. Similar questions regarding historical performance and technological evolution were discussed by stakeholders in a DOE-sponsored wind technology program budget meeting in 2008 in which NYSERDA participated. Similar issues surfaced again in a recent symposium in New York where researchers presented views on industry trends, experiences and challenges.

Let me offer the following observations in regard to several challenges faced by the industry, based on NYSERDA experience and engagement with industry and university researchers. European experience shows that the mean time to failure for key turbine components such as gear boxes, main bearings, generators and rotor blades can be less than 10 years for a technology that was designed to have a life of 20 years. NYSERDA learned of a replacement of gear boxes for one make of turbines in New York after less than two years of operation. In addition, experience with off-shore technology in Europe indicates that computational modeling of wind flow at project boundaries and within turbine fields could be better refined as actual experience often departs from that which was predicted. Such refinement will be essential to improving turbine design because inaccurate estimation of turbine component loading will keep the industry from achieving cost and performance goals and hinder the design of new and larger turbine components. While the industry strives to increase turbine size and energy capture, the costs of land-transport of turbine components may become prohibitive. In-situ (on-site) fabrication of turbine towers and rotor blades may need to be considered as components grow larger. In-situ fabrication could require the development of new blade materials and blade fabrication processes that are robust enough for less-clean and uncontrolled site environmental conditions. Increased energy capture will translate in the need for longer blades and redesigned blade structures to manage greater stresses. Added stress on blades must be accommodated by the drive trains. Design validation of larger turbines will require new testing equipment. For instance, the magnitude of torque that must be applied to these large drive trains for testing is among the largest for any rotating piece of equipment. To meet operating and maintenance cost reduction goals, the industry will need to develop and deploy advanced condition monitoring devices to signal impending failure/performance degradation so maintenance can be performed on a preventive basis, rather than in reaction to unscheduled turbine outages. Increased reliance on the technology will place greater pressure on the turbine component supply chain. Increasing the number of component suppliers is desirable over the long-term but the pace of development must be managed in order to preclude degradation in materials and fabrication process quality. These are just a few of the challenges that should keep the industry, universities, laboratories and organizations, such as NYSERDA, busy.

NYSERDA believes these challenges are manageable and not unlike challenges other technologies face. The evolution from scientific research and analysis progressing toward product and material development, product demonstration and validation, analysis of commercial feasibility and ultimately to operating practices and codes, remains a continuum of integrated activities. It is along this continuum where NYSERDA makes its home. As an organization that for over three decades has committed itself to objective research and development, NYSERDA is committed to working with the private sector, institutions of higher learning and the Federal Government to characterize challenges along this continuum and collaborating where appropriate to overcome them.

By example, with respect to wind energy technology, NYSERDA supported early large and small turbine project demonstrations starting in the late 1990s, and developed early stage wind resource estimation/site prospecting programs. These NYSERDA funded activities leveraged private capital to foster the development of a pipeline of wind projects and developable site areas. NYSERDA assisted one firm in the development of state-of-the-art wind resource estimation models, resulting in the commercial release of a web-based resource estimation service for wind developers that is now in wide use. NYSERDA is now working with this same commercial enterprise to develop a diagnostic software tool for wind plant operators. This tool will be able to manipulate the significant quantity of environmental and operating data associated with a turbine and signal potential component problems in advance of failure, thereby triggering the execution of preventive measures by plant operators. NYSERDA is currently partnered with other public and private sector organizations in a collaborative that will explore the development of an off-shore ocean wind project in New York. As a member of the collaborative, NYSERDA is currently providing technical services to the membership as they engage with parties interested in developing such a project. NYSERDA expects to work with collaborative members and private sector interests to identify challenges to project development and costs that could benefit from research and development activities that NYSERDA and other parties would fund. Such research could benefit greatly from co-funding from an increased federal wind technology budget as proposed in the legislation *"Wind Energy Research and Development Act of 2009"* being considered by the Committee.

With respect to a federal vision for renewable energy and the hope of decreasing the pace of climate change, and for states such as New York, that share that vision, NYSERDA cannot state emphatically enough that greater emphasis on wind research and development is essential. Increased federal support for collaborative research between the private sector, laboratories, universities and public benefit organizations such as NYSERDA, could not come at a more critical time. If the promise of wind energy is to be realized over the long-run in pursuit of aggressive climate goals, solutions to the technology challenges we speak of today must also be aggressively pursued.

NYSERDA, in administering the New York RPS, will respect the interests of private power producers and equipment suppliers to manage the technology and satisfy the due-diligence requirements of the investment community. However, to the extent the technology is called upon to produce a far greater share of the Nation's energy, there is risk it may not deliver completely on the promise without further investment in research and development including field demonstration.

New York is unique in that the application for wind technology will be on two frontiers: land-based and off-shore, either in the Great Lakes or the ocean. NYSERDA believes in a research agenda that addresses needs on both of these frontiers yet expresses a need to increase the focus of our collective energies toward off-shore development.

New York could benefit from this new legislation and the funding associated therewith in many ways, but I will only speak to several in this testimony. As stated earlier, New York is already home to nearly 1,300 megawatts of land-based wind capacity that is situated some distance from load centers. Energy production is not coincident with demands in the large load centers in New York. To make progress towards its renewable goals, New York will likely see a significant increase in similar land-based development over the next five years. Advances in the development of energy storage technologies, that could store wind generated energy and release it to the electric grid when demanded, would help the state and offer similar benefits to other regions in the Nation.

Advances in diagnostic tools are necessary to allow operators to proactively respond to problems and reduce unscheduled outages. Wind projects in New York are situated on complex terrain, and the current state of resource modeling as such relates to turbine micro-siting, plant layout and turbine structural loading could stand improvement.

In addition to renewed interest in advancing the state of wind technology for on-shore turbines, New York believes that the focus of wind research should shift to turbines situated in the ocean or the Great Lakes that share its border. Such a shift in direction will bring new challenges. It has become generally recognized that computational modeling of wind resources and fluid flow within turbine arrays must become more sophisticated. Offshore wind array performance is very sensitive to atmospheric boundary layer stability, which tends to vary temporally at a given site. Current array models need to be improved as they do not adequately represent these stability effects. Better models are needed to predict the impact of turbulence inside the wind plant. Accurate characterization of atmospheric behavior and more accurate wake models will be essential to understand and design turbines to withstand wind plant turbulence. To the extent these advanced computational capabilities result in turbines being sited more appropriately and, once installed, operating more efficiently and reliably, the costs to consumers in New York and across the Nation will decrease. Improvements in this regard will benefit both on and off-shore turbine applications.

The challenges of measuring and verifying the wind resource in expansive off-shore tracts is great. Conventional practices in Europe involve the installation of a fixed meteorological mast with a pier-type foundation driven into the seabed. Such structures cost at least several million dollars to install, with costs a function of water depth and maximum wave height. Across large project areas, more than one tower may be needed to document the spatial resolution of the resource. Alternatives to fixed towers include the use of surface-based remote sensing technologies such as LIDAR, which can be mounted on stub masts or possibly on spar buoys, and floating towers that are relatively stable because they are tethered to the seabed. These alternatives show great promise but require further field testing and validation before being widely accepted as "bankable" data monitoring approaches by developers, investors, and lenders.

The predominant turbine design in use in the United States is not suited for application off-shore. It is widely accepted that turbines for off-shore use will be larger on the order of two to four times the scale now in use for land-based turbines. There is strong interest in using such turbines in the Great Plains as well. Public opposition or sensitivity to the physical scale and increased aerodynamic sound from larger blade rotation may pose less of a problem when siting in places in the midsection of the country where population density is not great. Migrating to such scale for on-shore application and designing a turbine specifically suited for the off-shore operating environment will require a bold effort in engineering, prototyping, testing and manufacturing.

New York could benefit from these and other research activities described in the work of the American Wind Energy Association Offshore Wind Working Group that is attached for reference.[1] For off-shore development to move forward and performance of land-based turbines to be improved, NYSERDA believes that State-funded research in this arena needs to be significantly leveraged with federal funding that is of material scale and duration as proposed in the legislation before the Committee.

In closing, NYSERDA, as a user of wind technology to satisfy New York climate goals and as a science-based, research organization focused on the development and commercialization of clean energy technologies, strongly encourages the Committees to consider substantially increasing federal funding for wind technology research and development. NYSERDA has a history of collaborating with the Department of Energy, its laboratories, institutions of higher learning and the private sector on research, and would welcome the opportunity to continue this relationship in support of achieving ambitious but necessary climate change and energy independence goals.

[1] Research and Development Needs for Offshore Wind, R&D Subcommittee, Offshore Wind Working Group, American Wind Energy Association, April 2009.

Research and Development Needs for Offshore Wind

AMERICAN WIND ENERGY ASSOCIATION
OFFSHORE WIND WORKING GROUP

APRIL 3, 2009

R&D Subcommittee Chairman:
Willett Kempton—U. of Delaware, willett@udel.edu

Subcommittee Members:
Peter Mandelstam—Bluewater Wind
Michael Mercurio—Island Wind Power
Walt Musial—National Renewable Energy Laboratory
Greg Watson—Massachusetts Technology Collaborative
John Ulliman—American Superconductor
Susan Stewart—Penn State

Subcommittee Advisors:
Ed Demeo—Renewable Energy Consulting Services, Inc.
Soren Peterson—Rambol Engineering
Steve Lockard—TPI Composites
J. Charles Smith—Utility Wind Integration Group

Introduction

Rationale: This report summarizes the findings from the Offshore Wind Working Group (OWWG) Subcommittee on Research and Development (R&D). The largest and most energy-intensive area of the United States, the Northeast and Mid-Atlantic coastal states, is far from large terrestrial wind resources such as the Great Plains. Fast growing population centers in the southeastern U.S. are also much farther from terrestrial wind resources than to potential offshore wind resources. The Gulf and West coasts similarly have large loads closer to the ocean than to large terrestrial wind resources. To reach 20 percent wind integration, as laid out in the Department of Energy's *20% Wind Energy by 2030* report, the offshore wind potential of the U.S. coasts will be important. Several projects along the East and Gulf coasts are already designed and moving through the permitting process. Nevertheless, levelized cost of electricity (LCE) is still higher than market in many areas. The R&D proposed here is designed to lower LCE, thereby leading to more widespread implementation—making the achievement of 20 percent wind integration more widespread regionally and not concentrated primarily in the heartland.

Process followed: In 2007, the OWWG created a document to outline the R&D needs of the offshore wind industry in the United States. The overall OWWG put forward suggestions for needed R&D and the Subcommittee additionally solicited suggestions from industry experts on offshore wind. The list was reviewed by the entire OWWG, resulting in edits and revisions. The Subcommittee and experts then rank ordered this list and combined related topics. The R&D efforts below ranked in the top half by priority and are roughly listed in priority order. The lower-ranked half is not reported here. Higher ranks were given each R&D suggestion that:

1. Is essential to begin and develop the offshore wind industry (note: the U.S. today has zero offshore turbines installed)
2. Will lead to new turbines, other components, or installation methods that are better, cheaper or more reliable, or bring such components to market more quickly
3. Will lead to lower levelized cost of energy
4. Is uniquely required by offshore wind energy
5. Would lead to commercial development, possibly by multiple firms
6. Will help the U.S. Federal Government, states, or communities make better decisions or reduce uncertainties regarding offshore wind
7. Begins long-term research that needs to be started now
8. Is unlikely to be done by companies on their own

9. Provides diversity—the entire list includes at least one of each of the following:

   shallow water
   transitional depth (25–60m depth)
   deep water (> 60m)

10. Affects large resource areas

Some of these R&D areas are described in more detail in *"A Framework for Offshore Wind Energy Development in the United States"* by the Offshore Wind Collaborative in Massachusetts, and we have drawn from that document for some R&D recommendations.

In March 2009, the same subcommittee was re-convened to update the list of R&D needs, and to estimate approximate budget and scheduling for the highest-ranked items on the list. In the fall of 2008, a team of over 80 AWEA members and advisors from industry, government and academic institutions identified $201 million as the DOE funding level that will be necessary to support the research and development and related programs needed to provide at least 20 percent of America's electricity from wind by 2030. This funding level includes $108 million for Wind Turbine Technology (components, reliability and offshore applications), with $15 million annually allocated specifically for offshore wind. In light of these cost allocations, the OWWG has created cost estimates for each of the following action items under a "blue sky" scenario.

Research and Development Priorities

The following R&D areas appear in the rank order developed by the Committee. R&D areas that were ranked at the halfway point or below are not shown.

1. Fundamental design evaluation for 5–10 MW offshore machines

The currently predominant turbine design has been optimized for land applications. Optimization for offshore removes or alters many design parameters. There is a need to develop a basic analysis of fundamentally different designs. For example, one of many possible outcomes could be that a viable 5–10 MW offshore machine might be two-bladed, downwind, mostly-passive yaw with a lattice tower. First phase of this effort would be extensive engineering analysis of fundamentally different design configurations, with publicly-owned intellectual property. Second phase begins prototyping, possibly with public-private partnerships and leading to commercial products. Note that there has not yet been a public commitment from any U.S. manufacturer for serial production of offshore-class turbines. The first development projects already in the pipeline will probably use marinized versions of land designs and draw on European experience. But for designs as described in this section, manufacturers may need support and/or incentives to begin the development of optimized ocean turbines.

1a. Highly experienced design teams should be commissioned to implement new design requirements that take into account relaxed constraints in the offshore environment, such as noise and esthetics. A first-cut design study should be done, including multi-turbine grids, downwind, two bladed rotors, passive yaw, high speed rotors, direct drive systems, etc., with competition between at least two design teams. This effort should produce guidance for subsequently building several fundamentally different prototypes by private firms, or public-private partnerships.

Optimized offshore turbines will likely favor larger sizes than are available today. New size-enabling technologies will be required to push wind turbines to the 5–10 MW size. These technologies include lightweight composite materials and composite manufacturing, lightweight drive trains, modular highly reliable direct drive generators, hybrid space frame towers and integrated gearboxes. Ultra-large turbines also present new opportunities that are not practical in smaller sizes. For example, control systems and sensors that monitor and diagnose turbine status and health do not grow in cost as turbine size increases, so larger turbines will enable a higher level of controls and condition-monitoring intelligence. Research is needed on control methods using innovative sensor and data processing technologies to mitigate turbine subsystem loads, to improve energy capture and to improve integration into the electric grid. New rotor technologies will include advanced materials, improved aero and structural design, active controls, passive controls, and higher tip speeds. Methods to enlarge the wind turbine rotor to increase the energy capture in ways that do not increase structural loads, cost, or electrical power equipment should be employed. Concepts such as active extendable rotors, bend twist coupled blades or more active control surfaces may become practical. Structural loads due to turbulence can be limited by using both passive and active controls on the longer blades. However, since gravity loads grow with the blade length cubed, one must seek technologies that offer higher material performance as blades grow. New materials and manufacturing processes are used to simultaneously reduce total blade weight for 10 MW turbine blades. Blade designers will have to consider the extremes of marine moisture and corrosion and the incidence of storm conditions unlike those encountered on shore, including extreme tropical weather in the Southeast and Gulf and ice in the Great Lakes. In addition to these problems, the higher humidity levels offshore create added problems associated with icing in higher latitudes.

1b. Potentially a separate project would be development of floating wind turbines. These are necessary to large offshore wind exploitation on the West Coast. The development of optimized floating wind turbine systems will require additional innovation to reduce the weight of turbine and tower components as a large portion of the buoyancy structure exists to support the dead weight aloft. The exact relationship in this weight advantage needs to be analyzed through further studies and will be dependent on the specific platform architecture. This may be achieved through high-speed rotors, lightweight drive trains, composite towers or substructures using lightweight aggregates.

1c. A parallel open design competition should be set up, open to university student teams or others with design expertise but not employed in wind manufacturing. This effort would facilitate interest and some expertise among American institutions of higher learning, and among newly graduating engineers, and could possibly be synergistic with 1a and 1b in generating "out of the box" design concepts. It would be judged by volunteer professional engineers with wind expertise, possibly at the site of a national wind conference. The program would include five one-year competitions, each judged and with prizes awarded—budget would be $400,000/year for five years.

Budget and Scheduling

Design and development is a long-term effort and should be broken down into multiple phases and technology pathways. For turbines and fixed-platform, bottom-mounted tower designs, we envision an initial phase for a public private partnership with industry that allows designs, components, or full systems to be developed at varying levels of funding. First year funding is $10 million but ramps to a $20 million/year program with expectation of 10 year duration and 50 percent cost sharing on all major hardware development.

Floating projects would be done the same way but the hardware phase should not start until conceptual designs have been proven on desktop studies with full dynamic modeling, so that designs have been fully validated prior to co-funding prototype builds. The first stage would be a conceptual design competition for approximately $10 million (about 10 awards) and would lead to the selection of the five best designs, which would then submit a detailed design. The next step would be a demonstration project building phase beginning in about three years.

2. Large Scale National Offshore Wind Testing Facilities

A major R&D priority is the need for a large scale national offshore wind testing facility. This would presumably be done with DOE, working in cooperation with multiple turbine manufacturers. This would provide testing facilities for the new larger offshore-class machines, which are too large for existing U.S. facilities. There are two components to this facility, component testing and site testing.

2a. Large offshore turbines will require test facilities for components such as blades, drive trains and generators. Currently no facilities exist in the U.S. where one can test a 5 MW size blade and none exist anywhere that can perform the necessary testing for a 10 MW wind turbine blade. Gearbox and generator testing are also essential to developing low-maintenance components. Testing is essential to reliability improvements and, in turn, is critical to long-term cost effectiveness. DOE estimated in 2002 that at least $24 million is needed to construct component test facilities.

2b. The site testing would allow DOE and manufacturers to understand the requirements for offshore wind. This could serve as a site for pilot projects at sea to demonstrate fundamental turbine and substructure technologies, to measure the true MET Ocean environment and to reveal issues relating to permitting and potential environmental impacts. New initiatives could be conducted in the public domain to maximize benefits to a wide industry base, including potential new entries from the offshore oil and gas industry. The output should yield critical design methods and codes, uniform standards for structural reliability, design specification guidelines, industry accepted safety margins, and valuable data to validate design models, codes and assumptions. This could be a North American testing facility with Canadian partnership to share resources and data for a more cost effective approach. The DOE should begin scoping the costs and requirements of such a site and solicit feedback from industry.

Budget and Scheduling

Funding is needed for 2a—large component test facilities for blades, gearbox and generators. This is a near-term effort that could start fairly quickly. The test facility could be one site, or blades in one site and gearbox/generator in another. Total cost could be $25 million to $50 million, for 10 MW component facilities. For 2b, an in-ocean testing facility should be scoped. It may make sense for federal lab management of a few turbines, used for generic testing and development of standards. Due to mobilization cost of offshore installations as well as O&M costs, in-site installations would likely be shared with commercial developments and/or turbine manufacturers.

3. Offshore Design Computer Codes and Methods

The development of accurate offshore computer codes to predict the dynamic forces and motions acting on turbines deployed at sea is essential before the next generation of turbines can reliably be designed. One of the immediate challenges common to all support structure designs is the ability to predict loads and resulting dynamic responses of the coupled wind turbine and support structure when subjected to combined stochastic wave and wind loading. The offshore oil industry must consider only the wave loading when extrapolating to predict extreme events, but offshore wind turbine designers must consider wind and wave load spectrums simultaneously.

Hydrodynamic effects need to be included with analysis tools that incorporate combined wave loading models for regular and irregular waves. Time domain wave loading theories, including free surface memory effects, are used to relate simulated ambient wave elevation records to loads on the platform. The complexity of the task to develop accurate offshore modeling tools will increase with the degree of flexibility and coupling of the turbine and substructure. Usually, greater substructure flexibility results in greater responses and motions to wave and wind loading. Perhaps the most important and least understood analysis task is the determination of the extreme load generated by these two different dominant stochastic load environments. Only recently has research begun on developing this type of extreme load extrapolation technique.

Additional offshore loads arise from impact of floating debris and ice and from marine growth buildup on the substructure. Offshore turbine structural analysis must also account for the dynamic coupling between the translational (surge, sway, and heave) and rotational (roll, pitch, and yaw) platform motions and turbine motions, as well as the dynamic characterization of mooring lines for compliant floating systems.

Budget and Scheduling

This requires a sustained effort to get validated models and design tools. Historically a 10-year effort or more requiring a sustained group of 10 modelers at about $3 million/year.

4. Cost Effective Offshore Wind Foundations

A large cost fraction for offshore wind systems resides in the foundations and substructures. Taking into account installation costs, long-term maintenance, coupled turbine loads and weight, as well as the cost of the substructure itself, the optimal turbine/substructure system needs to be established. Due to the wide range of variables this effort will require extensive trade-off studies and a much better understanding of what the existing and long-term offshore infrastructure can deliver. Before considering deeper waters, an earlier goal should be to develop primary support structures that can be deployed out to nominal depths of 50 meters. A qualified engineering team should evaluate prototyped designs such as those being used at the Beatrice site, determine the feasibility and cost to do this in the U.S., and make recommendations for what alternative designs should be considered, if any. For example, new drop-in foundation designs that avoid costly offshore vessel dependence and work at sea may provide better alternatives to the current options. Fixed bottom systems comprising rigid lightweight substructures, automated mass-production fabrication facilities and integrated mooring/piling deployments systems that minimize dependence on large sea vessels should be developed as a possible low-cost option.

This effort should be extended to deeper waters at a slightly lower priority. Several designs should be evaluated for bottom-mounted turbines to 100 meter depth and floating foundations beyond 100 meters of water. Floating systems require anchors to maintain position and stability. The anchor systems available in the oil and gas industry are expensive and have not been optimized for mass production or for wind energy. For floating systems, platforms that do not depend on mooring line tension as their primary means for achieving stability would benefit from the development of new low-cost drag embedment type anchors or vertical load anchors (VLA). Deployable gravity anchors show promise for all platform types because of their simplicity. Finally, better models of scour processes are needed in conjunction with improved design methods for scour protection.

Budget and Scheduling

imilar design team approach as for recommendations 1a and 1b above—we recommend design team awards for industry professional, possibly drawing on industry experts in offshore foundations (oil and gas construction). These teams would innovate on what they know and demonstrate new foundation technologies designed for wind. One or two phases with a total cost of $60 million (four-year effort at $15 million/year at 50/50 cost share) leading to new commercial foundations.

5. Marine Grid, Power Conditioning, and Infrastructure Development

To reach the Nation's 20 percent wind goal, we will need large turbine arrays, e.g., over 100 turbines installed in a single array. These are being planned both in large land installations, for example in the Great Plains, and for offshore wind. But for such arrays, the current distribution of power conditioning may not be optimum. Also, improved marine power transmission cables are needed.

5a. Currently, each turbine must independently provide all electrical components and controls needed for grid synchronization and power conditioning. For an array of hundreds of turbines, it may be more economical to redesign both generator and power conditioning, and to centralize much of the power conditioning on clusters or trunks of turbines, or for the whole array. The individual machine might have minimal power conditioning. As one of several examples, each turbine might only produce variable-voltage, constant current DC for a series DC bus along each row of turbines. The centralized power electronics would synchronize to grid phase, frequency and voltage. For remote sites, the centralized array power conditioning might not even produce AC; it might produce high-voltage DC to feed a HVDC power line, and let the load side of the HVDC transmission produce AC and do the grid matching.

5b. For large scale offshore deployment of multiple projects, there will be substantial advantages in developing large capacity submarine power cables and associated converter stations. This effort might begin as technology neutral, including a diversity of approaches including high-voltage direct current (HVDC) with thyristor valves in the converter stations, smaller HVDC using IGBT valves, and superconducting cables for example. These would be used to connect to large installations further offshore and to interconnect multiple offshore wind farms, e.g., along the East Coast. Currently there are no U.S.-made marine-certified cables for offshore wind. The goal is to develop high capacity, high efficiency and cost-effective marine cables.

Budget and schedule

5a should identify two teams with high-voltage, high-current, power electronics expertise to develop alternatives to power conditioning in each turbine. This would take $2 million/year for years 1–3 for design, review and evaluation. Then develop prototypes of power conditioning (not entire turbine), cost-shared with industry at $20 million/year for years 4–6. Item 5b will require $10–15 million/year.

6. Certification and Standards Development

Research funding is needed to build confidence that adequate safety is being provided without excessive caution that will raise costs unnecessarily. The Minerals Management Service (MMS) has been authorized to set the standards for structural safety for all offshore wind turbine structures. We have a common goal to create safe structures. The wind industry and MMS should work together to build a reasonable regulatory system and a set of offshore standards that will promote the safety needed to instill investor confidence without hindering deployment.

Budget and Scheduling

Research funding should be an ongoing effort to be sustained at $1 million/year. Include supporting research to address analysis required to understand structural reliability issues working with the Minerals Management Service.

7. Improved data on the offshore wind resource and development constraints

7a. Conduct a survey of the continental shelf physical resources using existing data bases in the near-term. Using existing data from multiple sources, locate and quantify the practical wind resource of the U.S. Continental Shelf to 100 meter depth. Combine direct oceanic wind data, geological and bathymetric data, existing tower designs, and easily-accessible conflicting uses that appear on navigation charts. This would yield total areas of viable resource and breakdown by state. This could guide private developers, national and regional planning, technology development and State-level policies such as State Renewable Portfolio Standards. For wind, document both strength and auto-correlations across sites in order to determine the value of offshore interconnections; this could identify areas that would, if connected, reduce intermittency and potential opportunities for marine interconnections. This is a near-term project that should be started immediately. Early priority should be given to the East Coast.

7b. Survey the outer continental shelf using GIS land-use overlays to characterize marine use activities, ocean ecology, and other parameters relevant to offshore wind development. This activity should be conducted in close cooperation with each state's local and regional stakeholders. These studies need to take into account a wide range of environmental and land/sea use issues in advance of wind development prospectors; including sensitive ecosystems, avian flyways, aviation fly zones, shipping channels, military zones, fisheries, existing easements, and other competing uses. Because this high level data is not intended for siting decisions, site-level studies will still be necessary for individual projects. Also, point conflicts such as historical shipwrecks may be better left to developer site-level surveys. Early priority should be given to the U.S. east coast.

7c. Install a series of meteorological towers of 100m height, along coastal areas believed to have good resources, based on 7a and 7b. On-site, hub height met towers would both improve the characterization of the ocean meteorological environment and provide some of the due diligence data needed by investors, thus shortening the site study and development cycle. Due to the cost of mobilization, a series of towers installed, for example, by a consortium, would be far cheaper than installation of single towers at a time by developers. These platforms could also be used for other instruments, such as bird radar, SODAR or LIDAR, which require either greater height or stationary platforms, rather than buoys. Organizational effort here emphasizes federal agency staff and university experts to establish and maintain public data access, maintain facilities and build expertise.

7d. Measurements and models are needed to characterize the nature of wind and waves since offshore wind turbine designs depend on accurate understanding of the physical ocean environment. This must be done at different geographic locations since offshore structural design requirements will be based on site specific data. The series of meteorological towers described in 7c would provide additional needed measurement components, if they were strategically dispersed to 6–7 locations that would include representative measurements to classify the impacts of warm weather climates (e.g., lightning, hurricanes, warm water conditions, etc.) as well as cold weather climates (e.g., icing in the Great Lakes, perhaps in cooperation with Canada). A European Union effort is underway to improve meteorological predictions of wind power output. By joining this effort, greater gains could be made per unit cost, while insuring that resulting methods and models are applicable to North America.

Budget and Scheduling

Item 7a is very high priority and can proceed immediately without waiting for item 7b, 7c or 7d. The cost would be $2 million/year for five years. Use university experts or environmental firms with track records on ocean-specific wind analysis, expertise on using existing data and models, and proven ability communicate in a form usable to State policy-makers (e.g., how many MW are practical in this state). Use known teams and existing data so as to get practical actionable results soon, with later refinement by items 7b, 7c and 7d.

Item 7b might be able to leverage Interior or National Oceanic and Atmospheric Administration (NOAA) funds.

Item 7c would require $120 million over two years to deploy 30 towers, each 100 meters with multiple instruments. Also, $5 million/year over five years for a team bridging National Buoy Data Center (NBDC) and university and federal ocean meteorology experts. This team would initially specify tower locations, archive and provide open data access (NBDC) and maintain instruments and calibration (NDBC). Then the team will perform and publish strategic analysis (ocean meteorology experts) and, once the towers are in place, publish data use guidelines usable by private developers and by State and federal energy planners (energy policy experts).

Item 7d would draw on the met towers in 7c and thus, the additional funds for meteorological characterization would be $1 million/year over five years.

8. Offshore Wind Farm Arrays

Offshore wind array performance is very sensitive to atmospheric boundary layer stability which tends to vary temporally at a given site. Current array models do not adequately represent these stability effects and need improvement. Better models are needed to predict the impact of turbulence inside the wind plant. Accurate characterization of the atmospheric boundary layer behavior and more accurate wake models will be essential to understand and design turbines to withstand wind plant turbulence. Since turbulence causes wear and tear on the turbines, as the industry grows it will be a high priority to be able to quantify the degree of turbine generated turbulence under a wide range of conditions and to develop tools to design wind plants that minimize turbulence at the source.

The configuration and spacing of wind turbines within an array has been shown to a have a marked effect on power production from the aggregate wind plant as well as for each individual turbine. Typical offshore wind farms lose 10 percent of their energy to array effects. Improvements in array layout may allow some recovery. Uncertainties in power production represent a large risk factor for offshore development. Today's wake codes attempt to model performance but empirical data show inadequate representation of individual turbine output. Large cost reduction opportunities exist in improving wind farm performance models.

The impact of one wind plant on another is likely to be a larger problem than for land-based systems because the open ocean contains continuous tracks of unobstructed windy territory. Wind plants introduce downstream turbulence that regenerates over some distance but analytical models to predict optimum spacing between arrays are very immature. Wind plants installed upstream must take into account their effect on downstream wind plants in terms of energy capture predictions as well as structural loads due to modifications of the wind characteristics. The understanding and managing of "wind rights" and set backs will be important.

Budget and Schedule

This effort will require a sustained team of 3–4 people over a five-year effort at $1.5 million/year.

9. Potential Effect of Offshore Wind Development on Coastal Tourism

Tourism and recreation-related development is one of the major factors shaping development patterns in coastal zones and can affect coastal lands, near-shore waters and beaches. The coastal zone is a limited resource being used by many different stakeholders, including local residents, foreign and domestic tourists, and industry. Data from the U.S. Census Bureau indicate of those who were surveyed in 2003, over fifty million had visited a beach within the past twelve months. Although it is often alleged that an offshore wind farm in the United States will have a specified effect on tourism, the impacts (negative or positive), if any exist, have not been empirically studied. A survey should thus be conducted to collect data on beach-goer selection trends, beach-goer preferences, and demographics to examine the link between beach selection and the presence of offshore wind farms.

Budget and Schedule

Initial prospective surveys in six states with near-term development plans will cost $400,000 over two years. Coastal tourism data combined with on-beach surveys at two development sites, before, during construction and two years after project completion, will cost $1 million/year over four years.

10. Advanced Deployment and Maintenance Strategies

The largest components of higher offshore LCE cost is the higher cost of construction and maintenance in offshore environments, including installation and logistics. A database of offshore equipment and cost is needed so that costs can be accurately represented and cost reduction efforts can be assessed. Lifting systems should be developed that will enable the use of alternative towers, turbines and rotors to reduce or eliminate the need for specialized heavy-lift ships. For example, the development of a streamline system for installation to float out turbine and towers assembled in dry dock to a project area would reduce cost and cost over-runs due to bad weather conditions. European wind farms have incurred up to 30 percent cost overruns because of bad weather on some projects.

The reliability of wind turbines must be improved for offshore systems. Fewer repairs would further eliminate the need for expensive vessels. New offshore strategies must be developed that minimize work done at sea. It is essential that new turbine designs, starting with the preliminary concepts, rigorously place a higher premium on reliability and in-situ repair methods. Materials must be selected for durability and environmental tolerance. The design basis must be continuously refined to minimize uncertainty in the offshore design load envelope. There must be an emphasis on the avoidance of large maintenance events that require the deployment of expensive and specialized equipment. Much of this should be done at the design stage through ruggedized components, improved quality control and inspection, and increased testing at all stages of development. Offshore machines must be proven on land first before they are deployed in numbers and the industry must establish guidelines to determine when a machine is ready for deployment at sea.

Potential developments of new manufacturing processes and improvements of existing processes that will reduce labor, reduce material usage, and improve part quality, is an area of great potential for offshore cost reductions. Offshore installations may allow for manufacturing and assembly to occur in close proximity to well developed industrial facilities as well as the offshore site. The use of large barges for transport then allows the full turbine to be transported from the manufacturing and assembly facility to the final point of installation.

To further reduce offshore maintenance, coatings that would last the life of the project for the primary structure, tower and blades should be developed. Materials to protect secondary structures (platforms, j-tubes, etc.) should also be developed. Current European offshore wind shows that deposits of insects and salt spray, and pitting, cost two to three percent of electrical output. New methods for cleaning, and/or recoating blades at sea should be developed and tested.

Budget and schedule

The R&D Subcommittee does not have a firm basis for estimating the cost of this effort. We estimate $5 million for vessel-based research and $5 million for O&M focused research, the latter would be cost-shared with industry.

11. Integration of large offshore power into Eastern grid

Because the offshore wind resource of the coastal Eastern states is estimated to be substantially greater than the load of these states, practical use of this resource will require advances in the integration of large fluctuating resources into the grid. A comprehensive set of integration options might include at least the following two.

11a. Transmission strategies for coastal areas need to be understood, and may be different from mid-continental areas. For example, transmission inland may be used to absorb power when offshore wind power exceeds 100 percent of load in coastal electric systems. Another strategy is to build transmission along the coast, offshore (like the European so-called SuperGrid); this would connect offshore wind facilities and use meteorological diversity to level output fluctuations.

11b. Devices and methods for management of wind fluctuations should be tested and modeled. These include planning of greater loads during winter when the offshore wind resource is greatest (e.g., electric heat displacing combustion furnaces in buildings), management of centralized storage and active management of storage inherent in loads (e.g., heat storage added to building heating systems). Two methods for storage include centralized purpose-built electrical storage, and use of plug-in vehicles for electrical storage during excess wind and release during insufficient wind.

Budget and schedule

11a. This effort would require $2 million/year for a three-year transmission study, including use of existing Eastern grid, and alternative designs for offshore Atlantic connector.

11b. This effort would require $2 million/year for four years and would include two parallel efforts: first, field experiments using managed loads, storage heaters, and plug-in vehicles to level wind output; second, a modeling effort combining site storage techniques, centralized storage, and transmission.

12. Avian and Marine Ecology Research

Extensive avian research has been conducted in European wind farms without finding a major problem associated with mortality due to wind turbine collisions. However, concerns still exist and European experience is insufficient to fully demonstrate the impact of wind turbines on birds in the United States.

12a. Prospectively and area-wide, a single ornithological study should be conducted over the entire Eastern United States flyway. More detailed research should focus on areas most suitable for wind energy deployment.

Many species of fish and other marine life are more abundant in shallow waters favored also by current offshore wind projects. These species may include both resident and migratory seabirds (including gulls, terns, gannets, cormorants, storm-petrels, shearwaters and others) which come to these banks for food year round. Because the U.S. continental shelf is less shallow than in Europe, there may be a greater concentration of marine life in these shallow areas than similar areas in Europe. The feeding ecology of seabirds and other water fowl needs to be studied on offshore banks and over submerged ledges.

12b. Before and after construction studies should be conducted at early wind farms in the United States with public disclosure of the findings. Estimating post construction mortality of birds at terrestrial projects is a matter of physically searching the area around turbines and correcting for misses and scavenging. Offshore, new remote sensing methods to detect bird strikes need to be designed and field tested. Careful studies are needed to determine the effects of offshore turbines on various avian species, building on extensive work conducted in Europe and in the U.S. onshore wind turbine market.

Budget and Schedule

For the prospective area-wide study mentioned in 12a, the cost is estimated by extrapolation from a New Jersey comprehensive study, underway in 2009, extrapolated by area to cover Virginia through Maine out to 30 nautical miles. On this basis, flyway survey cost over two seasons would be $132 million—however, a more refined cost estimate is needed. 12b. This effort requires two site studies (pre- and post-construction) managed by federal agencies and not by developer, with results publicly available. $7 million per study, synchronized to timing of early two developments in diverse ecological zones.

13. Recommended methods for evaluating costs and benefits of projects

During both the Long Island offshore wind process and the Delaware power purchase agreement process, there was considerable debate over the cost and benefit analyses of each project. Development of recommended criteria and methods for evaluating the costs and benefits of offshore wind projects, including guidelines for evaluating direct, indirect and induced job impacts, would help to eliminate debate on this issue. These criteria and methods could optionally be used by states, developers, or non-governmental groups to evaluate specific offshore wind proposals.

Budget and Schedule

This effort would require $400,000 over two years.

BIOGRAPHY FOR JOHN SAINTCROSS

John Saintcross is the Program Manager, Energy and Environmental Markets at the New York State Energy Research & Development Authority (NYSERDA) where he is currently responsible for managing the centralized procurement of renewable resources under the Renewable Portfolio Standard in New York and the auctions/sales of allowances under the Regional Greenhouse Gas Initiative and Clean Air Interstate Rule programs. Mr. Saintcross is a member of the New York State nuclear assessment and evaluation team responsible for conducting evaluations of physical reactor plant conditions and plant personnel responses to unusual or emergency reactor and other plant system events. Before assuming these current responsibilities at NYSERDA, Mr. Saintcross managed various renewable technology product development and deployment activities including those associated with the development of green power markets. Prior to joining NYSERDA, Mr. Saintcross was the Director of Resource Portfolio Management for Green Mountain Power Corporation, where his responsibilities included the development of renewable and distributed power technologies, integrated generation and demand planning, and power contracting, delivery and trading. At Green Mountain Power, Mr. Saintcross lead the effort, working with the Electric Power Research Institute and the Department of Energy to develop one of the Nation's first utility owned wind projects for the testing of large-scale, pre-commercial turbines located in Searsburg, Vermont. Before entering the energy business, he was employed by Westinghouse working in the Naval Nuclear Propulsion Program where he was responsible for component specification, manufacturing and ship-board maintenance. Mr. Saintcross has testified numerous times on utility planning matters as well as co-authored and collaborated on various papers and studies. He was a founding member of the Utility Wind Interest Group and a past member of the National Wind Coordinating Committee. Mr. Saintcross received his B.S. in Nuclear Engineering from the State University of New York at Buffalo in 1977.

Chairman BAIRD. Thank you, Mr. Saintcross. Dr. Swift.

STATEMENT OF DR. ANDREW SWIFT, DIRECTOR, WIND SCIENCE AND ENGINEERING RESEARCH CENTER, TEXAS TECH UNIVERSITY

Dr. SWIFT. Good afternoon, Mr. Chairman, and thank you to the Members of the Committee for inviting me. It is an honor to testify before this committee. As Congressman Neugebauer mentioned, I am a faculty member in Civil Engineering and Director of the Wind Science and Engineering Research Center at Texas Tech University in Lubbock, Texas, and the Center has been in existence for almost 40 years. I have been doing wind research for about 30 years myself, and Texas ranks first in wind power installed capacity, and in Lubbock, we are at the geographic epicenter of that development in Texas, and of course, it expands through the southern Great Plains region.

Wind is the fastest-growing source of bulk electric power in both the US and the world, and it is a clean, domestic renewable source of energy, and it uses no water. Most thermal power plants use a lot of water, and I know there have been some Committee hearings here before this committee talking about the relationship between energy and water. That is an important fact I think as we look about the dispersion of wind through the Great Plains where water can be scarce.

Mr. Lockard gave a good review of the Department of Energy's 20 Percent by 2030 Report, and we are at about 28 gigawatts of installed capacity. That report calls for 300 gigawatts of needed capacity, and also it talks about not only the need for transmission but also the need for reduced cost and improved performance and reliability of wind turbines and about workforce. I would like to use my last few minutes here to comment on these.

On the research for turbine reliability and performance, there are really two areas, and I compliment Congressman Tonko and his bill for distinguishing between those two. One is individual turbine research, which needs to be done in order to improve components. They talk about improved rotors, improved generators, improved blades. There is a lot of work that can be done in those various areas. These will combine together to provide individual turbine performance enhancement.

The second area is the development part of the bill really addresses the array effects of wind turbines. One of the issues for research is that as these turbines are put into large wind farms, the downwind turbines, the ones that are in the second, third and fourth row typically don't perform as well as those in the front row. And this is an issue because researchers and folks at the labs, et cetera, our students cannot get access to these turbines because they are all privately held and privately owned. So there is a huge need for public access to wind farms in order to begin to look at these wake effects and array effects.

When we talk about the $200 million that has been proposed per year, that is a lot of money. It is a healthy increase, but it is a needed increase. It brings wind on a parity I think with some of the other research areas. Solar has been pretty close to that range for a number of years. If one were to look at that as an investment, take an investment approach, the 2030 report by DOE calls for about 15 gigawatts per year in order to reach that goal.[1] If one takes that 15 gigawatts and applies a one percent performance improvement, that is all, just one percent to that 15 gigawatts due to this research and then takes that over the life of the wind farm, net present value of that is about $300 million given the current cost and with some assumptions. I have those calculations available if anyone is interested.

My point is that the leverage of those dollars is significant, and that is because of the huge amount of energy produced from these large wind farms and the value of that energy.

I would like to take my last minute to talk about workforce needs. In the DOE 2030 report, they talk about 180,000 direct jobs are going to be needed. We have had some economists at Texas Tech take a look at these numbers, and we estimate that about 20,000 to 25,000 of those jobs will be professional jobs which will require some kind of university education. The rest will require a two-year degree in maintenance and oversight of these wind farms, and that effort is going on as I say mostly at the two-year schools. At the University, as Congressman Neugebauer pointed out, we have the only Ph.D. program in wind science and engineering, something we are proud of, but if we are going to have this kind of development, we need programs across this country. Texas Tech is not going to lead this development all by itself. A number of universities are stepping up, but in order to make this happen, we need to get faculty involved, and research dollars bring faculty, the faculty bring the graduate students, the graduate students then innovate, bring new ideas back, new programs are installed, and then that forms the basis for the workforce needs for this industry.

I see that my time is up. I again appreciate very much the opportunity to be here. I am happy to take questions a little bit later. My written testimony gives more details. Thank you.

[The prepared statement of Dr. Swift follows:]

PREPARED STATEMENT OF ANDREW SWIFT

Good afternoon. Thank you, Mr. Chairman and Members of the Committee. My name is Andrew Swift and I appreciate this opportunity to provide testimony on the importance of wind energy research.

Background:

I am a faculty member in Civil Engineering at Texas Tech University in Lubbock, Texas, and have been engaged in wind energy research and education at the university level since the late 1970s. I presently serve as the Director of the Wind Science and Engineering Research Center at Texas Tech University which has conducted

[1] Capacity per year to be installed in order to reach the 20 percent by 2030 goal. Clarified by Dr. Swift.

wind-related research and education since 1970, and offers the only multi-disciplinary Ph.D. degree program in Wind Science and Engineering in the Nation.

The University is located on the High Plains of West Texas and is at the geographic epicenter of thousands of Megawatts and billions of dollars of large, utility scale wind turbine development in the southern Great Plains region—to include eastern New Mexico, southern Colorado, western Oklahoma and the Panhandle of Texas. The wind resources are excellent and the people of the region are familiar with the wind, windmills historically used for water pumping, and integrating energy production from the land (typically oil and gas) with ranching and agriculture. Texas is ranked first in the Nation in wind power installed capacity.

Wind Energy Overview and Barriers to Development:

Over the past decade, wind power has been the fastest growing source of new bulk electrical power generation in the U.S. and the world. Wind energy is a clean, domestic and renewable source of electrical energy. Additionally, unlike thermal power plants which use large amounts of water for cooling, wind energy generation uses no water—an important fact in the Great Plains wind corridor where water resources are severely strained. Current U.S. wind power capacity is approximately 28 gigawatts, generating sufficient electrical energy to power approximately 10 million U.S. households—a small fraction of current U.S. electrical energy consumption. Robust growth is expected to continue, with the U.S. DOE projecting that wind energy could provide 20 percent of the total U.S. electrical energy needs by the year 2030.[1]

The U.S. DOE report, completed in spring 2008, outlined the costs, benefits and barriers to successfully developing the 300 GW of installed wind power capacity, more than ten times the current capacity, needed to meet the 20 percent goal. The report has been generally well received by the wind energy community and most are supportive of the 20 percent target. In outlining barriers to attaining the goal, the need for expanded electric transmission resources to move wind-generated electrical energy from high wind resource areas to load centers was emphasized. However, the report also points to the critical need for additional research and development to reduce capital costs, increase performance and reliability and reduce environmental impacts of wind turbine power generation as compared to the current state of the technology. The report also points to the need for accelerated wind energy workforce development to meet industry needs. Let me focus on four points:

1. **Wind Turbine and Wind Farm Turbine Research Needs:**

   Decreased capital cost, improved performance and improved reliability of both individual wind turbines and entire wind farm multiple turbine arrays will require significant investments of research and development funds. These are actually two separate research thrusts and the proposed *"Wind Energy Research and Development Act of 2009"* addresses these two programmatic needs.

   The first will require improvements in individual wind turbine technology such as improved generators, gear boxes and drive trains, improved rotor designs and controls technology, and advanced components and materials. Investment and emphasis on individual component areas will combine to improve the entire wind turbine.

   The second research thrust will also require significant investment but must address system level, multiple wind turbine array issues and must be approached in a different manner. Access to wind farm data is currently very difficult to obtain due to the private nature of wind farm ownership. Wind inflow characterization, wake turbulence and wind turbine array response measurements are very much needed to address current unexplained decreases in performance and reliability. Answers to these system and array questions will require public funding of research and a very different approach than the component research. It is important that the research data and results be in the public domain, benefiting the entire U.S. wind industry thereby assuring the adoption of best practices throughout the industry, reducing negative impacts, improving reliability and performance and providing energy at the lowest cost from the Nation's wind turbines and wind

[1] "20% Wind Energy by 2030," USDOE, *www.20percentwind.org*

farms.[2] The AWEA Action Plan Report[3] provides excellent detail of the required research thrust areas and should be a template for implementation.

2. Wind Power Forecasting Research:

Since wind is an intermittent source of power generation, integration studies of wind with the electric grid system and the proposed "smart grid" are needed. Full integration of wind resources will require area-wide load balancing and dispatch and will rely heavily on high fidelity wind and wind power forecasting so that power is delivered reliably and all resources are utilized to their potential.

This will require the atmospheric science community to approach forecasting of wind on a variety of temporal and spatial scales and with an accuracy not usually associated with weather forecasting. The solution will require a synergistic approach to research and development and a strong partnership between the atmospheric science community and wind power generation community. These research topics are not listed in the current bill, but should be considered for inclusion in the program.

3. Research Funding as a Technology Investment:

The proposed research program, the *"Wind Energy Research and Development Act of 2009"* addresses the points made above and represents a significant, and much needed, increase in wind energy related research funding at the proposed level of $200 million per year through 2014. The amount is reasonable when compared with other federal energy research programs or when viewed as an investment in technology advancement. Assuming growth rates in wind capacity from the 20 percent wind energy by 2030 report of approximately 15 gigawatts per year, each one percent increase in performance due to technology improvement will represent approximately $300 million net present value of revenue over the life of the turbines installed that year—a 50 percent increase over the proposed annual federal investment.

4. Education and Workforce Development:

The DOE 2030 report estimates a wind energy workforce of 180,000 direct jobs at full capacity. Estimates by Texas Tech University economics faculty and Wind Science and Engineering staff estimate that approximately 20 to 25,000 of these will be professional jobs requiring a university education. Significant wind energy programs at universities require active and knowledgeable faculty and strong student enrollment. It is very important that universities partner in real and synergistic ways with industry and DOE laboratory personnel in these research programs. Not only do the faculty and student researchers bring new ideas and innovation to the research agenda, they bring the connections back to the university for new programs in wind energy and opportunities for students. Wind energy is strongly multi-disciplinary and faculty and students are needed to support this industry not only in engineering for new turbine designs and development, but also in atmospheric science for wind and power forecasting and resource assessment, in ecology to study and minimize wildlife impacts, in project management and financial analysis, in agriculture and economics to integrate the technology with agriculture interests throughout the central U.S. wind corridor, and so forth. Inclusion of strong university, industry and government research and education funding and partnerships are crucial to effective wind energy workforce development in support of this industry.

This is an exciting time to work in wind power. I believe if research and education investments are made on the scale proposed and comparable with support of other sources of electrical power that this industry can provide 20 percent of the Nation's electrical energy by 2030—providing a clean, affordable and domestic source of renewable power to the citizens of our nation.

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[2] Texas Tech University has proposed a National Wind Resource Center and publicly funded wind farm on university land near Amarillo, Texas for the purpose of obtaining operational wind farm data. That project is under consideration in the FY 2010 Federal Budget process.

[3] "Action Plan to Achieve 20% Wind Energy by 2030," American Wind Energy Association, Research and Development Committee.

BIOGRAPHY FOR ANDREW SWIFT

Dr. Andrew Swift is presently a Professor of Civil Engineering and Director of the Wind Science and Engineering Research Center at Texas Tech University. His previous employment included more than 20 years as a professor of Mechanical Engineering at U.T. El Paso, the last seven of which were spent as Dean of the College of Engineering. He completed his engineering graduate work obtaining a Doctor of Science degree at Washington University in St. Louis where he began conducting research in wind turbine engineering with a focus on the dynamics and aerodynamics of wind turbine rotors. Dr. Swift has worked in wind energy research for over 25 years, has over one hundred published articles and book chapters in the area of wind turbine engineering and renewable energy, and in 1995, he received the American Wind Energy Society Academic Award for continuing contributions to wind energy technology as a teacher, researcher, and author.

Chairman BAIRD. Thank you, Dr. Swift. Mr. Zweibel.

STATEMENT OF MR. KEN ZWEIBEL, PROFESSOR OF ENERGY; DIRECTOR, GEORGE WASHINGTON SOLAR INSTITUTE, GEORGE WASHINGTON UNIVERSITY

Mr. ZWEIBEL. Thank you very much, Mr. Chairman, distinguished Members for having me.

We are pressed by climate change and energy price escalation challenges. In response, we are quite likely to deploy many billions, even trillions of dollars worth of renewables, including solar. This is the path Europe and Japan appear to be on, and of all the future paths, it seems to me the most likely for us. In my opinion, it is by far the most sustainable, sensible, even most affordable.

We should assure that our deployment expectations of these trillions of dollars are supported by technological progress to keep our cost to a minimum. This is especially true of solar, where current costs are higher than other renewables, but potential for cost reductions are faster and greater and the payoff is greatest, because solar is the largest and most widely available energy source on the planet, much larger than fossil fuels. In fact, I suggest a combined deployment of solar and my respected wind colleagues and electric transportation will address our problems successfully. If we can solve our energy problems with solar and wind and electric transportation, they will be solved for a long time to come.

If we do not try to connect our solar technology development in government with our deployment expectations, we will be doing ourselves a disservice, paying more and perhaps much more than we should for the same electricity.

In addition, we have the responsibility to maximize our domestic competitiveness since solar can provide a huge harvest of jobs. Our suite of solar technologies is exceptionally rich and with the proper support should reach cost levels appropriate for deployment sufficient to stabilize energy prices and reduce greenhouse gas emissions. That means we do not need any breakthroughs. We have all the technology we need to be able to meet the greenhouse gas and energy price stabilization.

We are in danger of losing technical leadership in these technologies if we hesitate to support them, misled by claims about nascent, futuristic technologies with poor risk profiles.

I worked 25 years on solar PV technology development and had the good fortune to be involved with a small DOE program of $5 to $15 million during that period. The Thin Film PV Partnership and its precursors nurtured several second-generation PV technologies from bench-top to multi-billion dollar annual sales. Two key U.S. companies, UniSolar here to my left and First Solar were substantial participants in this program. Both are now world leaders in PV. In fact, First Solar was the second-largest manufacturer of PV modules in the world last year. When the numbers come in this year, they may be the largest with over a billion watts of module sales and $2 billion dollars in revenue. This is a notable success in a world dominated by foreign, even Chinese competitors that tout low-cost labor as their competitive advantage. In this case, technology is our competitive advantage, and we would like to keep it that way.

We can learn some lessons from the history of First Solar which was intimately involved with the funding for the Department of Energy during their period of nurturing since 1989.

I want to make a point about commitment to excellent technologies. Solar Cells, Inc., First Solar's precursor company, was not the first to work in their chosen technology. Before it, Kodak, Ametek, Photon Power, Coors, Matsushita, and BP Solar worked on it and gave up. During that whole time, several universities, including Stanford and Southern Methodist University, were also participating. We at NREL started in about 1985. We stuck with their technology during corporate ups and downs because we had a technical roadmap based on three critical criteria: PV module cost, performance and reliability. These same criteria are mostly the criteria we all use in everyday matters, cost, performance and reliability. They are pretty much universal.

We were not lost in the technological woods, assuming everything equally worthy of support or jumping from one hot new idea to another. We knew what we needed in the way of manufacturing cost, in the way of output and in the way of reliability for a 30-year life. Knowing where we were going allowed us to stick with technologies through thick and thin and to drop those that demonstrated an inability to get there with reasonable risk and cost. We exercised technically knowledgeable judgment, and we got to our goals.

Today, First Solar has surpassed all our metrics, and they are now the lowest cost producer of solar PV electricity in the world. They have become a huge spur to progress in solar energy because they are the new benchmark against which everyone is measured. We are fortunate, because without this competition, prices will be dropping instead of being static, the way they were before their reaching first tier, becoming a first-tier supplier.

Let me thank Ohio Representative Marcy Kaptur for being a champion——

Chairman BAIRD. Mr. Zweibel, you have reached about five minutes, so I hate to cut you short, but I am going to ask you to conclude your remarks shortly.

Mr. ZWEIBEL. All right. Who as part of this development during this whole period.

Technical roadmaps are not magic. They have well-known pitfalls like being too narrowly defined, not allowing enough out-of-the-box thinking and being parochial. But they are also wonderful in assuring us research focus and highlighting pinch points. Used wisely, they can be a major step forward. Put differently, without them we are in danger of wandering in the woods, from one hot excitement to another, or treating every proposal as of equal value. Adoption of a technical roadmap should be done sensitively——

Chairman BAIRD. Mr. Zweibel, I am going to ask you to conclude at this point.

Mr. ZWEIBEL.—with openness to frequent revision. Thank you very much.

[The prepared statement of Mr. Zweibel follows:]

PREPARED STATEMENT OF KEN ZWEIBEL

We are pressed by climate change and energy price escalation challenges. In response, we are quite likely to deploy many billions, even trillions of dollars worth of renewables, including solar. This is the path Europe and Japan appear to be on, and of all the future paths, it seems to me the most likely for us. In my opinion, it is by far the most sustainable, sensible, even most affordable.

We should assure that our deployment expectations of these trillions of dollars are supported by technological progress to keep our cost to a minimum. This is especially true of solar, where current costs are higher than other renewables, *but potential cost reductions are faster and greater—and the payoff is greatest, because solar is the largest and most widely available energy source on the planet.* Much larger than fossil fuels. In fact, I suggest a combined deployment of solar, wind, and electric transport will best address our problems. If we can solve our energy problems with solar and wind and electric transportation, they will be solved for a long time.

If we do not try to connect our solar technology development in government with our deployment expectations, we will be doing ourselves a disservice, paying more and perhaps much more than we would otherwise for the same solar electricity. In addition, we have a responsibility to maximize our domestic competitiveness in solar, since solar can provide a huge harvest of jobs. Our suite of solar technologies is exceptionally rich, and with the proper support should reach cost levels appropriate for deployment sufficient to stabilize energy prices and reduce GHG emissions. We are in danger of losing technical leadership in these technologies if we hesitate to support them, misled by claims about nascent, futuristic technologies with poor risk profiles.

I worked twenty-five years on solar PV technology development and had the good fortune to be involved with a small DOE program of $5–$15M per year for those 25 years. The Thin Film PV Partnership and its precursors nurtured several second generation PV technologies from bench-top to multi-billion dollar annual sales. Two key U.S. companies, UniSolar and First Solar, were substantial participants. Both are now world leaders in PV technology, and in fact, First Solar was the second largest manufacturer of PV modules in the world last year. When the numbers come in for this year, they may be the largest, at over one billion watts of annual module production and two billion dollars in sales. This is a notable success in a world dominated by foreign, even Chinese competitors that tout low-cost labor as their competitive advantage. In this case, technology is our country's advantage developed with U.S. Government investment, and we would like to keep it that way.

We can learn some lessons from the history of the development of First Solar, which was intimately involved with the activities and funding of the Department of Energy's PV Program and the National Renewable Energy Lab in Golden, CO, from its inception in 1989 as Solar Cells Inc.

I want to make a point about commitment to excellent technologies. Solar Cells Inc. was not the first company to work in its chosen technology, a thin film semiconductor named cadmium telluride. Before and while they did so, Kodak, Ametek, Photon Power, Coors, Matsushita, and BP Solar worked on it *and gave up.* During that whole time, several university groups also worked on CdTe, especially Stanford under Professor Richard Bube and Southern Methodist University with Professor Ting Chu, perhaps the most important contributor in this field. We at NREL formalized an internal program about 1985. We stuck with thin film cadmium telluride despite the corporate ups and downs. Why? Because we had a technical roadmap based on three critical criteria: PV module cost, performance, and reliability. We were not bureaucratic babes lost in the technological woods, assuming everything equally worthy of support or jumping from one hot new idea to another. We knew what we needed in the way of manufacturing cost—about $100 per square meter of module area; in terms of performance—about 100 W of solar electricity from the same square meter; and reliability—less than one percent and preferably 0.5 percent degradation of output per year, leading to over 30-year outdoor life. Knowing where we were going allowed us to stick with technologies through thick and thin, and to drop those that demonstrated an inability to ever get there with reasonable risk and cost. We exercised technically knowledgeable judgment, and we got to our goals. Today, a company we nurtured, First Solar, has surpassed all our metrics, and they are now the lowest cost producer of solar PV electricity in the world. They have become a huge spur to progress in solar, because they are the new benchmark against which everyone is measured. We are fortunate, because without this stark competition, prices might be static, or even increasing, as they did before the advent of First Solar as a first-tier supplier.

Let me thank Ohio Representative Marcy Kaptur for being a champion throughout this period; the University of Toledo for incubating Solar Cells Inc.; NREL, DOE and EERE for sticking with it; and the Walton family for buying Solar Cells Inc. in 2001 and getting it through the expensive (quarter billion) and technically challenging 'valley of death' to commercial success.

Technical roadmaps are not magic. They have well-known pitfalls like being too narrowly defined; not allowing for enough 'out of the box' thinking; and being parochial. But they are also wonderful in assuring research focus and highlighting pinch points. Used wisely, they can be a major step forward. Put differently, without them we are in danger of wandering in the woods, from one hot "nano" excitement to another, or treating every proposal as equally valid. Adoption of a technical roadmap should be done sensitively, with openness to frequent revision,. The best programs have good guidelines of cost, performance and reliability; and creative, knowledgeable managers who appreciate both focus and change. Yes, we want it all, not just one extreme or the other—not "wild-eyed creativity" or "nose to the grindstone dullness." We want it all. We need both focus and sensitivity to change, and with good oversight, should lead to it.

Would requiring a deployment-related technical roadmap impose imbalance on our solar effort in the government? I do not believe so. Observing today's federal solar funding, we have made strides in creating a program that does blue-sky research on all sorts of potential technologies at Basic Energy Sciences in DOE. With the ARPA–E program, we have opened the doors to cross-cutting ideas that assemble pieces from different disciplines into something not well-supported before. Now we are suggesting that our federal program at EERE be focused technologically in support of our deployment expectations to solve climate change and energy price challenges. I applaud efforts that support these kinds of activities.

In closing, I would like to thank the Subcommittee for inviting me to participate.

BIOGRAPHY FOR KEN ZWEIBEL

Ken Zweibel has almost 30 years experience in solar photovoltaics. He was at the National Renewable Energy Laboratory (Golden, CO) much of that time and the program leader for the Thin Film PV Partnership Program until 2006. The Thin Film Partnership worked with most U.S. participants in thin film PV (companies, universities, scientists) and is often credited with being important to the success of thin film PV in the U.S. Corporate participants in the Partnership included First Solar, UniSolar, Global Solar, Shell Solar, BP Solar, and numerous others.

Zweibel subsequently co-founded and became President of a thin film CdTe PV start-up, PrimeStar Solar, a majority share of which was purchased by General Electric. Zweibel became the founding Director of The George Washington University Solar Institute at its formation in 2008.

Zweibel is frequently published and known worldwide in solar energy. He has written two books on PV and co-authored a *Scientific American* article (January 2008) on solar energy as a solution to climate change and energy problems.

Chairman BAIRD. Thank you, Mr. Zweibel. I apologize for that. Ms. Bacon.

STATEMENT OF MS. NANCY M. BACON, SENIOR ADVISOR, UNITED SOLAR OVONIC AND ENERGY CONVERSION DEVICES, INC.

Ms. BACON. Thank you, Mr. Chairman, and all the distinguished Members of the Committee. I very much appreciate being here. It is an honor.

I am Nancy Bacon, of course, Senior Advisor of a company in Michigan which is Energy Conversion Devices.

Our largest business unit is United Solar Ovonic. It is a global leader in manufacturing thin film photovoltaics that convert sunlight into clean, renewable energy. As you can see from this small sample that I have, our products are significantly different from the other, conventional products. They are typically 18 feet long and 14 inches wide. They contain no glass which makes them flexible, durable, and extremely lightweight, perfect for PV rooftop installations. In fact, our products were chosen for the largest photovoltaic array in the world on a rooftop in Spain with General Motors. I have given a handout to the staff earlier, and you will see that pictured on page 6.

To make our United Solar laminates, we employ about 2,000 people, most of them in Michigan. Since 2006, United Solar has increased its Michigan employment base four-fold. We operate two plants in Auburn Hills, Michigan, two in Greenville, Michigan, and we are continuing to expand and we are constructing a fifth plant in Battle Creek. We are one of the few U.S. producers of solar cells and modules.

We have a history of innovation. We pioneered the use of roll-to-roll processing for depositing solar cells on one and a half mile long substrates.

We are very interested in the roadmap process, and we very much applaud the Committee's commitment to solar energy and support the DOE's solar photovoltaic programs. We also believe that strengthening the government-industry partnership to develop a robust solar-powered roadmap or solar vision to guide the U.S. research, development, demonstration, and commercial application would be of great value.

Such a program properly funded would address the national priorities effectively of addressing climate change, enhance U.S. competitiveness, and energy security.

We are competing against countries, not companies. Bell Labs invented photovoltaics 54 years ago. Less than a decade ago we had 40 percent of the world's PV manufacturing here in the United States. Today it is only about eight percent. We need to put the Nation's scientific, engineering and innovation talents to work to bring down the cost of solar power and revitalize our manufacturing base.

Other countries have visionary policies in making investments that are creating thousands of jobs, and we need to do that as well. Widespread use of solar PV can benefit the climate, the economy and our security.

While addressing the supply side I think is critical, we also need as a nation to address the demand side. In particular, we believe that the government should lead by example and install PV roofs on federal buildings and encourage states to do the same.

Before offering some specific suggestions, I would like to highlight some of the benefits of using solar photovoltaic for distributed generation to put some of my recommendations into context.

Solar rooftops are an ideal place to generate electricity. As this committee well knows, distributed generation simply refers to the generation of electricity at the point of consumption rather than at a remote location. Outlined in my written testimony, the benefits of distributed generation are numerous and they include better land utilization, reduced strain on our antiquated electrical grid, no transmission or distribution losses, less reliance on foreign oil and a drop in carbon dioxide production. That is five significant benefits in one.

If you think about it, rooftops are an idea place to install photovoltaics. They have no other purpose but to keep the building dry inside.

My written testimony outlines my recommendations, and I would like to highlight a few today. A solar vision roadmap should be properly funded to assure the U.S. industry achieves grid parity and the U.S. is competitive with other countries. All costs should be considered in the development of the roadmap in establishing priorities. As with the DOE's successful Solar America Initiative, focus should be on the lowest cost per kilowatt hour taking into consideration the installed cost per system and the amount of electricity generated in real-world conditions. Benefits of distributed generation should also be taken into account, i.e., no land, no transmission and distribution losses, et cetera, and we should also take into account the benefits of solar during peak times.

Health benefits and energy security benefits are also important. If we fund a vigorous program to develop advanced manufacturing technology, I believe this will be critical for the United States to help revitalize its manufacturing base and regain leadership in this important field. And this funding should be given priority as well.

Finally, I think that the taxpayers' investment should be protected with provisions to ensure technology developed with taxpayers' money is implemented here in the United States.

Chairman BAIRD. Ms. Bacon, I am going to ask you to reach your conclusion shortly.

Ms. BACON. I certainly will. Thank you. The last recommendation I have is really with regard to the demand side. The Federal Government spends $6 billion annually on electricity. I think they should lead by example, and they should be putting a procurement program in place that would change the way we create electricity, just the way we changed the way with the government funding, the way we communicate with the Internet. I think it is critical to success that we move ahead with these programs, and a timely implementation and deployment can help us regain our leadership once again.

Chairman BAIRD. I will ask you to conclude at that point, and we will have time for questions.

Ms. BACON. Thank you so much.

[The prepared statement of Ms. Bacon follows:]

PREPARED STATEMENT OF NANCY M. BACON

Chairman Baird, Ranking Member Inglis and distinguished Members of the Committee and staff, thank you for the opportunity to testify today. I am a Board Member of the Solar Energy Industries Association (SEIA), and a Senior Advisor for United Solar Ovonic and its Parent, Energy Conversion Devices ("ECD"), a publicly traded manufacturer of thin-film solar laminates based in Rochester Hills, Michigan—near Detroit.

ECD's largest business unit is its wholly owned subsidiary, United Solar Ovonic. United Solar is a global leader in manufacturing thin-film solar photovoltaic (PV) laminates that convert sunlight into clean, renewable electricity under the UNI–SOLAR® brand name.

Because of their unique properties (flexibility, durability, light weight), UNI–SOLAR® laminates are ideal for rooftop and other building-integrated applications. While we sell products for many applications, most of our solar laminates are installed on rooftops. In fact, our products were used to build the world's largest rooftop solar photovoltaic installation: a 12 Megawatt solar array on the roof of an automobile production plant in Zaragoza, Spain. UNI–SOLAR® also powers some of the largest installations here in the United States, including a two megawatt installation on the roof of a supermarket distribution center in Southern California.

To make our UNI–SOLAR® laminates, we employ more than 2,000 people, with most of those employed in Michigan. We operate two manufacturing facilities in Auburn Hills, Michigan, two manufacturing facilities in Greenville, Michigan—a town in desperate need of jobs after the Electrolux manufacturing plant shut down and we are constructing a fifth plant in Battle Creek Michigan. We are one of the few U.S. manufacturers of solar cells and modules.

Our global research and development efforts are also headquartered in Troy, Michigan. Since 2006, United Solar has increased its Michigan employee base fourfold. In fact, according to the Energy Information Administration (EIA), Michigan is the second largest producer of solar cells and modules among all 50 states,[1] primarily because of us.

We applaud the Subcommittee's commitment to solar energy and support of the Department of Energy's (DOE) solar research program. We also believe that a government/industry partnership to develop a Solar Power roadmap/Solar Vision to guide the U.S. research, development, demonstration and commercial application efforts would be of great value. Such a program, properly funded would address the national priorities of effectively addressing climate change, enhance U.S. competitiveness and energy security, revitalize our manufacturing base and create "green collar" jobs by investing in programs that decrease our dependence on foreign oil and address global climate change.

A great example of government/industry partnership is DOE's Solar America Initiative (SAI) program. Unlike previous programs that emphasized only on certain aspects of system cost, SAI focuses on achievement of c/kWh to reach grid parity. Many industries are participating in this program that has already led to significant cost reduction. We have developed new technology under this program that, when introduced in our manufacturing, will accelerate our progress to achieve grid parity.

We are interested in participating in further development in roadmapping process for solar electricity and believe that larger investment and coordination are important for accelerating the widespread adoption of solar energy production. We are competing against countries not companies. Bell labs invented photovoltaics 54 years ago, less than a decade ago we had 40 percent of the worlds PV manufacturing capacity here in the U.S., but today it is only about eight percent.

We need to put the Nation's engineering, scientific and innovation talents to work to bring down the cost of solar power and revitalize our manufacturing base. But as I will discuss in more detail later, we also need to create a robust market here at home for our products. Today we at United Solar export 80 percent of our products.

Other countries with visionary policies and investments are creating thousands of green jobs. Germany is the largest PV market in the world. Its programs and policies have lead to huge numbers of new jobs both on the manufacturing side and on deployment side, creating jobs for not only companies that manufacture PV cells and modules but also for electricians, roofers, balance of systems providers who install the PV modules. Today Germany, home of BMW and Mercedes has more people employed in renewable energy than in the automotive business.

A roadmap and federal support is an excellent vehicle to help achieve the Subcommittees and the Administrations goals. We believe we can play an important role in making this happen, but no solar company is large enough to bear the financial burden of doing research all along the supply chain in an efficient manner. There are areas where collaboration makes sense and we and others in the industry support working with academia, national labs and each other.

DOE in coordination with other agencies of the Federal Government and Industry can play an important role as a neutral party that can facilitate communication and support along the research, development and commercialization path to reduce the costs of solar systems and help advance solar photovoltaic technology and processes to make domestically manufactured solar systems accessible and affordable across the country.

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[1] Energy Information Administration: *Shipments of Photovoltaic Cell and Modules by Origin,* 2006 and 2007; *http://www.eia.doe.gov/cneaf/solar.renewables/page/solarreport/table3_—5.html*

While addressing the supply side is critical; we also need as a nation to address the demand side. In particular, we believe the government should lead by example and install PV on roofs of federal buildings and encourage states to do the same. Before offering some specific suggestions, I would like to highlight the benefits of using solar photovoltaic technology for distributed generation to put some of my recommendations in context.

Distributed Generation from Solar Photovoltaics

Stated simply, distributed generation is when electricity is generated at the point of use.

Today, nearly all of our electricity comes from big, centralized power plants—mostly coal, natural gas and nuclear plants—that depend on an inefficient electricity grid to get power to users.

These centralized power plants are generally located in isolated areas away from densely populated areas, which means that the power must be transmitted over great distances to population centers where it is consumed. This additional infrastructure, known generally as our electrical grid, is antiquated, inefficient, and entirely inadequate to support our growing national demand for energy. One study estimated that six to eight percent of the electricity generated in power plants is lost through today's transmission and distribution system.[2] Many renewable power plants are also located far from population centers. Many utility-scale solar plants are located in sparsely populated desert regions, where land is cheap. Wind farms are obviously built in windy areas, or even offshore. These large-scale solar and wind fields also take up vast acreage. In other words, much of the renewable energy generated today is actually piped right back into the same electrical grid, and subject to the same inefficiencies, limitations and delivery costs.

Distributed Generation solves the infrastructure problem because the power is produced at the point of consumption and solar photovoltaic technology is the cleanest and best suited means of democratizing power production. For most buildings, the roof has no other purpose than to cover what lies beneath it. Solar material is infinitely scalable and has the advantage of producing most of its power when electricity from the grid is in highest demand and most expensive, saving solar energy users' money.

The benefits of distributed generation are numerous, and the Federal Government can harness these benefits by purchasing PV systems directly or via power purchase agreements and installing thousands of rooftop solar systems on government facilities, businesses and homes across the country. A large-scale rooftop solar distributed generation program will help our nation become more energy efficient, less dependent on foreign fuels, reduce the emissions of CO_2 thereby improving our environment, and create hundreds of thousands of new "green jobs" here at home.

Commercial property owners are already harnessing the benefits of solar PV for Distributed Generation. In fact, commercial property owners purchased roughly half of all domestic solar cell and module shipments in 2007.[3] Commercial property owners understand the value of real estate, and were early supporters of rooftop solar installations since they could maximize the financial return of existing buildings while also saving money on their electricity bills.

Benefits of Using Solar for Distributed Generation

- *Is available immediately.* Traditional power plants take years, even decades, to secure approval, design and construct. Solar rooftop installations can be designed and installed in a matter of months, or even less for smaller systems. And the solar industry in the United States already has enough production capacity to meet existing domestic demand, as well as any new government procurement programs. We are also in a position to accelerate our expansion plans if the government adopts a robust procurement plan for solar rooftop installations.
- *Creates new "green" jobs across the country.* Production and installation of solar energy systems creates more high-quality jobs than investment in any

[2] ABB Inc.: *Energy Efficiency in the Power Grid,* 2007; *http://www04.abb.com/global/seitp/seitp202.nsf/c71c66c1f02e6575c125711f004660e6/64cee3203250d1b7c12572c8003b2b48/$FILE/Energy%20efficiency%20in%20the%20power%20grid.pdf*

[3] Energy Information Administration: *Domestic Shipments of Photovoltaic Cells and Modules by Market Sector, End Use and Type,* 2006 and 2007; *http://www.eia.doe.gov/cneaf/solar.renewables/page/solarreport/table3_7.html*

other energy technology.[4] According to SEIA, ten megawatts of PV capacity (enough to power 1,500 homes) creates as many as 140 manufacturing jobs, 100 installation jobs, and three ongoing operation and maintenance jobs. These jobs will re-employ workers in hard-hit industries.

- *A federal program to install solar power* on millions of rooftops would create hundreds of thousands of new jobs in the design, production and installation of solar PV systems. Distributed power is produced locally, so the design and installation jobs are created here in the USA. This job creation will immediately stimulate the economy, and will create sustainable "green collar" jobs for the industries of the twenty-first century and establish the United States as a leader in this sector. That is why it is important for you to insist on U.S. manufacturing for all federal PV solutions. With a requirement of U.S. manufacturing for federal procurement of solar systems, high-quality jobs can be retained and created not only for PV manufacturers like our company, United Solar , but also for electricians, installers, other balance of systems manufacturers as well as for constructing manufacturing facilities and building PV manufacturing equipment.
- *Reduces CO_2 emissions.* Solar energy is clean, renewable, and free. The more electricity we generate from solar power, the less we need to burn fossil fuels like coal, oil or natural gas. Solar power is acknowledged as one of the leading technologies to quickly begin carbon mitigation. According to SEIA, one megawatt of PV will displace 1,200 tons of CO_2 from traditional electricity generation each year it is in service, and modern solar PV systems typically last 20–25 years.
- *Optimizes land utilization.* Densely populated areas face the challenge of needing more power generation, while also facing high land values. Rooftop solar arrays do not use land that may have higher and better uses, but instead take advantage of unused space to produce power right where it is most needed.
- *Reduces strain on antiquated electrical grid.* The average output period of a solar system over the course of a normal day matches the average U.S. daily demand cycle. Therefore, distributed solar power can help relieve the strain on the existing electricity grid when demand is highest.
- *Saves capital by avoiding infrastructure construction.* As this Committee well knows, the existing transmission and distribution system for our nation's electrical grid is at the breaking point. Distributed Generation reduces the need for additional transmission lines, since the power is consumed at the point of production. Additionally, any leftover power can be sold back into the local community. And since rooftop solar generation takes advantage of otherwise unused space, there is no wasted land.
- *Provides strategic backup in case of grid interruption.* One of the benefits of distributed generation is to have a source of back-up power in case of outages. Solar systems have a limitless fuel source (the sun), which means they can be configured to extend the uptime of any facility that loses its supply of grid electricity.
- *Improved Air Quality.* Because rooftop PV systems produce the most power when demand is highest, they reduce the need to turn on additional electric power plants, which are usually the dirty peaker plants that acerbate air pollution on hot summer days.
- *No Water Consumption.* Distributed solar systems do not require any fresh water for electricity generation, an especially important issue where solar resources are greatest, the American Southwest.

What the Federal Government Should Do

Research, development, analysis and demonstration

- Properly fund the programs to achieve grid parity.
- Ensure that all costs are considered in the development of a solar roadmap and recommending priorities.
    - Focus should be on lowest cost per kilowatt hour taking into consideration the installed cost of the system per watt and amount of electricity

[4] Apollo Alliance and Urban Habitat, "Community Jobs in the Green Economy," 2007.

generated per year. Focus should be on performance of PV under real life conditions, not on efficiency measured in the laboratory.

- In comparing costs with convention power plants benefits of solar during peak demand should be taken into account.
- Energy payback, i.e., the time required to produce the energy required to manufacture the products should be taken into consideration in evaluating technologies and costs.
- Consideration should be given to land use, need for new transmission and distribution (T&D) infrastructure, and T&D losses from centralized facilities vs. distributed generation.
- Cost of disposal of PV products should also be studied including evaluation of the costs of disposal of toxic materials.
- Health benefits and security benefits should also be taken into consideration.

- Funding priorities and demonstration.
  - Continuation of programs like SAI with focus on c/kWh should be a priority.
  - Funding of a robust initiative to develop advanced manufacturing technology will be critical for the U.S. to help revitalize the U.S. manufacturing base and regain the U.S. leadership in this important field.
  - The programs should focus on development of new technologies such as thin-films rather than established crystalline based technologies.
  - Consider demonstrations greater than two MW and projects that demonstrate roof top solar when possible—to demonstrate advantages of no land use, no T&D losses, immediately available—no long permitting required, greater energy security and cyber security benefits.
  - Funding should also be provided for pilot manufacturing plants to demonstrate new manufacturing technologies.
  - Demonstrations funded with tax payer funding must use PV modules manufactured here in the U.S.
  - Provisions should be considered that would insure technology that is developed with tax payer money is implemented here in the U.S., i.e., production plants employing advanced manufacturing technology funded by tax payers should be located in the U.S.
- Timing
  - The programs should be aggressive and interim targets should be established.
- Competitiveness
  - Incentives and programs should be bench marked with incentives, programs, job creation and competitiveness of other countries.
- Interagency coordination
  - Critical to the success of the programs will be interagency coordination in both development and deployment.

Deployment

The Federal Government is the country's largest single consumer of electricity, spending over $6 billion annually. Therefore, in addition to having the regulatory authority to make the U.S. solar industry the envy of the world, the Federal Government also has the unique opportunity to lead by example. Federal support of rooftop solar photovoltaics will significantly advance the Nation's commitment to renewable energy, and can be executed rapidly enough to have a significant positive near-term impact on our struggling economy. Below are the suggested priorities that we believe the government should enact.

- *Install rooftop solar systems on federal buildings.* The U.S. General Services Administration (GSA) owns and manages 8,600 buildings in 2,200 communities across the country.[5] The Departments of Energy and Defense have already taken the initiative by installing solar systems on rooftops. By enhanc-

[5] General Services Administration, Properties Overview; *http://www.gsa.gov/Portal/gsa/ep/contentView.do?contentType=GSA_OVERVIEW&contentId=8513*

ing and expanding the government's commitment to rooftop solar into a robust, multi-year procurement program, the government can dramatically advance the entire U.S. solar photovoltaic industry. The results of this kind of national procurement program via direct purchase or power purchase agreements would include significant job creation, reduced manufacturing costs for solar systems through economies of scale, and the development of a vibrant installation industry in areas of the country where it does not yet thrive, as well as the national economic and strategic goal of reduced reliance on foreign fuels.

- *Integrate the government effort.* Regardless of where the money is put in the budget, the Nation needs to take advantage of the needs and enthusiasm of the Department of Defense (DOD) to increase solar power use. The DOD owns more buildings than the rest of the government. Many are large buildings. Imagine every military aircraft hangar in the Sunbelt covered with solar systems. DOD has an aggressive energy program for its installations and is very interested in photovoltaic power production. However, the DOD effort needs to be coordinated with other government efforts. DOD facilities would be a great place to start. They could produce power, as well as allow utility companies to benefit from free or low-cost roof space in exchange for long-term power purchase agreements giving DOD predictable power bills. This would make these precious facilities even more valuable and treasured by their communities. Instead of individual projects, a large-scale integrated effort with DOD facilities could quickly transform the whole industry.
- *Encourage the use of domestically manufactured components.* In addition to creating new jobs in the design and installation of systems, the government should support a "Made in the USA" plan to encourage solar cell and module component manufacturers to build new factories here and hire U.S. workers. With a robust PV government procurement program that includes a "Made in the USA" requirement we and others in the industry will accelerate plans to meet the increasing demand for solar PV products. Continued development of solar PV technology in the U.S. will make our industry the world leader.
- *Provide additional incentives for rooftop and building-integrated solar installations.* France, Italy and Spain are trying to encourage rooftop solar installations today. They have created enormous interest in rooftop solar by offering higher incentives for rooftop and building-integrated installations over ground-mount installations. These countries understand that rooftop systems do not require land, nor do they suffer from transmission and distribution losses. Adopting similar incentive programs would multiply the effectiveness of the solar Investment Tax Credit (ITC) that took effect at the beginning of the year.
- *Encourage flexible rules.* More forward looking analysis is needed to optimize both the best technology and the best use of rooftops. Rules on contracting, land use, and entering into long-term power purchase agreements need overhauling to generate the needed flexibility, and financial returns, to motivate power companies and government facilities into cooperative action. The evolving market needs more flexible rules. Payback periods, for example, will be better when conventional power prices rise and PV system costs continue to decline.
- *Provide funding for states and local governments.* All levels of government should be encouraged to install solar photovoltaic systems on the rooftops of their buildings. Offices, schools, universities, courthouses, and hospitals are excellent sites for clean, made in the USA, rooftop solar PV systems.

  Implement programs on a timely basis. We need to insure that programs that are adopted are implemented in an expeditious fashion. ARRA included a number of provisions that would be very beneficial to the solar industry and achievement of the Administrations goals, but regrettably most of the programs have not yet been implemented.

We applaud the Committee for its commitment to lead the green revolution. I hope my testimony today has been helpful, and I would be happy to answer any questions you may have. I look forward to continuing to work with the Committee and its staff on ensuring that the U.S. is once again a world leader in solar photovoltaics, while also reviving our economy and putting our fellow Americans back to work. Thank You.

Biography for Nancy M. Bacon

Nancy Bacon works as a consultant to Energy Conversion Devices (ECD) and United Solar Ovonic, principally in government affairs and government relations as well as business development. She is active in policy development to advance clean energy technologies particularly photovoltaics. Ms. Bacon represents ECD and United Solar on the boards of the Energy and Environmental Study Institute (EESI), the Solar Energy Industries Association (SEIA) and the United States Industry Coalition (USIC) and she is also an Advisor to University of Michigan Erb Institute.

After 32 years at ECD, in April 1, 2008, Ms. Bacon retired and has been working part time as a consultant to ECD and United Solar. Ms Bacon was Senior Vice President of ECD and a member of the Board of Directors of United Solar Ovonic where her responsibilities included government relations, business development including finance and business and strategic planning regarding commercialization of ECD technologies. In 1997, Ms. Bacon was recognized by Crain's Detroit Business as one of Detroit's Most Influential Women. Ms. Bacon has a B.S. in Accounting and is a certified public accountant (CPA). Prior to joining ECD, she was a manager at Deloitte & Touché.

Discussion

Chairman BAIRD. Thank you. I apologize to the witnesses. It is always difficult. You have tremendous expertise, and with a large panel we always have to try to keep it within time, but thank you very much.

I will recognize myself for five minutes, and then we will proceed in alternating order. I want to recognize Mr. Rohrabacher and Mr. Diaz-Balart for joining us. Thank you, gentlemen, for your participation.

The Economic Impacts of Energy Policy Changes

I am so sorry to hear this testimony about the tremendous job loss being created by this industry. We recently passed a comprehensive energy bill, as you know, and one of the criticisms of it is that it will be catastrophic from an employment and an economic perspective. That is not what I have been hearing from the testimony today. Would any of you like to comment on that briefly? Mr. Lockard, you had some impressive statistics, and if others wish to comment, I would welcome that.

Mr. LOCKARD. Yeah, I think 2008 represented a terrific year for the wind industry in the United States with tremendous growth, 8,500 megawatts job creation. 2009 is not going to reflect that same growth by the way, so just so that stat is clear. Other things like a Federal Renewable Electricity Standard (RES) will send a much stronger, consistent long-term signal that is an important piece of this in order for companies like ours and others to build more plants, create more jobs, and create sustainable long-term jobs, not just the boom cycles that we have had up until now.

So while there is a lot of enthusiasm and tremendous opportunity, our job isn't done here, and I think there are several key issues, key opportunities including a federal RES. A strong consistent signal would help drive that even stronger.

Chairman BAIRD. Thank you. Others wish to comment on that economic development, job potential?

Ms. BACON. Yes. I would like to very much. We actually have increased our employment in Michigan four-fold since 2006, and we are making excellent progress and that is going very well. The problem is that now, with the recession and with a number of the problems with regard to the finance institutions, things are slowing. So in our Battle Creek plant that is under construction, we have put a hold on some of the equipment until things turn around. From a point of view where we are as a nation, we export 80 percent of our products, and as I talked about the General Motors facility that is 12 megawatt, the largest in the world, we created jobs in Michigan by manufacturing the solar laminates but we created more jobs over in Spain with the installers and the electricians and the construction folks. So I think some of these things to look at the supply side will be very important here and to move these programs along timely will be also very important. Thank you.

Chairman BAIRD. Ms. Bacon, I appreciate that. You will be pleased to know that the Chairman of the Transportation and Infrastructure Committee has made it a passionate pursuit to install solar and other technologies on many federal buildings.

Ms. BACON. I understand that, and I actually testified in that committee as well, and we were delighted to get a lot of things in the bill. The problem is that it hasn't come out of the bill into the bank, and everybody is waiting for it.

Chairman BAIRD. Point well said.

Ms. BACON. We think that with some of the programs that are going on with this committee, too, urgency is really important for the sustainability of this job growth as well. Thank you.

TECHNOLOGY OFFSHORING

Chairman BAIRD. The next line of questioning I would like to pursue relates to an article in this month's *Harvard Business Review.*[2] To all my colleagues, I would really commend this article. It is in *Harvard Business Review,* and it discusses what happens when U.S. core, fundamental research technology gets shifted overseas and we fall off that supply and engineering train. It is directly relevant to your work and traces back from everything from the transistor to battery technology, et cetera, and I think it has got the potential. We are seeing it already in renewable energy.

And so the question is, how can we not see that happen here? One of the points this article made was as domestic manufactures allowed battery technology for cell phones to go overseas, that seemed like so what, they can do it okay, but now as we want batteries for automobiles, we don't have the technology, the know-how, the manufacturing capacity here. They have it overseas. How can we avoid that? And I will be asking that in this committee for probably many, many months to come with different, similar panels. How do we avoid that in the area of renewable energies?

Ms. BACON. Well, I can take a crack at that as well. It is a little controversial, but as a taxpayer, I feel that if my money goes into investment into developing research and development, advanced technologies and so on, when my government buys products, I would like to see a preference for U.S. industry. And I also think advance manufacturing technology, which is critical to revitalizing

[2] See Appendix: Additional Material for the Record. "Restoring American Competitiveness," by Gary P. Pisano and Willy C. Shih. Included with permission of the *Harvard Business Review.*

our manufacturing base here in the United States with regard to photovoltaics, the dollars that go there, we should see that those plants are put here.

And the other side of it is creating the demand side again. I mean, that makes a difference. Germany is the largest market in the world for photovoltaics. They have less sun than we have in Michigan. And they employ more people in renewable energy now than they do in the automotive industry. And think of it. It is the home of the Mercedes and the VW and so on, and that is because of their policies, both on the supply and on the demand side with this. And I think those kind of policies will make all the difference in the world so we don't see this go the way of the VCR.

Chairman BAIRD. I will be providing a copy of that article to my colleagues. It is a profoundly interesting article and educational for all of us.

I will recognize—I would like to hear more on this, but I am going to recognize Mr. Inglis for five minutes.

SOLAR ROOF INSTALLATION

Mr. INGLIS. Thank you, Mr. Chairman. Ms. Bacon, it is very exciting to hear about the opportunity on the roofs for distributed electricity generation. Why are people doing that now? Is that cost-effective for them or are they leading because of commitment to the environment or stewardship or what? I mean because in a lot of places, the economics don't exactly work, is that right?

Ms. BACON. Well, actually, you can put photovoltaics on the roof as economically as you can in many solar farms, and you don't have the land use, you don't have the transmission distribution which is like six to eight percent. You don't have to wait for the SmartGrid, the Integrated Grid. There are all those advantages with it.

But solar in general, the reason we are all here, is we are not to grid parity yet. We really think it is the future. There is going to be a—there was a DOE study that just came out that they think that solar could be 50 percent building-integrated photovoltaics, and the next time you go into an airport, just look at all those roofs that you could put solar on. They can be done in any size. But the problem in industry in general is we are not to grid parity, hence we need the stimulus, whether it is procurement via direct payment or power purchase agreements or the ITC which has been enacted now and other things. And as we bring the volume up, we will bring down the cost. And it is just like anything else. I mean, high technology and low volume is high cost. We are working to grid parity, and we think with the government's help and the DOE's help and across all agencies including DOD, we can bring down to be grid parity. In the right location, we are already competitive. But these are 20-, 25-year lives, and to find out really competitive, you need your crystal ball to figure out what is the electricity going to be five years from now, 10 years from now.

You will appreciate that I had President Bush come out to see us. He calls me Solar Woman, but I asked him the same thing. He asked me about the competitiveness, and I asked him, I said, what do you think the price of electricity is going to be in five years, 10 years, 15 years? And he gave me one of those blank stares, and

Karl Rove and Allen Hubbard were there, and I said, well, maybe these guys know. He said, ah, they don't know anything.

But I ask you, what is the price of electricity going to be five years from now, 10 years from now, 15 years from now? Photovoltaic arrays on your roof will last you 25 years.

Mr. INGLIS. Yes, very exciting, too. So I guess the customers that you have got today have obviously made calculations that indicate that they are banking on the price off the grid being considerably higher than it is today. Therefore, they make the economic decision or they make some sort of other considerations going into their decision and buying your product?

Ms. BACON. Most of them are much tougher than that. most of them want to have the price today at the same price as the grid, and then there will be an escalation. A lot of the industry right now is being done with power purchase agreements where somebody else buys the power, buys the photovoltaic, like a financier. He takes all the ITC, accelerated depreciation, et cetera, and then he has a 20-, 25-year power purchase agreement. General Motors is a good example. We have a one megawatt installation in California. Their initial price started out at 12 cents a kilowatt hour, and it escalates each year a certain percentage. They are banking on what that is going to be, but that initial price was pretty close to what the parity price was at that point in time. But the only reason that worked was because of the incentives, ITC and some of the other incentives with it.

Mr. INGLIS. Does that mean you are basically selling to people with big roofs? It needs to be a pretty big roof at this point?

Ms. BACON. No. It can be done at any size. What we have done as a company—we are a small company. We have 2,000 people and we are, you know, a Michigan-based company. We typically have tried to sell very large arrays just because it is easier to sell than going to each household which maybe wants 2,500 KW or something small. It is a lot easier to sell a megawatt or a 12 megawatt array. But we will be coming out with, at the end of this year, a program for small households, and they can also end up being cost-effective in the long term. And I believe in the long term. I am old enough. The reason I am Senior Advisor, I am old. My mom had a telephone in her house that was owned by AT&T. You know, why not have photovoltaics on our roof that is owned by the local utility and they could manage it and they could take care of it and it wouldn't take any space up? You generate the electricity right where you need it.

So there is a lot of innovation here, both from the basic materials, the product design, the manufacturing, and even the financing and marketing mechanisms, and that is why I applaud some of the things that people are looking at in this Solar Vision and Roadmap. It is not just looking at efficiencies to have technical papers, it is looking at the whole program to be cost effective and to really have the energy security, climate and the economic benefits we are all looking forward to happen.

Mr. INGLIS. That is great. Thank you, Mr. Chairman.

Chairman BAIRD. Thank you, Mr. Inglis. Mr. Tonko.

OFFSHORE WIND POWER

Mr. TONKO. Thank you, Mr. Chairman. For our wind experts on the panel, it becomes more and more apparent that offshore wind holds great potential, not just for the wind portion of our energy supplies but really expanding the opportunities for renewables in general. Can you cite what sort of efficiencies might be achieved, what sort of focus might become critical with R&D investment in the offshore component?

Mr. LOCKARD. Yeah, first off, on the 20 Percent by 2030 Report, 300 gigawatts would be the total installed base for wind by 2030. 54 of the 300 is considered to be offshore, so something like 18, 20 percent of the total 20 percent number would be offshore. It was also viewed to be a bit later in the 22-year cycle. So the problems today are cost, siting-related, similar to land-based but probably magnified in terms of the cost problem and the siting problem. There is probably more of an opportunity in offshore for innovation to drive a breakthrough change, where as the land-based product it seems is pretty much dialed in. The improvements are cost, performance reliability but probably not breakthrough. I think the breakthrough opportunities may extend themselves even better in the offshore side, so again, our funding the $217 million request, 15 of that was related to offshore specific technology. Other pools as well would go toward offshore. I think our group is growing in the view that offshore should represent, can represent, a significant part of the wind future, particularly New England and the Gulf Coast, and it should be important source of innovation.

Mr. TONKO. Mr. Saintcross, in your testimony you talked about the difficulty and the expense of installing a meteorological mast with a pier-type foundation driven into the seabed. You know, how crucial is it that we discover a more efficient alternative for that portion of wind to work?

Mr. SAINTCROSS. First, you are going to need to put many towers up if you are going to try to see the kind of offshore development that folks are talking about. A meteorological tower now runs about $4 million to $6 million to site it and physically install it. And then you have to hope that it is going to operate for a certain number of—maybe two years or whatever. And you need a lot of those. You are not going to typically go to a 400 or 500 megawatt project size with one tower because you won't be able to adequately characterize all the atmospheric conditions. You are going to want to have that turbine operating. That becomes very costly for the developing community to take on. I think New Jersey has put some of its own money on the table to do that. I know that in New York we are considering that as a program element going down the road, but if you are going to look at $4 million to $6 million per tower, you know, you probably should be looking at, as the Europeans are, different forms of measurement, LIDAR and SODAR, different technologies that heretofore haven't been widely accepted or bankable by the lending community and the financial community. So developers won't use that.

So the kind of research we are talking about today would go toward that, making that technology bankable to the extent we can reduce the cost of that technology. Then we can deploy more of it, and we can better characterize the resource which then will allow us to understand better what these turbines are going to be operating in, what that environment is like. Because you have to learn about how they will operate from the perspective of generating energy, the actual energy you want, as well as their lifetime. Can they survive those conditions such as dynamic loading that the resources will impart on blades and other components?

But those are very, very critical pieces that are necessary if you are really going to see an offshore vision because that is a very, very high-cost, high-risk enterprise for a developer to come in and take on. Those are the kinds of things that the Federal Government leveraging with State funding like NYSERDA's funding I think is a better space for us to play in.

Mr. TONKO. Great. Anything else to add on that?

Dr. SWIFT. Yes, I echo everything that my colleagues said here, and we have been looking at wind resource measurements in the Gulf, and it is expensive. There is an opportunity, and I am really repeating here, for new technologies. We have talked about air-mounted technology to scan and look at resource, but there is also the lifetime issue. The Gulf has a lot of hurricanes. Great wind resource but the extreme events, a lot of the people in our center do a lot of work on hurricane research and investigation. People think the wind is just a uniform front of wind. You know, the wind is the wind. It is very complex. There is a lot of structure embedded, and we have to understand these things better if we really want to make these kinds of investments and make sure they can survive the environment.

Mr. TONKO. Thank you.

Chairman BAIRD. Thank you, Mr. Tonko. Dr. Ehlers.

GENERAL CHALLENGES WITH WIND AND SOLAR

Mr. EHLERS. And as you can see from the testimony and the comments, that once again Michigan has the best answer.

Just a few comments. First of all, simple is better in general, and I appreciate the role of wind. I think it is a very important component. I think we are very far along in wind energy, but I think if you look at the grand scheme of things, you have to decide that solar has potentially more advantages. Now, I am really puzzled why our nation has always felt that the way to get solar energy is to pave over Nevada or Arizona, build a big facility, put the energy into the grid, and that this is the way to go. I don't think it is. As Mr. Zweibel mentioned, solar energy, it is very important to know, and I don't recall the exact amount of energy hitting the earth per day. Now you can give it to us later or give it to me later, but I know it is an immense amount of energy from the Sun, hits the Earth every day constantly. And a lot of people worry about clouds. But solar energy can work through the clouds, too, maybe not as efficiently but it will work.

But the difficulty with solar energy, there are two problems. One, it is very diffuse, so it is all over the Earth. It is not localized. And the second problem is that it is of low quality which means it is low temperature. Now, you can get rid of the low temperature problem by using solar panels because you are converting the energy directly into electrical energy, converting light energy directly into it. The diffuse factor I think is best handled by making certain, and this is my dream for this country, that every house within a few years will have solar shingles instead of asphalt shingles. As soon as we get the price down so they are comparable, that is just a very common-sense thing to do. If energy is diffuse, then collect it in a diffuse manner and stop worrying about paving over Nevada to collect the solar energy.

I think this is the direction in which we have to go. Whether or not we can conquer the cost problem, I don't know. But I know as long as we are doing research and we keep trying, we are likely to get there.

I think the single-biggest problem for both, however, is the one Mr. Saintcross referred to earlier and that is a storage problem. He referred to batteries. Batteries are very problematic. They are expensive, they are heavy, they don't last that long. Unless you can develop deep discharge, they are not terribly efficient. So maybe batteries are the answer, but we have an immense amount of research to do there if we are going to use them. In Michigan we tried to solve it with pump storage plants which has worked rather well, except that it kills an excessive amount of fish. We have handled that, but it is a good way to do it. But what I have said for 30 years, what this world needs is a good, efficient means of storing electrical energy. If you do that, both solar energy and wind energy and other forms of energy become much more viable, and that is where a lot of our research efforts should be.

I have pontificated, and now I am going to ask if there are any responses, particularly negative responses. Mr. Saintcross.

Mr. SAINTCROSS. I would concur with your characterization for solar. We have a solar program in New York, and it is diffused. We have a large residential program, but the market is not really, in terms of funding, it is not a significant duration or scale for us in New York to drive the kind of cost reductions that we need. So we are providing about $3 a watt as an incentive against the other federal and State tax credits to bring that market to bear.

On storage, I did mention the battery storage. Most of the work we are doing now is really in the transportation sector. But if we look at the offshore picture and we look at things like smart grid, we look at residential-based storage mediums or even plug-in hybrid vehicles, again, they are still batteries but I think we have some interesting ideas floating around that we at NYSERDA are trying to engage on in batteries and storage, working with the utilities to solve it, like LIPA[3] and ConEdison.

So I agree with you, so I think that storage is important. I think in New York we have looked at storage into the larger reservoirs in Hydro-Québec. But that would require transmission which in itself has its own set of issues that must be addressed. Most of that is cost and perhaps political. But, you know, we have reservoirs there. We can pond wind. But that will take, you know, a multistate effort and some, what I call, old-fashioned, integrated planning which I spent a lot of years doing in the utilities.

So I think that you are dead on when you make those statements about storing this energy.

[3] Long Island Power Authority

Mr. EHLERS. Let me just use the few seconds remaining to thank the panel. I very much appreciate your testimony. You are right on, you understand the issues. I wish more Americans understood the issues, and I think if they did, we would be putting a lot more effort into both wind and solar energy as viable alternatives of the future. So thank you very much for being here. I really appreciate it.

Chairman BAIRD. Dr. Ehlers' closing remarks demonstrate yet again that great things do come from Michigan, Dr. Ehlers. Ms. Giffords.

Ms. GIFFORDS. Thank you, Mr. Chairman. With all due respect to Mr. Ehlers, my good friend who made his comment about the home State of Michigan, I just wanted to do a shout-out to Mr. Lockard for the State of Arizona and also Mr. Zweibel who wrote the Solar Grand Plan which is about the State of Arizona and the plan that we could produce. So those are fighting words. We are very proud of the work that is coming out of my home state.

Also, Mr. Chairman, I just want to make a comment——

Mr. EHLERS. I will match you dollar for dollar.

GOVERNMENT'S ROLE IN TECHNOLOGY DEPLOYMENT

Ms. GIFFORDS. Okay. This is the first time I think in really any committee that I have been in where the average age of the audience is under the age of 30. So I want to thank all of the people for coming here today. It really reflects the future of our country and the interest that we have in renewables, and what an excellent panel we have.

Earlier today I had a chance to meet with one of the branches of the military, specifically talking about what the plan is for renewables, and it is very, very exciting. I noticed in the comments made by Ms. Bacon, actually I think in the written testimony as well, that the Federal Government is the largest consumer of electricity, around $6 billion, and of course, the Department of Defense is the largest user of all energy, not just electricity. And that is a concern.

Now, I know a lot of Members don't have time to actually read everything that is in our packets, but it is really important to look through what happened, the story of what happened in the 1980s when the DOD became concerned about the Japanese semiconductor industry and the manufacturers limiting access. And with this concern, we worked together to create a national roadmap for semiconductors.

And so my first question, which goes to Mr. Zweibel and also Ms. Bacon, is if you can talk about this plan, you know, basically briefly how it worked for the semiconductor industry, but more important, whether or not that roadmap plan is a good idea for solar and what that could possibly do for us.

Mr. ZWEIBEL. I thank you very much. The idea of a roadmap is to try to address the critical issues with the best of your productive capabilities, and in the past I think we have had a number of activities in solar energy that have been reaching out in many different directions without necessarily a central theme.

But we have reached the stage now where the central theme is deployment on a scale to meet greenhouse gas emission issues and energy stabilization. So we have a mission now that is very clear, and we have a set of technologies that are excellent, that are capable of meeting that mission.

So it is time for us to get serious about a technical plan, a roadmap that can be capable of supporting those successful goals. So whether or not it is semiconductor analog, it basically needs to be a focused plan with clear goals of successfully being able to reduce the cost of solar energy. I want to take a moment to say that there has been tremendous progress in the reduction of the cost of solar energy that wasn't that obvious during a period of boom when prices were rising, but in fact are becoming obvious now that the demand worldwide is hurt by the financial recession. So the solar energy prices at the system level are dropping and have dropped in the last 12 months and in the next 12 months by about 30 percent from about a year ago. So the systems that used to be going in at $5 to $6 a watt are now going in at $4 a watt, and systems are being talked up at $3 a watt. There is a substantial amount of progress technologically that was hidden. We have the opportunity to take those $3- and $4-watt systems today and bring them down to $2 a watt, and I might say that at $2 to $3 a watt, those systems are going to be quite competitive with say, for example, offshore wind, which is another very large source of energy.

So I think we are that close to being able to use solar energy for these big terawatt hours scale demands, and if I might just add one word about paving over the desert, we have put in one percent of our land area behind dams during a time period when the rest of us weren't paying attention. As you heard earlier, one-fourth percent would produce all of our electricity in the United States if used for solar energy. For dams, it produces only seven percent. So I guess we were more liberal back then about putting in dams than we would like to be now about putting in solar energy. So I suggest we can have it all. We can have rooftops, we can also have large fields.

Ms. GIFFORDS. Thank you, Mr. Chairman. Can we hear from Ms. Bacon? I know my time is short.

Ms. BACON. Yes. Thank you very much. And I think also I would echo much of what Ken said as well. I think it is time for a solar roadmap. I think it would be very critical to have the right investment, the right coordination, and the right direction for us to be able to move ahead, to be getting to grid parity with photovoltaics without any subsidies. And that is really what our goal is. As a company, we have a path that we are working down. We would be very interested in working with the U.S. Government, not just DOE but across applications. You mentioned DOD and DOD being the largest user of electricity I think in the world. As I mentioned, they could change the way that we create electricity, just like they changed the way we communicate with the Internet. It would have a massive impact on the whole solar industry. And I think we need that roadmap. We need to make sure that we are all working not just on the cells and modules, but the whole system. And what is important to people is the cost per kilowatt hour, and that is critical and no one asks, you know, is your coal-fired plant or your gas-fired plant 80 percent efficient or 60 percent efficient? What the consumer cares about is, what is the cost—cents-for-kilowatt hours? So we need to look at all of this.

We need I think a neutral party that can really look through this, help us with the direction as a nation to be able to do this. And we very much are in favor of it. We would love to participate on it. We have had a wonderful, rewarding relationship with the DOE and the DOD, but it has been small and I think that it is time with the energy security benefits, the climate benefits, the economic benefits, the health benefits as I mentioned because of what we are dealing with in terms of air pollution, aside from the climate change.

And you know, finally, when we talk about DOD, I have no idea how much the DOD spends looking at all of those bad parts of the world where we get fuel, but I think there is also savings there. So a group that is looking at a solar roadmap at a high level making sure they get the right technical and economic and other experts together I think would make a major difference in terms of moving these industries ahead, particularly in solar, but obviously wind as well. Thank you.

Ms. GIFFORDS. Thank you.

Mr. TONKO. [Presiding] Thank you, Ms. Giffords. The Chairman recognizes Mr. Neugebauer, please.

INCREASING EFFICIENCIES

Mr. NEUGEBAUER. Thank you, Mr. Chairman. Dr. Swift, I want to go back to something you said during your testimony. You said something about, you know, it is important that when you are looking at research, not only to look at the efficiency of the turbines, the devices I guess it would be, but also to look at the research of making sure that the wind farms and the configurations and all of those things are equally as important. Are there ways to pick up efficiencies and are there things to learn from the farms as well?

Dr. SWIFT. Thank you. I really believe there is a need in this country for at least one and probably several national research wind farms in order to address this issue. I pointed out these array effects. There are siting issues, there is modeling that needs to be done. The tools that we have available right now just do not give the optimum performance, the optimum loads which relate into lifetime which relates into dollars. And if we can address this issue, I gave that one investment example. Just a one percent improvement in performance is something like $300 million a year given the rate that we are deploying these turbines.

At least one national wind farm where it would be publicly accessible data. Researchers from across the country could do this, and I say we probably need more than one because there are different regions of the country where the wind is different.

I will point out another thing, that this industry has grown really in two ways. We have an atmospheric science community, and we have a wind power community. There is an opportunity for these two to come together and work in ways that they haven't. And part of it is just history, atmospheric science, you have a lot of scientists who look at boundary layer issues. We really haven't established the communication links between these, and I think this national research wind farm could address some of these losses that this industry is seeing.

And I might defer to Steve to comment on what he thinks those losses are. I have heard numbers as high as 10 percent.

Chairman BAIRD. And I am going to interrupt you for one second. I will give you back enough time, Mr. Neugebauer. What we have right now is a motion to adjourn. What I would like to do is keep the hearing going, but if Members want to go do the vote and then come back, so if some Members want to go, we will do it in sequence and then we can keep the hearing going. So I think you will be up next on our side if you want. We have got about 10 minutes to go, so Mr. Neugebauer, continue with your questioning, Ms. Edwards, and then when others come back, we will cycle back in. I apologize for the interruption but we could do it that way. Mr. Neugebauer, please continue. I will add some time to your clock.

Mr. NEUGEBAUER. Mr. Lockard, did you want to expand on that as well?

Mr. LOCKARD. Yeah, I don't have much to add specific to Andy's point on the research farms. I do think broadening the test platforms, be it test turbines or raise of turbines. We have a new blade test facility that is funded now. We have a new dynamometer that is being proposed and funded, all those platforms. And the wind industry has been described to me as kind of like the automotive industry in the 1940s. It is one thing for us all to look at it and say $17 billion worth of business in 2008, the job is done. And that is not the case. So whether it is forecasting, other reliability conditions, the things we are talking about are kind of bottoms-up, technical experts, looking at the work saying we have got to ratchet this industry up to be something that is really going to withstand the test of time. And I would echo the comment across the whole range of issues, forecasting and others.

ACHIEVING ECONOMIC VIABILITY

Mr. NEUGEBAUER. I think one of the things that I heard many of you say, and I think this is something that all of us struggled with during the debate on energy, is you know, making it a stand-alone viable industry without having to have additional incentives where there are tax credits, other kinds of—and so what does it take, for example, let us just take wind, to get to a point on parity with say natural gas or coal or nuclear because those are the technologies that are available and usable today? I mean, are we closing that gap or are we looking at long-term need to subsidize those differences?

Mr. LOCKARD. Yeah, I guess a couple of comments. One is all the electric energy technologies are subsidized today, so part of this is I think it needs to be looked in that larger context. But the 20 Percent by 2030 Report required a 10 percent reduction in costs, 15 percent improvement in performance. If you combine those, you can think about we are kind of 25 percent away from what might be necessary to be at parity. That is not really far away, but that scale doesn't necessarily drive cost. A lot of our costs, raw material costs and otherwise in the industry, are going up. U.S. manufacturing is more expensive. So there needs to be innovation to drive this piece. More automation, more manufacturing technology, innovation on the product side that can drive out cost and continue to drive the engine that way.

Mr. NEUGEBAUER. Ms. Bacon do you want to or Mr. Zweibel?

Mr. ZWEIBEL. About solar, a couple of things. One of the things is I usually compare solar and wind against other non-CO_2 sources. That helps to focus what the externalities are about. In most cases, energy independence and non-CO_2 and both of them have it. So I don't usually compare with coal unless it is sequestered.

All of us are attempting to bring down cost, and with the history of cost reduction say in solar energy, we can be confident that we are going to continue to bring the cost down approximately 20 percent every doubling of worldwide production. That has been the history. In fact, new technologies that have come on have actually exceeded that rate of cost reduction. So we have every intention of doing that.

But for technologies like wind and solar that don't use fuel, they are not exposed to that fuel cost escalation issue and so that moving target issue, and over the course of their real lifetime, and I have heard that almost every plant that was ever put in the United States to make electricity is still in actual use because they get repermitted, and over the course of those long lifetimes, because solar and wind have no fuel, their costs become very tiny once you have paid up the capital costs. So actually, you can actually come to a calculation that even at today's prices, they are cheaper than using a fuel-based approach because eventually the total investment is lower.

Ms. BACON. Just to add to that, we do have a plan to get down to grid parity without incentives, and that has got to be our goal as an industry. And those gains can be made from a number of things. One of the things we do is thin film. I mean, it is literally, you know, a fraction of a thickness of a human hair, so we are talking about very low material costs. We also need to do work on higher efficiencies because the higher the efficiency is, the better the cost is. We are working on that. We manufacture in a roll-to-roll process, almost like you do photographic film on one and a half mile long substrates. We are working with some technology that is VHF, very high frequency, to be able to speed up the process and still get good quality solar cells.

So there are all of those things that help bring down the cost. And by the way, a lot of these have been worked on with DOE in the thin film partnership going back with Ken as well as other things that we are doing, like Solar America initiative. On the deployment side, then you have got all the things that are in the balance of systems because you have got to look at everything. Just the solar module or a laminate doesn't do you any good. You have got to have the inverters and all the electronics, a good way to install it and all the way through. So that is what the roadmap can do. Because there is no one company that has every piece of that supply chain——

Chairman BAIRD. Ms. Bacon, I am going to interrupt you because I want to give Ms. Edwards a chance.

Ms. BACON. No problem.

Chairman BAIRD. Mr. Neugebauer, give Ms. Edwards a chance to ask questions and still possibly make the vote if she chooses. We are down about five minutes.

DECENTRALIZING THE TRANSMISSION SYSTEM

Ms. EDWARDS. Thank you, Mr. Chairman, and I hope this is as profound as it needs to be having interrupted you.

My question actually has to do with what consumers really see. I mean, most people I know, when they flip on the light switch, they don't ask where does my power come from? They don't care. They just want it to be as cheap and affordable as possible and for the lights to come on. And so I have a question that relates to the question around transmission, you know, the debate that is going on, you know, reported in today's *New York Times,* the western states and the eastern states and what is commercialized and how it is transmitting. And I wonder why there isn't more discussion about decentralizing the transmission system, localizing it so that you have the potential, you know, to use maybe limited sources of power generation that may be a mix of different things in a community and produce, then transmit and store locally. But it seems to me that all of our policy discussions involve this, you know, intricate, nationwide, large-scale transmission system that I think in the end is going to be far more expensive than if we figured out another shot. And I just wondered if I could hear your responses to that.

Ms. BACON. Well, this sounds almost like it was a planted question for me because I love——

Ms. EDWARDS. No, but good to meet you.

Ms. BACON. I love distributed generation. It just makes sense. We put photovoltaics on rooftops. Why not generate the power right where you are going to use it? You don't have the land, you don't have the infrastructure, you don't have the transmission and distribution losses. Now, with solar, we are blessed with being able to do that because the sun shines everywhere, some places better than others. Wind, they have specific areas where the wind is much better so it makes much more sense to do wind farms and then transmit it. But I think the more that we can do that, the better. And the other point of this with regard to distributed generation, you don't have to just put it on one rooftop. You can also have distributed wind, if you will, or distributed solar that could handle a community. And the other point of it is you can do it now, it is immediate. I mean, in a matter of months, as opposed to waiting for all the infrastructure investments and the permitting and all these fights about it. I think in the long term there is going to be a mix between centralized with transmission and also the distributed generation.

Ms. EDWARDS. I think I will go vote, Mr. Chairman.

Chairman BAIRD. Thank you. I will hold the fort. That is why I did this, actually. I figured I would have free reign.

PERMITTING AND WILDLIFE ISSUES

I stepped out for a moment. One of the issues that was raised on the wind front had to do with permitting, and we have got some wind facilities proposed in our area. And one of the issues is regulatory agencies are telling us we just don't know the answers to some of the questions because it is a new technology, especially regarding the *Endangered Species Act* (ESA) issues and migratory birds and things of that sort.

Where are we at in terms of learning what can be done to reduce bird mortality? You know, I remember years ago when the airlines discovered they can paint those little curlicues on jet engines and scare away birds. Didn't work in the Hudson River case, but apparently has been relatively successful.

What can we do? What is the state of the regulatory issues, and how do we expedite the permitting to get this technology on line?

Dr. SWIFT. I think there is a lot of recognition in the industry from where I sit that these are issues that need to be addressed. I think if you look at the 2030 roadmap, and as Steve pointed out in his testimony that we want to reduce the impacts of large-scale wind generation. There are some new technologies. We are looking at radar for measuring wind. Inflow to turbines is the thing I have been harping on this, the array effect issue, but those same radar can also be looked at to determine bats and birds and things. And some of the new wind farms in the coastal area in Texas actually have bird mitigation radar. As they see flocks of birds coming, they can actually shut down the wind farm. I think there is a lot of opportunity here as we go forward and work with the various ecological communities with the power people, the wind turbine people, et cetera. Good question.

Mr. SAINTCROSS. I would like to add to—you know one of the questions is the agencies responsible for dealing with wildlife. They don't have baseline data. They didn't have it onshore. In New York, we are doing post-construction monitoring at wind projects to do all the scavenging reviews to find out—mist netting for bats and so forth because our agency, the Department of Environmental Conservation, really doesn't have that information. They have general ideas where flyways are, but they have not been characterized at that broad a scale using a common set of accepted scientific principles.

Now, if we are going to go offshore, the scale grows even larger. When we did our prospecting in New York for about 30 site areas, we paid for that. We co-funded that with the private sector in the early—about 10 years ago. But offshore, that is a big expense, and it is a brand new area for people. Again, that is something that if we launch new advanced renewable programs at an organization like NYSERDA, we would probably look to do those kinds of resource characterizations because they don't have that data. And industry, I think Dr. Swift identified that you can use radar. You can operate your facilities differently to address wildlife, but developers don't want to offer that without being told they have to. So the wildlife community has to be able to communicate. This is what we think we are concerned with. But you need scientific knowledge to do that.

Chairman BAIRD. And that would presumably——

Mr. SAINTCROSS. And that is if——

Chairman BAIRD. The radar thing would presumably only work for fairly large flocks of major migratory birds. It would be a little tougher for a marbled murrelet which is the case in our—I mean, they don't even know where they live. And so the whole risk is, we don't know where these critters are, but they are more or less in this neck of the woods and we are afraid to chop them up with a wind turbine. And therefore——

Mr. SAINTCROSS. I mean we are—excuse me.

Chairman BAIRD. No, go ahead.

Mr. SAINTCROSS. We are getting better at it. With NEXRAD data, you can actually see the flocks come up at night on the radar. You can see where they move around, but then finding out what those species are is the next level. And that next round, we will just tell you, there is a large body of birds coming up at nighttime, and then they will see where they settle down. And you can plot that with technology. But you really don't know what species they are.

Chairman BAIRD. Mr. Lockard and then I want to acknowledge Mr. Diaz-Balart or I can't remember, whoever is next. Mr. Bartlett will be next. Let me acknowledge Mr. Bartlett because I have gone over my time. Mr. Bartlett.

MORE ON STORAGE

Mr. BARTLETT. Thank you. For a quarter of a century now, I have had solar PV and for the last couple of years I have had a sky stream, and I was amazed that the sky stream produces as much electricity when the wind blows adequately as 32–60-watt solar panels. So wind potential is real. But I am very happy with the solar PV.

As Dr. Ehlers mentioned, the big challenge that faces us is storage. As long as solar and wind are trifling percentages of our total energy, storage doesn't matter. But we will one day not have fossil fuels and so we will be producing our energy in some alternative fashion. So storage is going to become very important.

Pump storage, of course, is very efficient. Where you have the topography differences, you can certainly do that. But aside from that or just, you know, thousands, millions of batteries in hybrid cars and so forth, I know of no silver bullet for storage, and I wonder if we are moving as aggressively on this storage front as we are on the solar PV and the wind front.

There is of course a potential for wind that if you are widely enough distributed that there may be enough wind blowing somewhere if you have a net which could carry the electricity. That is not true of solar, of course, because the sun shines only in the daytime. Are you comfortable that we have adequate research investment in storage and have we taken a really good look at how self-sufficient we could be with wind without storage, with a proper kind of a net or grid?

Mr. LOCKARD. Yeah, I think a really important question and one that the AWEA R&D and governing group has wrestled with quite a bit. The 20 Percent by 2030 Wind Report, by the way, is interesting to me, although I am in support of cost-effective storage technology development. One thing it showed was that 20 percent of our nation's electricity can come from wind without storage, actually. We were surprised I think, some of us, to see that outcome. And some of that has to do as you said with the build out of transmission and broadening the market control areas and the jurisdiction areas and whatnot for transmission. So it is built out of transmission but also the planning and management of the broader areas. And I think from our group's perspective, cost-effective storage is something that is interesting and should be worked on, not only for transportation applications but for megawatt scale storage, and maybe our wind goal then becomes 30 or 40 percent with cost-effective storages opposed to 20.

Mr. ZWEIBEL. I would like to say that we have the same kind of paradigm in solar that we discovered that we could do an awful lot of solar without straining the grid without storage. But this doesn't mean we don't want storage because your vision and our vision coincides, that we need to have some way to store these intermittents for other times. And so a proper storage research program in parallel with the aggressive deployment of solar and wind I think is totally desirable. And the good news is that it might be in the right timeframe. In other words, even if it takes 20 years to develop the best new kinds of storage will be ready—we won't need it all that much before then, and we will be ready at that time for using it. So I think those kind of research programs really need to be done and should be done, and we definitely appreciate seeing you guys do that. It should not be considered as a roadblock to deployment of solar and wind because as the wind person said, distributed wind and transmitted solar and distributed solar can make up for an awful lot of that variation.

Ms. BACON. Just to add to what the other speakers said, I completely agree. Right now, storage is not a problem for solar, except for off-grid applications, and the one nice thing about solar is as it is shining during the day, it is producing during electricity typically in the peak hours.

So most of our applications are grid-tied, and most of the utilities in the evening do not have problems in terms of any capacity problems whatsoever.

In the longer-term, we certainly do need to look at that. One of the other things as you know, Congressman Bartlett, that we have done is our company also invented the nickel metal hydride battery, which is the battery of choice for today's hybrid electric vehicles. Much work is being done with lithium because the plug-in hybrids need higher capacity. We think we can also improve the nickel metal hydride battery but when we did studies of that as well, there can be a second life for these batteries. After the car is done with them, after about eight or nine years when they aren't of good enough capacity for running a vehicle, they are still good enough to have a second life with solar and other things. So I think again, some of these programs could be looked at in a very holistic approach as to how we can reuse some of these things. And I am sure that is going on in a lot of places, sort of reuse and recycle with it. But having said that, I think in the long-term, we are going to have to deal with storage, and it is not just battery storage. There are other mechanisms of storage. I don't think the funding is sufficient now, but there are choices that need to be made, and in our industry, it is not holding our expansion up or our cost reductions. Thank you.

Mr. BARTLETT. Thank you.

Chairman BAIRD. Thank you, Dr. Bartlett. One of the major contributions Dr. Bartlett makes is he is, probably more than any other Member of Congress, "off the grid" in the sense that he has implemented this technology in his own home and provides very valuable insights on that, everything from solar to photovoltaics to wind and his vehicles, et cetera. So the solution to our energy problem is for us all to live more like Roscoe Bartlett and we would quite sincerely would have a significant cut in energy.

Mr. Diaz-Balart.

BRINGING DOWN COSTS TO THE CONSUMER

Mr. DIAZ-BALART. Thank you, Mr. Chairman. I think this has been a very interesting panel. Thank you for this.

I have some questions about storage because that seems to be a big issue. I do want to—Ms. Bacon, you mentioned cost per kilowatt hour, and that frankly is where the rubber meets the road. Everything else is theory in the sense. And you mentioned about how Germany I guess is number one in the world now in solar. Is that correct? Do you know what their cost of kilowatt hours? Have they been able to bring it down comparable to other sources of more traditional, you know, old-fashioned energy?

Ms. BACON. Well, they are bringing it down, but the reason Germany has the biggest market in the world now is because of the policies that they have.

Mr. DIAZ-BALART. Subsidies?

Ms. BACON. Yes, they have a feed-in tariff which basically agrees—for those of you that don't know, it will buy the power created by the photovoltaic array at very high rates to make it feasible to be able to pay everybody from the module manufacturer to the installer to the owner to the integrator and the finance——

Mr. DIAZ-BALART. Right. No, I understand that. But I mean, since one of the things that we always hear about, and I heard it today, is that obviously, when you have more of it, the prices should go down because of technology, and yet in Germany, that still is not to the point of where it is competitive or is it? Where are we?

Ms. BACON. It is not competitive with the grid yet.

Mr. ZWEIBEL. Of course, Germany has about half the sunlight that we have here, and since cost per kilowatt hour is proportional to sunlight. So solar, both concentrated thermal and PV is about 15 cents a kilowatt hour in the U.S. Southwest. So it is getting closer to being cost effective, and that of course, is the point which is that good technology development can get you to cost effectiveness.

Mr. DIAZ-BALART. Well, that is obviously the key. If it is going to be something that is widespread, it has to be something that is competitive. But again, so how does it compare to kilowatt hour on regular, old-fashioned technology?

Mr. ZWEIBEL. As I said earlier, I generally use non-CO_2 to compare it because we are looking at——

Mr. DIAZ-BALART. Yeah, but I am just talking about right now.

Mr. ZWEIBEL. Right. So coal is a nickel a kilowatt hour to eight cents a kilowatt hour. Natural gas is about 12 cents per peak period. It is about nine cents for base load. And wind is about eight cents a kilowatt hour onshore and about, in Germany, 22 cents a kilowatt hour offshore.

Mr. DIAZ-BALART. Okay. So we still have a little ways to go, but obviously you hope the technology——

Mr. ZWEIBEL. Right.

Mr. DIAZ-BALART. And R&D which is something that I am a big fan of is obviously key there because we are not there yet.

I spent my formative years living in Spain, and we have seen some success stories and some dismal failures in Spain with their energy policies. They are now actually facing even some sporadic blackouts. Obviously doing very well as far as their percentages of renewable energy, but they are having a lot of issues with obviously the cost of energy, the level that the government has to subsidize it, the problem that is created for them there. Could you tell me some things that they have done right and then some things that they—that we clearly need to not replicate?

Mr. ZWEIBEL. Spain made a big mistake in putting out a tariff that was way too high, and that is not an unusual mistake when programs are just starting because they don't know where to put the number and they want to kick-start something. So they got a huge influx of installed systems that basically overwhelmed their system, and they got more than they wanted. So then the second year they just cut back to zero, and then that kicked everybody off of the system. So instead of starting a domestic industry, they made everybody go boom to bust in about a one and a half year cycle.

So it is good to tune your incentives to being the proper size so that you don't have that kind of process. In fact, one of the best things about these feed-in tariffs is that they go down every year. So they incentivize the idea that you are going to have to improve every year, and the kind of costs in PV that have come down over the last 10 years because of this have been unbelievable. They have been fabulous.

So I am very strongly in favor of the least cost to our society, and that is why I am very much behind the idea of good technology development and good incentive programs that come down with time.

Mr. DIAZ-BALART. And with my 38 seconds, Mr. Chairman, if I may, Ms. Bacon, you mentioned about, which is really exciting, the fact that, you know, people being able to have solar panels on their roofs. That I would imagine though is still very dependent on storage capacity or the fact that they are still on the grid and it would be a complementary type system. And also, would it work in hurricane-prone areas like Florida where we have very strict building codes for obvious reasons?

Ms. BACON. Another planted question. We are Category IV hurricane strength, and actually we are working with DOD because you know they are thinking of moving a lot of people down to Guam, and they have a lot of hurricanes there. And you know, they are lightweight, they are rugged. Senator Levin had to shoot bullets through it to show they still work. So they are about .7 pounds per square foot compared to the competition which is almost all glass-based, which is like five or six. So yes, they are very rugged, and they can work with that. And you were also correct that nearly all of our customers are tied to the grid. So during the day, we will size this such that it will provide all the daytime needs and they buy from the grid. There are other cases that the customer wants size larger and they have metering. The meter runs backwards, and they have hardly any bill at all. We have also done——

Chairman BAIRD. Ms. Bacon, I want to make sure we give——

Ms. BACON. Fair enough.

Chairman BAIRD.—Mr. Rohrabacher——

Ms. BACON. Yes.

Chairman BAIRD.—an opportunity. Is that a version of product placement, Mr. Diaz-Balart?

Mr. Rohrabacher.

Mr. ROHRABACHER. Thank you very much, Mr. Chairman. This has been a very fascinating hearing. I have been in and out but I caught most of it. Let me just note for the record the argument about climate change has been used several times here. Those of us who think that global warming is the biggest hoax that has ever been played on human kind do not necessarily disagree with you about developing alternative energy resources. I mean, those of us who note that it has gotten colder for the last eight years and that CO_2 in the air is supposed to make it warmer, thus—anyway, we won't go into that. But just so you will know that those of us who reject that are committed to cleaner air and energy independence, and what is being advocated today fits right into that strategy. So let us look at this a little bit.

NET METERING

I would like to ask you about open or net metering and an open grid and what is the relationship—what is the status today? This is where you can put into the grid and get credit for it and then have to pay for what you get out. Is that a status today in the United States?

Ms. BACON. Some of the wind colleagues might know better than I do, but there are many places that have net metering. There are a couple of ways they do it, and they are in the states. So it is up to the state to do it.

In some cases the net metering where you can—and there are various names, by the way, for this same concept—you can run the meter backwards so that, you know, that is one aspect. There is another way that they charge you in the evening, and then in some cases they pay you the avoided cost which could be two cents a kilowatt hour, which isn't so great. In some cases, they charge you what they would normally have or they pay you, if you will, at a higher rate.

Mr. ROHRABACHER. Perhaps we should have some sort of a national standard on that that would then encourage people to utilize these alternative sources. And let me ask you about your specific alternative, Ms. Bacon. How much electricity does it produce?

Ms. BACON. In terms of photovoltaics?

Mr. ROHRABACHER. Yes.

Ms. BACON. You can do PV at any size. We have done some things in Hawaii——

Mr. ROHRABACHER. As compared to, let us say, a solar panel. A panel of that. What produces more electricity?

Ms. BACON. Well, they are both solar panels. So if you want a one megawatt installation, you could do it with our technology, or you could do it with the crystaline and glass based. As I mentioned, we did a 12 megawatt system on a roof in Spain. So they can be done of any size, and that is true with any of us in the industry. So we have done some things in houses for two kilowatts.

Mr. ROHRABACHER. Okay. How long does it last?

Ms. BACON. We typically give warranties for 20 to 25 years. It is a semiconductor, no moving parts. It is expected to last longer.

Mr. ROHRABACHER. So it might last 25 years. So solar panels, I understand after about five years you have to replace them?

Ms. BACON. No. The solar panels—this is a different type of solar panel. It is a thin film on a flexible substrate.

Mr. ROHRABACHER. So solar panels are not—you don't have to—whoever told me that is wrong.

Ms. BACON. They are wrong. They are wrong.

Mr. ROHRABACHER. Okay.

Ms. BACON. The crystaline and solar panels which have been around for 54 years, they are also warranted in the 20, 25 year range.

Mr. ROHRABACHER. And is your product biodegradable at the end of that?

Ms. BACON. We don't use any toxic materials. I think the stainless steel is probably going to last for a while.

NUCLEAR POWER

Mr. ROHRABACHER. Okay. Now, the two—by the way, I believe electrification of our society is going to be the answer, and I think in the end, what you are advocating, which is trying to focus on letting everybody contribute to the grid or take out of the grid, is going to be the answer to giving people incentives to producing the electricity that they are capable of producing that will, based on the technology that we are developing, I see that as the future of our country, including automobiles, I might add.

However, with that, let me ask you about the production of electricity through nuclear power, which nobody seems to have talked about here today and which seems to be—some of the environmentalists who are talking about global warming never can get themselves to talk about nuclear energy as an alternative. In terms of costs, are we talking about nuclear power being more expensive than what solar power offers, today or perhaps in the future, or less expensive?

Ms. BACON. There are other, better experts than I am on this, that is for sure, and probably the gentleman sitting right next to you has a better flavor for this than anybody in the room.

But there have been some studies out with nuclear power that talks about as much as 30 cents per kilowatt hour. There are some that are as low as six cents a kilowatt hour for new plants that are put in, so one doesn't know. In my state, Michigan, it is too bad Dr. Ehlers wasn't here when we put in nuclear, it was three times the budget of what was anticipated.

Mr. ROHRABACHER. One last thing. Chairman, indulge me in one last question, and that is I have been told again—I was mistold about the solar panels having to be replaced every five years. That is clearly misinformation. But I was also told that to produce the amount of electricity that you would get from a nuclear power plant, it would take 5,000 windmills to generate that same power.

Chairman BAIRD. I am going to ask for a brief answer to this.

Mr. ROHRABACHER. Yes. Is that off and what is the number of windmills that you would have to build to produce the same electricity as a nuclear power plant?

Mr. LOCKARD. He says go ahead, but I don't know what the answer is.

Chairman BAIRD. That never stops us.

Mr. LOCKARD. Yeah, exactly. So I will keep going as well. What I know is the average wind turbine today, 1.5 megawatt turbine, for example, generates about enough electricity when running for about 300 to 400 U.S. homes. One machine.

Mr. ROHRABACHER. One windmill?

Mr. LOCKARD. One machine. These are huge—I would have brought a product today, but it wouldn't have fit in this room. They are huge machines. They are megawatt, utility-scale machines. And part of those——

Chairman BAIRD. Straightforward math, 1.5 megawatt multiplied by whatever.

Mr. LOCKARD. And the other point is just there is plenty of wind resource, there is plenty of land. One of the issues that was raised earlier related to siting, and I think we ran out of time a little bit on some of the siting.

Mr. ROHRABACHER. Wait a minute. How many of those big ones that you are talking about would we have to have for one nuclear power plant to replace it?

Mr. SAINTCROSS. I think, you know, the scale of nuclear is all over the board. There are big ones, there are small ones. If you break it down to one megawatt level, a wind turbine will produce about 30 percent of that one megawatt. A nuclear plant for one megawatt may be at 90 percent, 95 percent. So that is the difference, three times the energy from the nuclear fuel.

Mr. ROHRABACHER. So you only need three of those big turbines for one nuclear power plant?

Mr. SAINTCROSS. I am just trying to break it down to a megawatt level because the power plants change to a different scale.

Mr. ROHRABACHER. Okay.

Mr. SAINTCROSS. You know, in New York there is a 1,638 megawatt nuclear facility.

Chairman BAIRD. What I am going to do at this point——

Mr. SAINTCROSS. So I am just showing you it is a three-to-one type scale on a megawatt basis. You can think of it that way, and it will make it a little simpler for you.

Chairman BAIRD. I am in favor of distributed nuclear power. Mr. Bartlett, did you have a comment or a question? I recognize the gentleman.

MORE ON NET METERING

Mr. BARTLETT. Mr. Chairman, I would like to ask a clarifying question on net metering. The digital meters, do they run backwards the same way as the mechanical meters? If they do, then you don't really need laws for net metering because you would have to have a huge array to produce more electricity than you use. So you don't need anybody's permission to have a wind machine or solar on your house and run your meter backwards. If you run it backwards more than zero, then they may not pay you for that. In any event, they can't stop you from running the meter backwards, I don't think. Can they? So we don't really need net metering laws. All you need to do is put it on your roof and be careful you don't produce more electricity than you use, and you would have to have a huge array to do that. Thank you.

Ms. BACON. I will do that. I will get back to you on that.

KEEPING JOBS AND PRODUCTS DOMESTIC

Chairman BAIRD. We have had an excellent hearing. I actually have just a couple of more brief questions. I don't' know if colleagues would like a second round. I am going to ask just one more follow up on a question I raised earlier, and I will give other Members an opportunity if they want follow-up questions as well. I had asked the question about export of technologies earlier, and I want to follow up on that line.

Ms. Bacon, I am a personal supporter of buy America provisions. As you know, there are profound trade implications and in your particular business, given what you said earlier about the amount you export versus import, that would be a pretty interesting cost benefit question for you. About that policy: On the wind side, my understanding is we did a lot, i.e., we in the United States, did a lot of early work on wind and a lot of that now has been exported. The main jobs coming from wind in my District are longshore jobs. That is quite true, importing blades and towers, et cetera. What can we do as we move towards a green economy, cognizant of buy America but also cognizant of also protectionism and WTO.[4] What else can we do to make sure that if we come up with newer technologies, we don't end up importing that technology like we import so many other things?

Mr. LOCKARD. Yes, I think wind for sure offers a unique opportunity for domestic manufacturing. The physical product's size—the blades are huge. They weigh 15,000, 20,000 pounds a piece. The towers are difficult and expensive to transport. So the trade-off is labor cost versus transportation cost and that of incentives, if there are any. And the other truth is, we don't like it, but Mexico is cheap. And so in the end of the day, and these products are fairly labor intensive as it turns out. So I think, what can we do? We talked a bit a while ago about the renewable electricity standards, just some strong, long-term fundamental policies that causes Boards of Directors to make investments in the United States for long-term periods of time. That is one. The other is just to help incentivize or create more competitive U.S. manufacturing. There is a technology angle to that. The plant we opened in Newton, Iowa, there were State and local incentives that didn't match one-for-one, matched maybe one-fourth-to-one of the investments we made of our company. But it was still an adequate incentive to cause us to not build that plant in Mexico and instead build that plant in Newton, Iowa.

[4] The World Trade Organization

So I think a wind opportunity offers a unique opportunity because of the transportation cost. The rest of it is on the policy side.

Chairman BAIRD. The key point about that from the article in the *Harvard Business Review* and elsewhere that I have read a lot and spoken to people is we may think, oh, we are going to develop the technology here, and we are going to just export the manufacturing. Well, when you export the manufacturing, you are exporting the seed corn for your technology because you just have to interact on a daily basis with the manufacturing to get the feel for how it works. So this myth that we are just going to do all the smart stuff here and export the manual labor outside, eventually the smart stuff is gone, too, and you got nothing left. Is that a fair concern? Any other comments on that before I recognize colleagues?

Mr. ZWEIBEL. I would just say that we lost the market leadership in these technologies, so they built the plants elsewhere. Where they build them they often incentivize them. In Germany they incentivize 50 percent of the capital costs. They build them in Michigan, they incentivize them in Michigan. The cost of transportation is an avoided cost in all these cases, but we should take advantage of that. And in the case of PV, it is not a high labor cost. So it is a technology we can do here in the United States and be competitive. But I do think that you are right. This is a national issue. It is not just an issue for renewable energy, it is an issue for our country, and it is much bigger than we are.

Chairman BAIRD. I hope to have some further hearings on that topic. Dr. Swift, did you——

Dr. SWIFT. Yes, I just wanted to comment on the university side of this. You know, as university programs depend on research which was pointed out before, that brings programs, that brings students, that brings technology innovation. Once you have a trained workforce, companies are very interested and will locate where that trained workforce is. So there is a huge education piece that we need to remember, and that is directly related to the research piece, at least at the university level.

Chairman BAIRD. Excellent point, Doctor. Mr. Inglis recognized for five minutes.

GRID COMPATIBILITY WITH POWER SOURCES

Mr. INGLIS. I think next week we are going to have hearings on the grid, but the connection here to wind and solar as to the grid is, as I understand it, there is some question about the ability of the grid as it exists now to accept many, many sources of electricity in a distributed system. Is that right? I mean, is there a question about the ability of the grid to accept all that power?

Mr. ZWEIBEL. That is a key issue. After the cost, that is the biggest challenge for all of us is to how to get beyond a certain level of penetration without destabilizing the grid. And so what you do there is a couple of things. First of all, there is a natural tendency to want to deal with smarter grids that can handle faster decision-making. So it is the SmartGrid aspect that actually goes back to the person who is dispatching and what the resources are that they are dispatching. The second thing was mentioned earlier on wind and now is starting to happen in solar and that is solar forecasting. So when you can forecast the intermittency, you don't have the spinning reserves spinning all the time waiting for that cloud to come over or that cloud bank to come over. You only turn them on a half hour before it comes over because you know well enough when it is going to come over. And so there is a lot of work being done on solar forecasting, very valuable.

So these things get us up toward those high levels of penetration that we were talking about. Whether it is 20 percent, 25, 30, 15 percent, it is somewhere in that range that you can do without storage. Once you get to that point, though, you are going to start looking at storage and you are going to start looking at distributive storage, you are going to start looking at issues with transportation like using batteries for plug-in hybrids and electric vehicles for some of that storage so that you move into that next level where you solve those grid-related problems. And as I said earlier, where I think the good news is that, I think this is rare that we can do almost as much solar and wind as we want for the next 10 to 15 years and not really shoot ourselves in the foot on this while we are doing the R&D to get the storage right.

So let us do them both. Let us try and chew gum and walk at the same time.

Chairman BAIRD. Dr. Bartlett.

STORAGE RESEARCH INITIATIVES

Mr. BARTLETT. Thank you. As you have noted, for the moment at least, when your grid is high, you are using the grid as your battery, and what you are doing is you are simply forcing the electric producers to modify their production to be consistent with your sporadic production. And for a long while, what, probably 15 to 20 years we will be okay there. But it may take that long or longer to develop alternative storage technologies that we need to get going, and my perception is that we aren't getting going.

I have the largest HuP–1 solar home size batteries that they sell. These are lead acid batteries. Still, nothing competes with lead acid batteries for storage per dollar. You can't put them in a car because they are too heavy, but storage per dollar, nothing competes with the lead acid. If you are going to store huge amounts, you are still not going to do it there because it just takes far too many. There are a lot of creative technologies out there like pumping air pressure into some big thing, like having a water tower with a membrane on top and loading it up with steel which is seven times as heavy as water and pumping that up until it gives you the effect of a very high water column. I have noticed no broad areas of solicitation that is asking for creative solutions to this energy thing. Have I missed something.

Mr. SAINTCROSS. I can comment with respect to New York State. New York is installing a 20 megawatt flywheels system in eastern New York State to store, to be able to address very immediate perturbation in the system. We do have a lot of interest for a compressed-air energy storage with some of the utilities in Upstate. We have funded some high-level feasibility analyses but we are really right now looking for greenhouse gas initiatives programs. We are sitting on about $127 million right now at NYSERDA. We have an operating plan that we have not launched yet because the cap-and-trade program in New York is under lawsuit right now. It is being challenged legally. But the compressed air energy storage program is a component of our advanced energy supply and delivery program, as is the advanced renewables program. So we are definitely intrigued with trying to do some of that work.

We have also done a lot of work on wind integration. We think we can take 10 percent or 15 percent integration in New York with wind and be just fine. We now do five-minute and 15-minute forecasting. We have developed brand-new forecasting systems so that our operators now on the grid are sort of controlling the dispatch of wind resources, and we are also instituting a new program to actually dispatch wind, where they are actually providing price signals. When a system perturbation occurs, they are asked to back down and curtail, and they can make economic decisions. So I think that we are getting far more sophisticated. I think we can trust we can handle more wind on the system, but I think we are intrigued by storage, and we are just at the cusp of moving forward with a lot more work in that area in New York.

Mr. BARTLETT. That is New York, but do we have a national, aggressive program in developing storage technologies?

Mr. ZWEIBEL. That is a wonderful idea that really should be done, especially with the knowledge that we have time to be creative and to do a really good job instead of kind of a cut-and-paste kind of job. So I think that would be a great idea. And it also suggests that it is probably going to happen with wind first before it happens with solar because it is going to be long time before we switch solar from the day to the night, but it will be a pretty short time before we start switching wind from night to day.

Chairman BAIRD. Dr. Bartlett, maybe we ought to consider having a hearing on that very topic. I would be interested in working with you.

Mr. BARTLETT. Thank you. Yes, I think that storage is one of the big challenges here, and the quantity and quality of energy and fossil fuels is just incredible. And when we are forced, and we will—eventually we will have a world in which we are not using fossil fuels. Geology will assure that. And when that time comes, we are going to have to have some huge storage capabilities or we are not going to be living the kind of lifestyle we live now. And it may take quite a long time to develop these, and so we need to get started. Thank you.

Chairman BAIRD. Dr. Swift.

Dr. SWIFT. I just wanted to comment and support the need for a storage program. I served on a DOE wind review panel, and there was a significant discussion really just to make the point: most people in the wind community feel that it is kind of the same consensus—we don't need it right now. We need to use wind research dollars to address wind-specific issues. Storage needs to be addressed somewhere else. So I would support the idea very strongly for an independent hearing and some real focus on storage itself. Thanks.

Chairman BAIRD. I would be happy to work with the gentleman. As always, he has got I think a very important insight there.

Any further comments or questions, Dr. Bartlett, before we close?

CLOSING

With that, I want to thank the witnesses for a most informative and interesting hearing. Thank you for your time, and thanks for everyone else who attended today. The record will remain open for two weeks for additional statement from the Members and for answers to any follow-up questions the Subcommittee may ask of the witnesses. With that, the witnesses are excused. I thank my colleagues for their participation, and the hearing is now adjourned.

[Whereupon, at 4:15 p.m., the Subcommittee was adjourned.]

Appendix:

Additional Material for the Record

Congress of the United States
Washington, DC 20515

July 29, 2009

The Honorable Bart Gordon
Chairman, Committee on Science and Technology
2306 Rayburn House Office Building
United States Capitol
Washington, D.C. 20515

The Honorable Ralph M. Hall
Ranking Member, Committee on Science and Technology
2405 Rayburn House Office Building
United States Capitol
Washington, D.C. 20515

Dear Chairman Gordon and Ranking Member Hall:

As members of the House of Representatives Sustainable Energy and Environment Coalition (SEEC), we write you to express our support for H.R. 3165, the Wind Energy Research and Development Act of 2009. As our Coalition seeks to advance policies for promoting domestic clean energy innovation and job creation, and to move America toward a cleaner, more independent and secure energy future, we feel that this legislation will further these goals by allowing Americans to better harness one of today's cost-competitive and readily accessible homegrown energy resources: wind energy.

A 2008 report published by the U.S. Department of Energy found that domestically-produced wind energy has the potential to supply power for one-fifth of America's electricity demand by the year 2030. This report also concluded that in order to reach this level of power generation, the United States must realize improvements in the reliability and operability of wind systems, and an increase in the American capacity to manufacture wind turbines.

The Wind Energy Research and Development Act of 2009, as proposed by Congressman Paul Tonko of New York and cosponsored by other SEEC members, will ensure the investments in the research and development necessary to increase the efficiency, reliability and capacity of wind turbines, optimize the design and adaptability of wind systems, and reduce the costs of construction, generation and maintenance of wind systems. This legislation will help to ensure that the United States remains a world leader in wind energy technologies, and will help to create a prosperous new clean energy economy that will revitalize our American manufacturing industries.

In order for America to lead the world in the production of the energy technologies of the twenty-first century, and to ensure that the jobs of the future are created here in the United States, the members of the Sustainable Energy and Environment Coalition support investments in the research and development of advanced wind energy technologies. Our Coalition thanks the committee for considering the Wind Energy Research and Development Act of 2009, which will help Americans to take hold of a new energy future.

Sincerely,

The Members of the Sustainable Energy and Environment Coalition

Jay Inslee, Member of Congress
SEEC Co-Chair

Steve Israel, Member of Congress
SEEC Co-Chair

Jim Langevin, Member of Congress
SEEC Vice Chair

Paul Hodes, Member of Congress
SEEC Vice Chair

Jared Polis, Member of Congress
SEEC Vice Chair

Ben Ray Luján, Member of Congress

Mike Honda, Member of Congress

Harvard Business Review
www.hbr.org

Decades of outsourcing manufacturing has left U.S. industry without the means to invent the next generation of high-tech products that are key to rebuilding its economy.

Restoring American Competitiveness

by Gary P. Pisano and Willy C. Shih

Included with this full-text *Harvard Business Review* article:

Reprint R0907S

Restoring American Competitiveness

The Idea in Brief

- Thanks to destructive outsourcing and faltering investment in research, the U.S. has lost or is on the verge of losing its ability to develop and manufacture a slew of high-tech products.
- To address this crisis, government and business must work together to rebuild the country's *industrial commons*—the collective R&D, engineering, and manufacturing capabilities that sustain innovation. Both must step up their funding of research and encourage collaborative R&D initiatives to tackle society's big problems. And companies must overhaul the management practices and governance structures that have caused them to make destructive outsourcing decisions.
- Only by rejuvenating its high-tech sector can the U.S. hope to return to the path of sustained growth needed to pay down its huge deficits and raise its citizens' standard of living.

Decades of outsourcing manufacturing has left U.S. industry without the means to invent the next generation of high-tech products that are key to rebuilding its economy.

Restoring American Competitiveness

by Gary P. Pisano and Willy C. Shih

As the United States strives to recover from the current economic crisis, it's going to discover an unpleasant fact: The competitiveness problem of the 1980s and early 1990s didn't really go away. It was just hidden during the bubble years behind a mirage of prosperity, and all the while the country's industrial base continued to erode.

Now, the U.S. will finally have to take the problem seriously. Rebuilding its wealth-generating machine—that is, restoring the ability of enterprises to develop and manufacture high-technology products in America—is the only way the country can hope to pay down its enormous deficits and maintain, let alone raise, its citizens' standard of living. Reversing the decline in competitiveness will require two drastic changes:

The government must alter the way it supports both basic and applied scientific research to promote the kind of broad collaboration of business, academia, and government needed to tackle society's big problems.

Corporate management must overhaul its practices and governance structures so they no longer exaggerate the payoffs and discount the dangers of outsourcing production and cutting investments in R&D.

The Competitiveness Problem

For much of the past two decades, the stunning growth of the U.S. economy was widely hailed in academic, business, and government circles as evidence that America's competitiveness problem was as obsolete as leg warmers and Jazzercise. The data suggest otherwise. Beginning in 2000, the country's trade balance in high-technology products—historically a bastion of U.S. strength—began to decrease. By 2002, it turned negative for the first time and continued to decline through 2007. (See the exhibit "A Sign of Trouble.")

Even more worrisome, average real weekly wages have essentially remained flat since 1980, meaning that the U.S. economy has been unable to provide a rising standard of living for the majority of its people. This undoubtedly is one reason Americans have attempted to borrow their way to prosperity, a strategy that clearly is no longer tenable.

What, then, was actually happening when it seemed things were going so well? Companies operating in the U.S. were steadily outsourcing development and manufacturing work to specialists abroad and cutting their spending on basic research. In making their decisions to outsource, executives were heeding the advice du jour of business gurus and Wall Street: Focus on your core competencies, off-load your low-value-added activities, and redeploy the savings to innovation, the true source of your competitive advantage. But in reality, the outsourcing has not stopped with low-value tasks like simple assembly or circuit-board stuffing. Sophisticated engineering and manufacturing capabilities that underpin innovation in a wide range of products have been rapidly leaving too. As a result, the U.S. has lost or is in the process of losing the knowledge, skilled people, and supplier infrastructure needed to manufacture many of the cutting-edge products it invented.

Among these are such critical components as light-emitting diodes for the next generation of energy-efficient illumination; advanced displays for mobile phones and new consumer electronics products like Amazon's Kindle e-reader; the batteries that power electric and hybrid cars; flat-panel displays for TVs, computers, and handheld devices; and many of the carbon fiber components for Boeing's new 787 Dreamliner.

A similar trend is undermining the U.S. software industry. Initially, companies outsourced only relatively mundane code-writing projects to Indian firms to lower software-development costs. Over time, as Indian companies have developed their own software-engineering capabilities, they have been able to win more complex work, like developing architectural specifications and writing sophisticated firmware and device drivers.

Equally alarming is the U.S.'s diminished capacity to *create* new high-tech products. For example, nearly every U.S. brand of notebook computer, except Apple, is now designed in Asia, and the same is true for most cell phones and many other handheld electronic devices.

We have heard managers rationalize outsourcing decisions by saying that they can always reverse course if the quality of the work isn't good enough, if the anticipated cost savings prove ephemeral, if supply-chain complexities or risks are too great, or if the work turns out to be more strategic than they originally thought. But this logic overlooks the lasting damage that outsourcing inflicts not only on a firm's own capabilities but also on those of other companies that serve its industry, including suppliers of advanced materials, tools, production equipment, and components. We call these collective capabilities the *industrial commons*.

The World Is Not Flat

Centuries ago, "the commons" referred to the land where animals belonging to people in the community would graze. As the name implies, the commons did not belong to any one farmer. All were better off for having access to it. Industries also have commons. A foundation for innovation and competitiveness, a commons can include R&D know-how, advanced process development and engineering skills, and manufacturing competencies related to a specific technology.

Such resources may be embedded in a large number of companies and universities. Software knowledge and skills, for instance, are vital to an extremely wide range of industries (machine tools, medical devices, earth-moving equipment, automobiles, aircraft, computers, consumer electronics, defense). Similarly, capabilities related to thin-film deposition processes are crucial to sophisticated optics; to such electronic products as semiconductors and disk drives; and to industrial tools, packaging, solar panels, and advanced displays. The knowledge, skills, and equipment related to the development and production of advanced materials are a commons for such diverse industries as aerospace, automobiles, medical devices, and consumer products. Biotechnology is a commons not just for drugs but also for agriculture and the emerging alternative-fuels industry.

More often than not, a particular industrial commons will be geographically rooted. For instance, northern Italy is home to a design commons that feeds, and is fed by, several design-intensive businesses, including automobiles, furniture, apparel, and household products. The mechanical-engineering commons in Germany is tightly coupled to the country's automobile and machine tool industries. The geographic character of industrial commons helps to explain why companies in certain industries

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tend to cluster in particular regions—a phenomenon noted by Michael Porter and other scholars. Being geographically close to the commons is a source of competitive advantage.

What about the popular notion that distance and location no longer matter, or, as Thomas Friedman put it, "The world is flat"? While we agree with the general idea that geographic boundaries to trade are falling and that the global economy is more intertwined than ever, the evidence suggests that when it comes to knowledge, distance does matter. Detailed empirical work on knowledge flows among inventors by our HBS colleague Lee Fleming shows that proximity is crucial. An engineer in Silicon Valley, for instance, is more likely to exchange ideas with other engineers in Silicon Valley than with engineers in Boston. When you think about it, this is not surprising, given that much technical knowledge, even in hard sciences, is highly tacit and therefore far more effectively transmitted face-to-face. Other studies show that the main way knowledge spreads from company to company is when people switch jobs. And even in America's relatively mobile society, it turns out that the vast majority of job hopping is local.

This helps to explain why commons persist in specific locations in an era when huge amounts of scientific data can be accessed easily from anywhere. For example, even though virtually all the raw data from the Human Genome Project, the decade-plus effort to map the human genome, is available electronically all over the world, the drug research it has generated is heavily concentrated in the Boston, San Diego, and San Francisco areas.

Once an industrial commons has taken root in a region, a powerful virtuous cycle feeds its growth. Experts flock there because that's where the jobs and knowledge networks are. Firms do the same to tap the talent pool, stay abreast of advances, and be near suppliers and potential partners. The Swiss pharmaceutical giant Novartis, for instance, chose to move its research headquarters from Basel, Switzerland, to Cambridge, Massachusetts, to be close to universities and research institutes that are global leaders in biosciences and the hundreds of biotech firms already in the area. And its presence, in turn, has increased the Boston area's pull on yet more firms and individuals. These dynamics make it difficult for other regions that do not yet have a vibrant biotechnology commons to attract biotech companies, even with generous incentives.

Our research on the semiconductor, electronics, pharmaceutical, and biotech industries has found that commons are even more important to countries' and companies' prosperity than is generally believed. That's because innovation in one business can spawn whole new industries.

A historical example is the birth of the modern pharmaceutical industry. It began in the late 1800s in Switzerland and Germany because the earliest drugs were based on synthetic dye chemistry and the two countries were home to large chemical companies with strong research labs and deep technical expertise in synthetic dye production.

A current example is the solar panel industry, which is booming in Asian countries such as India, Japan, Taiwan, Korea, and especially China. India owes its position to Moser Baer, a leading manufacturer of optical storage media, which used its capabilities in thin-film coating and manufacturing to move into solar panels. China's, Japan's, Taiwan's and Korea's successes stem, at least in part, from their deep expertise in processing ultrapure crystalline silicon into wafers and applying thin films of silicon onto large glass sheets—capabilities developed by their semiconductor foundries and their manufacturers of flat-panel displays. (China has another advantage: It is the production base for the mundane components like power semiconductors, controllers, and housings that are needed to produce full panels.)

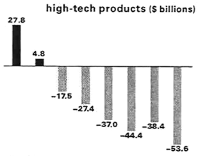
Although the U.S. still produces about 14% of the world's photovoltaic cells, it no longer is a significant player in crystalline silicon–based solar panels, the prevailing technology. Some U.S. manufacturers such as Tempe, Arizona–based First Solar are trying to become players in thin-film solar, the newest technology. But the decline of the domestic infrastructure in thin-film deposition and electronics manufacturing puts them at a big disadvantage.

Erosion of the Commons

When a major player in an industry outsources an activity, cuts funding for long-term research, and gains a short-term cost advantage, competitive pressure often forces rivals to follow suit. As potential employment opportunities shrink, experienced people change jobs, moving out of the region, and students shy away from enter-

A Sign of Trouble

The U.S. trade deficit in high-tech products ($ billions)



Note: Sectors included are: biotechnology, life sciences, optoelectronics, information and communications, electronics, flexible manufacturing, advanced materials, aerospace, weapons, nuclear technology, and computer software.

Source: National Science Board, "Science and Engineering Indicators 2008"

Why Amazon's Kindle 2 Can't Be Made in the U.S.

The Kindle 2 e-reader was designed by Amazon's Lab126 unit in California. The vast majority of its components are made in China, Taiwan, and South Korea, and it is assembled in China, a center for such work.

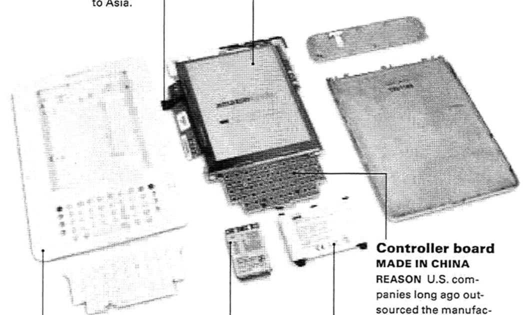


Photo courtesy of ifixit.com

ing the field. Eventually, the commons loses a critical mass of work, skills, and scientific knowledge and can no longer support providers of upstream and downstream activities, which are, in their turn, forced to move away as well. This is what happened to the industrial commons serving a number of high-tech sectors in the United States.

Consider the commons supporting the personal computer industry in the United States. In the late 1980s, original equipment manufacturers in the United States initially began to outsource the assembly of printed circuit boards to specialist contractors in South Korea, Taiwan, and China. These specialists offered significant cost savings, partly because of their location in low-wage countries and partly because of the economies of scale they achieved by serving lots of OEMs. The OEMs understandably didn't see the move as strategically risky because they held the critical intellectual property and design skills (they provided the contractors with detailed specifications) and because manufacturing the boards wasn't a source of competitive advantage.

Ferocious competition and razor-thin margins, however, prompted many of the contractors, particularly those in Taiwan, to seek higher-value-added work. They persuaded the OEMs to allow them to assemble a greater share of the overall product, and from there they moved into complete product assembly.

Going...Going...Gone

Many high-tech products can no longer be manufactured in the United States because critical knowledge, skills, and suppliers of advanced materials, tools, production equipment, and components have been lost through outsourcing. Many other products are on the verge of the same fate.

Semiconductors

Already Lost

"Fabless" chips

At Risk

DRAMs

Flash memory chips

Lighting

Already Lost

Compact fluorescent lighting

At Risk

LEDs for solid-state lighting, signs, indicators, and backlights

Electronic displays

Already Lost

LCDs for monitors, TVs, and handheld devices like mobile phones

Electrophoretic displays for Amazon's Kindle e-reader and electronic signs

At Risk

Next-generation "electronic paper" displays for portable devices like e-readers, retail signs, and advertising displays

Energy storage and green energy production

Already Lost

Lithium-ion, lithium polymer, and NiMH batteries for cell phones, portable consumer electronics, laptops, and power tools

Advanced rechargeable batteries (NiMH, Li-ion) for hybrid vehicles

Crystalline and polycrystalline silicon solar cells, inverters, and power semiconductors for solar panels

At Risk

Thin-film solar cells (the newest solar-power technology)

Computing and communications

Already Lost

Desktop, notebook, and netbook PCs

Low-end servers

Hard disk drives

Consumer-networking gear such as routers, access points, and home set-top boxes

At Risk

Blade servers, midrange servers

Mobile handsets

Optical-communication components

Core network equipment

Advanced materials

Already Lost

Advanced composites used in sporting goods and other consumer gear

Advanced ceramics

Integrated circuit packaging

At Risk

Carbon composite components for aerospace and wind energy applications

Nearly every U.S. brand of laptop and cell phone is not only manufactured but designed in Asia.

Given that many of the components were also sourced from Asia, a logical next step was to take over the management of the supply chain from their American customers.

Then came design. Initially, these firms took over design-engineering tasks on a contract basis. The OEM typically would still provide the high-level conceptual design and specifications, contracting with the Asian supplier to do the detailed engineering. Eventually, though, the suppliers took over those activities as well for products like notebooks, which require designers to interact frequently with manufacturing. The result: These "original design manufacturers," as they describe themselves, ended up designing and manufacturing virtually all Windows notebook PCs.

The standout exception is Apple, whose design capability in the U.S. for both notebook computers and consumer electronics has been critical to its success. Although Apple has outsourced the manufacture of its notebooks, iPod, and iPhone, it has been able to preserve a first-rate design capability in the States so far by remaining deeply involved in the selection of components, in industrial design, in software development, and in the articulation of the concept of its products and how they address users' needs. But for how long can it continue to do so? Given the perennially ruthless competition Apple faces and the continuing migration of design capabilities away from the U.S. to Asia, Apple's challenges promise to increase.

After a contractor has evolved into an ODM, there's little to prevent it from launching its own brand and becoming a competitor to its OEM customers. That's exactly what happened in consumer electronics, where U.S. pioneers like RCA and Sylvania in television manufacturing ultimately became nothing more than brands that were traded like playing cards among Asian manufacturers. Most U.S. companies in the notebook PC business now seem headed for the same fate.

The electronics-outsourcing story exposes several pieces of conventional wisdom as myths. One is the popular belief that an advanced economy like the United States no longer needs to manufacture and can thrive exclusively as a hub for high-value-added design and innovation. In reality, there are relatively few high-tech industries where the manufacturing process is not a factor in developing new—especially, radically new—products.

That's because in most of these industries product and process innovation are intertwined. So the decline of manufacturing in a region sets off a chain reaction. Once manufacturing is outsourced, process-engineering expertise can't be maintained, since it depends on daily interactions with manufacturing. Without process-engineering capabilities, companies find it increasingly difficult to conduct advanced research on next-generation process technologies. Without the ability to develop such new processes, they find they can no longer develop new products. In the long term, then, an economy that lacks an infrastructure for advanced process engineering and manufacturing will lose its ability to innovate.

Another myth is the prevailing view that the migration of mature manufacturing industries away from developed countries like the United States is just part of a healthy, natural process of economic evolution that allows resources to be redeployed to new, higher-potential businesses. We certainly agree that a dynamic global economy leads to shifting patterns of production and trade. We also agree that shedding certain activities that no longer provide opportunities for innovation and redeploying resources to others can spur economic growth and raise living standards. If that hadn't occurred in the U.S., its economy would still be largely agrarian and probably quite poor. But this logic has been taken to a dangerous extreme.

It ignores the fact that new cutting-edge high-tech products often depend in some critical way on the commons of a mature industry. Lose that commons, and you lose the opportunity to be the home of the hot new businesses of tomorrow. We mentioned one example earlier: The migration of semiconductor foundries to Asia, which caused a sharp decline in silicon-processing and thin-film-deposition capabilities in the U.S., greatly reducing, if not eliminating, its chances of becoming a major player in solar panels.

Another example is batteries for hybrid and electric vehicles like GM's forthcoming Chevy Volt. The Volt's lithium-ion battery—the highest-value-added component in the car—will be manufactured in South Korea. GM had no choice but to look abroad. Rechargeable-battery manufacturing left the U.S. long ago. Why? Most innovation in batteries in recent decades has been driven by the increasing demands of consumer electronics products for more and more power in smaller and smaller packages. When U.S. companies largely abandoned the "mature" consumer electronics business, the locus of R&D and manufacturing—not just for the laptops, cell phones, and such but also for the batteries that power them—shifted to Asia. Yes, there are some efforts (including one by General Electric–backed A123Systems) to resurrect rechargeable-battery manufacturing in the United States. But given the state of the U.S. commons relative to Asia's, players like A123 face an uphill battle.

So do U.S. automakers. Japan's and South Korea's strong battery and car industries give them an advantage over U.S. companies in developing electric and hybrid cars. And, as the *New York Times* reported in April, China's leaders want to make their country one of the world's top producers of hybrid and all-electric cars within three years. Chinese battery maker BYD has announced plans to begin selling hybrid and electric cars in the United States and Europe in 2011.

Restoring the Commons

During the 1980s and early 1990s, when outsourcing by U.S. firms and inroads by Japanese companies last raised concerns about U.S. competitiveness, there was heated debate about the remedies. Some called for Washington to follow the lead of Japan's Ministry of International Trade and Industry and provide special support for important industries. Others exhorted American companies to stop outsourcing for patriotic reasons. Neither of these recommendations is a realistic way to preserve U.S. competitiveness and jobs.

As Robert Reich astutely pointed out nearly 20 years ago in his provocative article "Who Is Us?" (HBR, January–February 1990), the national identities of large corporations have become meaningless. Given the realities of global competition and capital market pressures, it is too much to expect executives to demonstrate an allegiance to a particular location merely because it is their company's nation of origin. Nor does it make sense for Washington to favor multinationals that happen to be headquartered in the United States and discriminate against foreign-based corporations that run large operations in the country; both sets of companies are important contributors to the American economy.

That said, it is in the interests of Washington and all companies that operate in the U.S. to work together to reinvigorate the country's industrial commons. Washington's interest is obvious: to revitalize the all-important high-tech sector. Why should companies care? America is an important market. If a company, regardless of its nationality, is a player there, building or sustaining local capabilities is in its interest. Beyond that, a commons, regardless of where in the world it's located, can be a source of long-term competitive advantage for all its members. So whether you're the U.S. firm IBM with a major research laboratory in Switzerland or the Swiss company Novartis operating in the biotech commons in the Boston area, sacrificing such a commons for short-term cost benefits is a risky proposition.

We don't claim to have an elaborate master plan for repairing the U.S. commons. But especially at a time when Washington's efforts to save the banks and the U.S. auto industry are reigniting the industrial policy debate, we think it would be helpful to challenge some widely held perceptions about government involvement, suggest ways to learn from programs that worked in the past, and offer some ideas on what management needs to do.

What Government Should Do

All too often, the debate about what role Washington should play in supporting innovation degenerates into a battle between two extremes: the laissez-faire camp and advocates of centralized industrial policy. Listening to them, you'd think there could be no middle ground.

History says otherwise. While the U.S. has perhaps the most market-oriented economy in the world, federal and, to a lesser extent, state governments have long played a central role in supporting technological innovation. In the early twentieth century, the agricultural experiment stations created by state governments were instrumental in spawning innovations like hybrid corn that enormously boosted agricultural productivity. In the 1950s and 1960s, the Department of Defense spurred innovation in semiconductors through procurement and targeted research programs. In the 1960s through the 1980s, DOD- and NASA-sponsored research contributed heavily to building American science and engineering capabilities in chip design, aeronautics, and satellite communications.

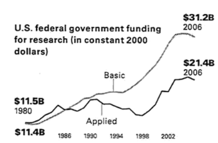
Not all government programs have been successful, of course. The supersonic transport program of the 1960s and the thermal solar and synthetic fuels initiatives in the late 1970s and 1980s are examples of failures. In general, government has been effective in its support for innovation when it has acted as a customer seeking a solution to a concrete, compelling need or when it has been a patron of basic or applied research that has the potential for broad application. Conversely, its support of innovation has generally failed when it has not had a user's stake in the outcome or when it has bet on unproven technical solutions that required extensive knowledge of commercial applications or market realities that it lacked. With this in mind, we offer three broad suggestions for what Washington should do to rebuild the industrial commons:

Reverse the slide in the funding of basic and applied science. Innovative activities can be grouped into three broad categories, whose boundaries are admittedly a bit blurry. *Basic scientific research* seeks to deepen our understanding of first principles, such as the genetic mechanisms that regulate how cells grow and divide. *Applied research* seeks to extend that knowledge to answer more specific questions about real-world problems, like which particular genes are involved in cancer. And *commercial R&D* focuses on finding marketable solutions—for example, discovering, developing, and testing a drug to treat a certain type of cancer. We can think of applied research as the bridge between basic research and commercial R&D.

Washington has long been the main supporter of basic research in the U.S. and a major provider of funding for applied research. No country, in fact, has invested more in basic research since the end of World War II than the United States, and three-quarters of the funding has come from the federal government. Through such agencies as the National Science Foundation and the National Institutes of Health, Washington has spent an inflation-adjusted total of $1.2 trillion since 1953. By funding knowledge, supporting skilled scientists and technical personnel, and underwriting vibrant research universities that have acted as magnets for the laboratories of private enterprises, this support has been a vital stimulus for commercial innovation in the United States. (We can't emphasize enough the importance of world-class universities in building a commons. Silicon Valley would never have become what it is without the presence of universities like Stanford and Berkeley.)

But while U.S. government funding for basic scientific research, adjusted for inflation, grew at a healthy pace through the 1990s, it began to drop in 2003 and has been flat or declining slightly since then. That's a worrisome trend.

Government funding for applied research has declined even more sharply. Historically, federal funding was split relatively evenly between basic and applied research, reflecting their equal importance. However, since around 1990, that has no longer been the case: Government funding for applied research declined 40% from 1990 to 1998. Even though it then rebounded, it's flattened in recent years and is still way behind funding for basic research (see the exhibit, "A Flagging Commitment to Scientific Research").



Source: National Science Board, "Science and Engineering Indicators 2008"

This is troubling because government support for applied research has been just as important to U.S. industrial competitiveness as its support of basic research. Government-sponsored endeavors that have made a huge difference in the past three decades include DARPA's VLSI chip development program and Strategic Computing Initiative; the DOD's and NASA's support of composite materials work; the NSF's funding of supercomputers and of NSFNET (an important contributor to the internet); and the DOD's support of the Global Positioning System, to mention a handful.

In most instances, these programs required a long-term commitment. Consider the internet, which sprang from a decades-long applied research effort that began in the late 1960s, when the federal government's Advanced Research Projects Agency, or

ARPA (later renamed DARPA when it became part of the Department of Defense), issued its first request for proposals to build a four-site computer network. Creating the internet involved little or no new basic science. It did, however, require significant investments in applied research on packet switching, communications protocols, and networking infrastructure—investments that the private sector probably would never have made because the time horizons were too long and the payoffs too difficult for any one company to capture. The way the project spurred collaboration among researchers in an array of companies and universities catalyzed the growth of basic networking-related capabilities, led to innovations such as the multiprotocol router, and resulted in the creation of a number of companies, including Cisco Systems, Juniper Networks, and Extreme Networks.

The U.S. cannot afford to be complacent. Governments in other countries like Singapore, China, Korea, and the United Arab Emirates are intent on fostering growth or building new world-class research universities. They are also investing heavily in applied science, hoping to replicate the success of Taiwan, whose Industrial Technology Research Institute built the foundations for that country's highly successful semiconductor industry.

Focus resources on solving "grand challenge problems." Climate change, a dependence on expensive dirty hydrocarbons, a lack of potable water, the ravages of diseases—these are some of the grand problems plaguing the world that will require fundamental advances in knowledge to solve. Governments are often uniquely positioned to mobilize and coordinate the efforts of the numerous organizations needed to confront these huge challenges. At its peak, for instance, the ARPA networking initiative involved dozens of private companies and universities. Under the purview of the Department of Energy and the NIH, the Human Genome Project involved a similar number of laboratories from around the world.

Such government-sponsored collaborative efforts have two benefits. First, they leverage resources: A dollar spent on research goes much further when the fruits of that spending are shared broadly. Second, they help to create networks of collaborators that cut across academia and industry, which can provide a foundation for an industrial commons.

Unfortunately, the granting process for much of the scientific funding in the U.S. is biased toward lower-risk, incremental projects ("normal science") that fit neatly into established academic fields and is weighted against higher-risk, high-return research that spans disciplines. To address this bias, the peer review process that such agencies as the NSF and NIH employ to award grants must be reformed. Currently, panels of academic scientists, each often composed of individuals from within a single discipline, make these decisions. Instead, groups comprising experts in a range of disciplines from the academic, business, and policymaking communities should be choosing the problems and deciding how best to structure basic and applied research programs to seek solutions. It is especially important for government policy makers involved in these decisions to have strong scientific backgrounds (as they do in Taiwan and Singapore).

Let ailing giants die. Throughout the world, governments have provided significant financial support to industrial companies struck by the economic crisis. As we were writing this article, Congress and the Obama administration were considering whether to give teetering GM more aid or let it go into bankruptcy proceedings. We oppose more support. There are rare instances when companies cannot be allowed to fail because of vital national interests (national security) or systemic effects (the impact that the failure of a big player like AIG or Citigroup would have on the interconnected financial system). Auto companies don't fall into either category.

Advocates of aid to the auto companies have argued that, in addition to preserving the huge number of jobs at those enterprises, a key reason to continue to prop them up is to preserve the supplier base. Lose these giants, they say, and you will lose feeder industries (machine tools, advanced metal fabrication, molding, and so on) crucial to the country's industrial base. We disagree and for two reasons believe that the potential impact on the U.S. commons has been exaggerated.

First, companies that are failing as a result of poor management or misguided strategy often suck the vitality out of the commons in which they participate, and government bailouts almost never succeed in restoring such compa-

Companies that are failing due to poor management or misguided strategy suck the vitality out of the commons.

nies to full health. Indeed, one cause of the U.S. automakers' current predicament is their failure to nurture a strong industrial commons. Several studies have documented a marked difference between the ways U.S. and Japanese companies have managed their supplier bases, for instance. Toyota has always understood the concept of industrial commons. It treats key suppliers as long-term partners, shares development work with them, and sticks with them over the long term. When a Toyota supplier is struggling, Toyota sends in its own people to help. In sharp contrast, U.S. auto companies have generally treated their suppliers as adversaries. They keep them on a tight leash. They offer them only short contracts. They all too often base their purchasing decisions largely on price. When a supplier has a problem, the U.S. auto company's typical response has been to terminate the contract.

Second, the bailout debate (in both the United States and Europe) completely ignores the global nature of the auto business and the contribution foreign-based companies make to the U.S. industrial commons. Not every player in the U.S. auto-manufacturing sector is a basket case. There are plenty of healthy factories. Most of them are owned and operated by foreign-based corporations like Toyota, Honda, Nissan, and BMW. These companies are contributing to the U.S. industrial commons.

If anything, Washington should encourage even more participation in the commons by foreign companies. An immediate case in point: the Fiat-Chrysler deal to save Chrysler. The Italian company has agreed to transfer its technology for producing highly efficient diesel engines to Chrysler in exchange for a substantial minority stake—contributing precisely the kind of clean technology that the Obama administration wants the U.S. to pursue. Ironically, some in Congress opposed the deal because they didn't want to use taxpayer money to benefit a "foreign" company. They just don't get it.

What Businesses Must Do

Government support of basic and applied research can fertilize the soil, but it takes private companies willing to make long-term investments in risky R&D to build a commons. The management challenge is a familiar one of balancing long-term and short-term performance. Here are six suggestions for striking that balance:

Make capabilities the main pillar of your strategy. Companies pour enormous amounts of resources into marketing to build brands. But with the exception of a few industries like soft drinks, brands are only as good as the distinctive products they represent. Creating and making distinctive products requires an array of strong technical, design, and operational capabilities. Given how demanding and sophisticated customers throughout the world have become, marketing cannot cover up weak innovation for long. Apple, Intel, Corning, Amazon, and Applied Materials are companies that understand this. They realize that the only way to stay ahead of competition is to maintain an innovation advantage over the long term, and the only way they can do that is if they invest in new, differentiated capabilities.

Stop blaming Wall Street for short-term behavior. We've heard it over and over again from executives: "We'd love to build capabilities over the long term, but Wall Street, with its relentless pressure to produce ever-higher quarterly earnings, won't let us. We have no choice. We have to outsource." This devil-made-me-do-it defense does not hold up.

When companies promise to increase returns quarter after quarter, that's what Wall Street expects. But when they articulate a credible long-term strategy and demonstrate a capacity to execute that strategy, the capital markets have given them the necessary room to achieve it. In his first letter to the shareholders in the 1997 annual report, Amazon CEO and founder Jeff Bezos explained that his company would take a long-term perspective in its strategy and operating decisions. This message has been consistently reinforced in every subsequent letter. So short-term investors know Amazon is not the company for them. Sure, Amazon's stock has taken some hits now and then when the company has suffered a setback. But Bezos and his team have understood that the stock will rebound, and they have stayed the course.

Recognize the limits of financial tools. Most companies are wedded to highly analytical methods for evaluating investment opportunities. Still, it remains enormously hard to assess long-term R&D programs with quantitative techniques—even sophisticated ones like real-options valuation and Monte Carlo simulations. Usually, the data, or even reasonable estimates, are simply not available. Nonetheless, all too often these tools become the ultimate arbiter of what gets funded and what does not. So short-term projects with more predictable outcomes beat out the long-term investments needed to replenish technical and operating capabilities. Managers would serve their companies more wisely by recognizing that informed judgment is a better guide to making such decisions than an analytical model loaded with arbitrary assumptions. There is no way to take the guesswork out of the process.

Reinvigorate basic and applied research. In the 1980s and 1990s, corporate research laboratories fell out of favor. They were deemed wasteful because many of their efforts could not be linked to the immediate business needs of their companies. Several—including Bell Labs and Xerox PARC, the birthplaces of many critical technologies that underpin important industrial commons—withered, disappeared, or were jettisoned by their corporate parents. Their resources were redeployed to business units.

Companies need to stop blaming Wall Street for their short-term focus. This devil-made-me-do-it defense does not hold up.

It's true that laboratories like PARC generated many inventions that didn't serve the needs of their owners' core businesses. (It's widely known that Xerox was content to let other companies commercialize many of PARC's inventions, like the graphical user interface, Ethernet, and ball mouse.) But the fact that PARC's labs were generating inventions that Xerox's core copier business couldn't use should have told Xerox's executives something: that there were *huge* opportunities outside the core. Their inability to read and react to those signals was the fault of their flawed resource-allocation processes and strategies, not of PARC.

Of course, focused R&D that serves customers' needs is vitally important. But so is the capacity to explore. Recognizing this, a few companies, including IBM and Corning, have maintained strong corporate research capabilities and look to them to spur the next major wave of business opportunities.

Collaborate. While we want large companies to dedicate more resources to basic and applied research, we're not suggesting they return to the days when corporate labs were largely insular places. Rather, they should follow the lead of companies like Corning, IBM, and Novartis, which recognize that their scientists needn't, and shouldn't, go it alone. They understand the value of the commons as a source of research capability.

IBM's leaders, for example, saw that the company could no longer afford on its own to make the investments required to stay on the cutting edge of semiconductor-manufacturing processes. Accordingly, over the past decade Big Blue has built what it calls a "radical collaboration" model in which it and a set of commercial partners share research capabilities and a common manufacturing platform, even though some of them compete downstream. IBM calculates the value of the benefits it receives from this relationship to be five to 10 times the amount it invests.

Create technology-savvy boards of directors. To effectively govern a company whose competitive advantage rests on science and technology, a board needs to have the same feel for technology as it has for finance and accounting. Boards—including those of many American high-tech corporations—are populated with plenty of lawyers, finance and accounting experts, and CEOs from other companies. Scientists are a very small minority. And while many corporations have scientific advisory groups, we have not yet come across one whose board has a science or technology committee. Regulations and good corporate governance call for audit, compensation, nominating, governance, finance, and executive committees. Shouldn't the boards of companies whose competitiveness heavily depends on science or technology also have a committee to ensure that all is well in this area?

• • •

Alfred Chandler, the noted Harvard business historian, described how American companies like DuPont and General Motors gained prominence in the twentieth century by developing and integrating R&D, manufacturing, and marketing capabilities. These enterprises did not create these capacities to be good corporate citizens. They were pursuing competitive advantage, and they understood that these capabilities were essential to that goal. Today, the United States is at an analogous juncture, but the challenge is no longer to create capabilities to manage the large-scale, vertically integrated enterprise of the twentieth century; it is to build anew the technological operational capabilities needed to conceive and produce high-value goods and services. We must recognize that the capacity to undertake advanced process engineering and complex manufacturing is as important to continued innovation as are strong universities and a robust venture capital industry.

If major venture capital firms like Kleiner Perkins and Sequoia Capital announced they were leaving the U.S. to go to, say, India because they saw more profitable investment opportunities there, it would cause an uproar. Outsourcing by high-tech manufacturers should do the same. It's unfortunate that the warning cries of the 1980s and early 1990s were ignored. Much has been lost since then, but it's not too late to rebuild the industrial commons. Only by rejuvenating its innovative capabilities can America return to a path of sustainable growth.

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