STATEMENT OF

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U.S. DEPARTMENT OF ENERGY

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COMMITTEE ON SCIENCE, SPACE AND TECHNOLOGY

SUBCOMMITTEE ON ENERGY AND ENVIRONMENT

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Introduction

Mr. Chairman, Ranking Member Miller, Members of the Subcommittee, thank you for the opportunity to testify on the U.S. Department of Energy's (DOE) Office of Energy Efficiency and Renewable Energy's (EERE) renewable energy and energy efficiency technology development activities.

EERE supports research, development, demonstration, and deployment (RDD&D) activities on technologies and practices important for meeting national goals to become more energy independent, reduce pollution, and spark innovation and entrepreneurship all across America to help us win the global competition for new jobs and new industries. EERE seeks to achieve these goals through the development of alternate technologies that minimize the cost of energy services and that also minimize the emissions associated with energy production and use. The energy efficiency and renewable energy technologies that are the focus of this research are in high demand worldwide and we work to ensure that clean energy innovation stimulated by EERE funding translates quickly into new business growth and new employment in the U.S.

We shouldn't have any illusions that this task will be easy. We face determined and increasingly sophisticated international competition. Nations such as China have carefully crafted plans to acquire the capability to begin low-cost manufacturing of innovative products developed principally by the U.S. in order to take leadership in the clean energy industry. We have lost market share in key parts of the clean energy industry – including production of solar devices and compact fluorescent lights – as well as in other areas. U.S. producers had a 40 percent market share in photovoltaics a decade ago and we're now below 7 percent. But even more troubling, losing U.S. production risks losing the incubators of innovation that begin to surround production of these technologies. We've seen this happen in key industries like electronics – producing flat panel displays, data storage devices, and cell phones. We can't afford to let this happen in clean energy.

Where China has employed unfair, or discriminatory policy tools the Obama Administration has been pressing China to eliminate those policies. For example, in December, pursuant to a section 301 petition filed by the United Steelworkers, USTR initiated a dispute at the WTO challenging Chinese policies in the wind power equipment sector. In June, the Office of the U.S. Trade Representative announced that as a result of this case, China had agreed to end the Special Fund for Wind Power Equipment Manufacturing, a subsidy program which appeared to be prohibited under WTO rules because it granted subsidies to Chinese companies based on the amount of domestic content used in their products. In addition, strong U.S. government and international pressure resulted this year in China's commitment that its innovation policies will not be tied to the provision of government procurement preferences.

But trade policy is just one aspect of the challenge of restoring our competitiveness in these critical sectors—ensuring that we have the right domestic policies in place is equally critical.

The EERE programs I will be laying out for you today are designed to ensure that we not only stem the loss of production and reverse the loss in market share, but also return clean energy manufacturing to the U.S. There's plenty of reason for optimism on this score. Many observers were confident that the U.S. had lost the Lithium-ion battery industry to overseas producers a few years ago. But strategic investments made by the American Recovery and Reinvestment Act

of 2009 (Recovery Act) mean that we're well on our way to establishing the capacity to produce enough batteries and components to support 500,000 plug-in and hybrid vehicles by 2015.

The key to success is encouraging domestic industries that can continually out-innovate and out-compete any country in the world. We measure our success by whether our work translates into a successful U.S. business opportunity – when a company can take a concept developed with EERE funding and make it a commercial success.

We work hard to ensure that the projects we undertake are in the areas of greatest interest to U.S. businesses and insist that industry participate with increasing levels of cost share as basic concepts approach a point where proprietary products emerge. But the industry has been clear that in order to compete with determined foreign competitors who receive strong financial support from their governments, they need the U.S. government to help them in key areas like advanced research, regulations that encourage innovative solutions, and, in some cases, early stage financing for first-of-a-kind production. The blunt fact is that nearly all the key technologies underlying today's clean energy equipment are the direct result of federal research support – including EERE research – made over the past several decades.

This includes:

- The batteries used in all new electric and hybrid vehicles,
- Compact fluorescent light bulbs that use a quarter of the energy of incandescent bulbs, and solid state lights that can use a tenth as much,
- Low emissivity windows that reduce heat conductivity and solar heat gain by at least 50 percent compared to standard windows and now represent over 50 percent of the windows sold in the U.S., and
- New processes with the potential to turn cellulose into cost effective biofuels.

For more examples of EERE accomplishments see Appendix 1.

The challenges we face mean that we have to build on these successes and move with unprecedented speed and scale. Well-crafted federal programs are essential to spurring private innovation and investment. EERE works in close collaboration with other DOE organizations that have distinct but related missions – including the Loan Guarantee Office, the Advanced Research Projects Agency-Energy (ARPA-E), and the Office of Science (SC). We also work closely with other Federal agencies and State and local governments.

Working together, we can look forward to meeting key goals such as:

- Doubling the share of electricity from clean energy sources by 2035.
- Putting one million electric vehicles on the road by 2015 through improved consumer incentives, new investments in R&D to advance batteries and other innovative technologies, and by encouraging communities to streamline codes and regulations and to invest in advanced vehicle infrastructure.
- Making our buildings more energy efficient, including reducing commercial buildings' energy use by 20 percent by 2020 through a Better Buildings Initiative that will ultimately reduce energy bills for American businesses.
- Rendering solar energy, offshore wind energy, and geothermal plants competitive with conventional sources of electricity without subsidy;

- Advancing biofuels that can be drop-in replacements for gasoline, diesel fuel, or jet fuel, priced competitively with products produced from petroleum;
- Ensuring that 100 percent of federal fleet acquisitions be advanced vehicles by 2015 as called for by President Obama's Executive Order 13514;
- Improving the fuel economy of our cars and trucks through historic fuel economy standards; and
- Continuing to create new jobs in growing industries that support a clean energy economy.

Because of the importance of these technologies to our future, the President's FY 2012 Budget requests an increase in funding for energy efficiency and renewable energy, even as it seeks to reduce overall domestic discretionary spending to the lowest levels in a generation.

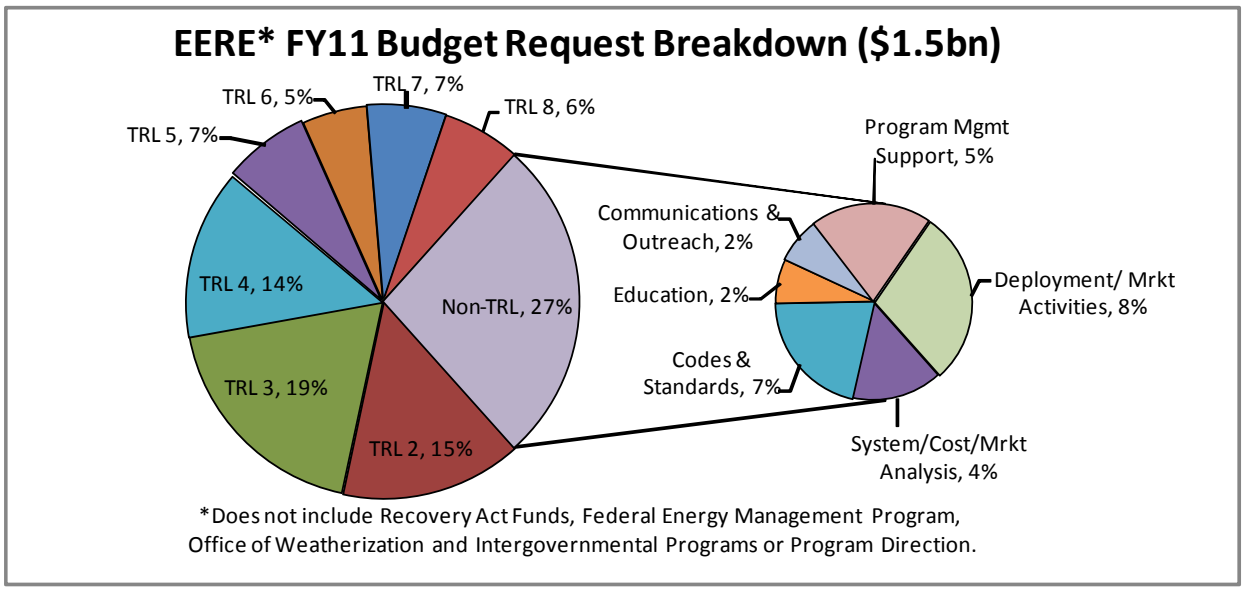
SETTING EERE PRIORITIES

EERE's strategic and research priorities were developed after a careful appraisal of where federal intervention could have the greatest leverage in meeting the Nation's energy security and environmental goals. This means taking a broad look at how the U.S. uses energy, and cost-effective ways we could reduce the energy used to deliver the services that enable transportation and comfortable homes and businesses. It also means finding the most cost effective ways to produce electricity and fuels from renewable resources. We want to be certain that the areas where we're working will have a major impact and we want to be certain that what we're doing fills critical gaps in what U.S. industry can do on its own.

A key theme in setting research priorities is finding ways to reduce the cost of renewable energy and efficiency technologies to the point where they can compete at current energy prices with no subsidies. We carefully consult with stakeholders, including industry groups, in each important technical area, often holding multiple workshops to understand both where research opportunities are greatest and where industry investment is likely to fall short of national needs because the risks are too high or because it is difficult for any single industry to capture the benefits of the research in ways that meet their tests of profitability. We include university and other research specialists in these discussions so that we can clearly understand where our research funds can be most productive. Often these workshops are conducted in collaboration with ARPA-E and SC.

EERE has begun to characterize its research activities using the Technology Readiness Levels (TRLs) that have been used by the Department of Defense and NASA for many years. TRLs assess the maturity of evolving technologies prior to commercialization. TRLs range from Basic Research (TRL 1) to System Proven and Ready for Full Commercial Deployment (TRL 9). EERE funds activities from Applied Research (TRL 2) through System Incorporated in Commercial Design (TRL 8). EERE does not work at all on basic research (TRL 1), which is exclusively an SC and National Nuclear Security Administration function in DOE, or on full commercial deployment (TRL 9) which is the domain of the Loan Guarantee Program. (***See Appendix 2 for detailed definitions).***

Figure 1:



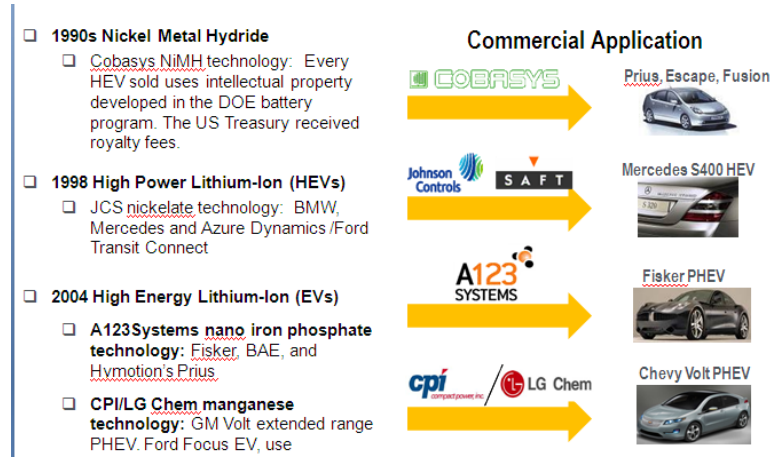
We use TRLs to describe the distribution and balance of applied research, technology development, and demonstration activities in our programs, and to determine the level of private cost sharing that is appropriate for our RD&D projects. As seen in Figure 1, about 55 percent of EERE's work is on research and development (levels 2-5), and 17 percent of our work is on demonstration projects (TRLs 6-8).[1] Twenty-seven percent of EERE's work is on non-TRL activities such as program management, codes, standards, and market analysis. Early stage R&D makes up 34 percent of our work. Each program works with its industry advisors to understand the appropriate TRL balance – a mix that serves one program may not work for another.

Our multi-year roadmaps outline plans for developing technologies and moving research from concepts in a laboratory to systems that can be entirely funded from private equity and loans, with federal funding terminating. For example:

- Our vehicles program has funded a series of battery technologies that have entered the market (see Figure 2). Our programs today focus on technical advances in Lithium-ion batteries that will power the next generation of hybrids and electric vehicles and we have begun exploring the role that EERE can play in advancing a generation of technologies beyond Lithium-ion that are currently under initial development through ARPA-E programs.
- Our wind program played an instrumental role in creating a commercial land-based wind industry and our emphasis today is focused almost entirely on the dramatically new class of technologies needed for cost-effective offshore wind (many of which are also expected to help land-based wind).
- Our biomass program is approaching its program goals for making cellulosic ethanol competitive and is directing increasing amounts of research to the next generation of technologies to permit production of jet fuels, diesel, and direct drop-in gasoline substitutes that do not face blend limits. We are working closely with DOD and USDA on this research.

[1] The TRL breakdown for the 2011 Continuing Resolution has not yet been compiled, and cannot be fully known until all of our Funding Opportunity Announcement selections have been finalized.

Figure 2: Battery Technology



EERE also works to identify barriers to the introduction of new renewable energy and energy efficiency technologies that can be addressed at the federal level. Many of these barriers slow or block the introduction of new energy efficiency and renewable energy technologies even when they are cost effective. Each technology faces its own set of barriers and solutions. For example, the challenges for moving solar technologies into utility markets will be different from those for moving next-generation heat pumps into building markets. While not an easy task, we're estimating the real economic costs of things like permitting delays and setting goals in these areas equivalent to the research goals. Work to address these goals includes developing appliance standards, developing model building codes, improving consumer information by providing test methods that lead to labels like Energy Star and Energy Guide labels, supporting the streamlining of regulatory and permitting processes, and helping provide funding for first-of-a-kind, high-risk production facilities. EERE also has a mandate to help all federal agencies meet the goals for clean energy use established in legislation and in executive orders issued under several presidents.

Collaboration within the DOE and other Federal Organizations

EERE works in close partnership with other DOE programs and offices (see Table 1). SC advances fundamental science underpinning a wide range of energy technologies. EERE's mission is to develop systematic roadmaps for reducing the cost of efficiency and renewable technologies and streamlining their movement into commercial markets. ARPA-E's focus is on high risk technologies that have the potential to transform an energy market with a bold innovation.

The battery example mentioned above offers a good illustration of how the organizations successfully work together and build on each other's work:

- SC developed the underpinning science that governs the mechanisms of ion and charge transport, chemical reactions, and structural changes in the electrodes, electrolytes, and

interfaces of advanced energy storage systems. In addition, SC-supported user facilities were essential for performing these studies and characterizing the materials and physical phenomena associated with these systems. The discoveries made by SC-supported researchers in the science related to Lithium-ion storage devices advanced the technology to the point where its applications in the marketplace could be explored in earnest.

- EERE built on SC's discoveries to design practical Lithium-ion components and devices. Through R&D, EERE is finding ways to meet the cost, safety, and performance standards required for a commercial product. For example, there are three different cathode materials that EERE helped develop and commercialize. EERE research also developed the battery cell technology (cell design, electrolytes and anode materials) for each of these cathode materials. Most new hybrid and electric vehicles use technology that went from SC through EERE, using these cathode materials. A very recent example is a new manganese spinel cathode technology, which is being used in extended-range electric vehicles. It has also been selected for use in hybrid drive heavy vehicles.
- In parallel with these efforts ARPA-E is researching radically distinct approaches to energy storage. For example, it is supporting Envia's System's efforts to develop advanced high capacity silicon-carbon nano-composite anodes to produce the world's highest energy density Lithium-ion batteries. If successful this anode technology would move quickly into commercial production. ARPA-E is also exploring other high risk, breakthrough projects that could create an entirely new generation of ultra-high energy density, low-cost battery technologies for long-range (300 to 500 miles) plug-in hybrid electric vehicles (PHEVs) and electric vehicles (EVs) from technologies such as metal-air (lithium-air, zinc-air, etc.) battery devices. Projects include using lithium air systems that can deliver as much energy as a tank of gasoline, and systems that may be able to provide cars with energy for up to a 500 mile range.

We are continuing to improve coordination between SC, ARPA-E and EERE in a plan that builds on the strengths of each organization, while ensuring there is no overlap in efforts. The SunShot project, which has a goal to reduce the total cost of installed solar systems by 75 percent by the end of the decade, enabling solar electricity to be broadly competitive with electricity from conventional generation sources without subsidies, is another good example. We developed a joint research and development (R&D) plan that goes from the basic research supported by SC to the integrated demonstrations that will be supported by EERE, while ARPA-E has a major program in power electronics and will take the lead in supporting innovations in that field. One recent outcome of this collaboration was the decision that organic photovoltaic cells were generally not mature enough to be included in EERE's portfolio and that fundamental research into organic photovoltaic materials and processes should be supported by SC.

As another example, the central mechanism for coordination of battery and energy storage-related R&D efforts is the DOE-wide Energy Storage Working Group. Representatives from each program supporting batteries or other energy storage research participate in the group, including EERE, the Office of Electricity Delivery and Energy Reliability, SC, and ARPA-E. The group's primary functions are coordination of current research, strategic planning, and linking existing researchers to facilitate information sharing and coordination across the basic science/technology-deployment continuum. This group meets regularly and supplements the collaboration between the various programs, which has included joint workshops, mutual

participation in peer reviews, cooperation/coordination of Small Business Innovative Research Program solicitations, and joint principal investigator meetings. All of these actions ensure a thorough mutual understanding of the work funded by each office and drive proper delineation and separation of research and goals, minimizing duplication while leveraging resources and expertise among individual programs.

Table 1: Examples of EERE collaboration with other DOE offices

- **Office of Science**: Collaborating to develop synthetic-biology tools to enhance national capabilities in biomanufacturing. Advances in nanotechnology and other new materials developed in the Office of Science are moved to advanced product concepts in areas including photovoltaic devices and solid state lighting. EERE works to ensure that SC is aware of areas where a breakthrough could cut costs or improve efficiency of key devices.
- **Advanced Research Projects Agency- Energy**: Collaborating to achieve SunShot objectives for power electronics and PV, design the buildings hub, and develop advanced biofuels feedstock.
- **Office of Electricity Delivery and Energy Reliability**: Close collaboration on utility policy and regulations for encouraging energy efficiency and on analysis showing how new transmission, smart grid technologies, energy storage, and other advances will facilitate introduction of renewable energy.
- **Fossil Energy**: Collaboration on design of facilities that burn mixtures of coal and biomass, and on analysis of risks of induced seismicity in geothermal energy generation.
- **Loan Guarantee**: Bolsters the development and deployment of renewable sources of energy like wind, biomass, geothermal and solar by supporting innovative renewable energy projects.
- **FERC**: Key partner for analyzing transmission and other needs associated with rapidly expanding use of wind and solar.

Pending new start approval from the Appropriations Committees, the Department is seeking to fund a Batteries and Energy Storage Hub in FY 2011.[2] Funding for the Hub is also proposed under the President's FY 2012 budget. The Hub would provide a nucleus of activity for the entire fundamental energy storage research community. Establishing a focused energy storage research effort with the size, scope, and duration of an Energy Innovation Hub would garner long-term commitment from the most innovative researchers in this field. The Energy Storage Working Group would help facilitate the flow of data and information from the technology programs to the Hub, and to ensure integration within the broader DOE-supported community, the Hub would be a full participant in principal investigator meetings focused on energy storage and related scientific topics.

[2] The Department has established three Energy Innovation Hubs in the areas of energy efficient buildings, modeling and simulation for nuclear reactors and fuels from sunlight. Three new hubs are proposed for establishment under the President's FY 2012 budget, in the areas of batteries and energy storage, smart grid technologies and systems, and critical materials. The Energy Innovation Hubs were modeled after the Department of Energy's BioEnergy Institutes, which have established an outstanding three-year track record for innovation.

To further accelerate the development and adoption of renewable energy and energy efficiency technologies, EERE also works closely with other Federal agencies with relevant resources and authorities (see examples in Table 2). These include federal procurement offices that can provide early markets for innovative technologies, regulatory and loan authorities, regulatory programs, and many others.

The Department is also committed to regularly engaging with other agencies about program activities in order to prevent interagency overlaps. For example, regarding biomass-related activities, DOE regularly coordinates through the Biomass Research and Development Board,[3] which is an interagency collaborative composed of senior decision-makers from federal agencies and the White House – including DOE and USDA (co-chairs); the Departments of the Interior, Transportation, and Defense; the Environmental Protection Agency; the National Science Foundation; and the White House Office of Science and Technology Policy. The Board is charged with maximizing the benefits of federal programs and bringing coherence to federal strategic planning in biomass R&D, including minimizing duplication of activities. Several other interagency formal and informal collaborations function to leverage existing expertise across agencies with similar missions and goals, such as Memoranda of Understanding (MOUs), regular working group meetings, joint solicitations, and other mechanisms. Examples of MOUs signed over the last two years include one on hydropower with the Army Corps of Engineers and the Interior Department; one on off-shore wind, marine and hydrokinetic devices with the Interior Department; and an updated MOU with EPA on Energy Star.

EERE's Federal Energy Management program provides support to all federal agencies to help them meet clean energy goals established by statute and a number of Executive Orders.

In many cases, accelerating the adoption of renewable energy and energy efficiency technologies can best be undertaken through programs that work with entities at the state and local level. One such program is the Energy Efficiency and Conservation Block Grant (EECBG) and State Energy Program's (SEP's) Technical Assistance Program (TAP), the goal of which is to provide EECBG and SEP recipients with resources needed to swiftly implement successful and sustainable clean energy programs. TAP offers direct assistance, aggregated assistance and facilitated peer exchanges that allow groups of grantees to work together on specific issues. Over 230 grantees have identified themselves as willing to mentor another grantee on a particular topic of expertise, and over 75 grantee to grantee technical assistance transactions have already occurred. For example, 10 Rhode Island towns are working together on energy savings performance contracting. This ensures that best practices quickly propagate.

[3] The Board, as well as the Technical Advisory Committee and the annual solicitation, were established by the Biomass Research and Development Act of 2000, as later amended by Section 9001 of the Food Conservation and Energy Act of 2008.

Table 2: Examples of EERE Collaboration with other Federal Agencies

- **EPA:** Collaborating on Energy Star and other issues. DOE testing provides essential data for E15 rule. Collaboration on advanced fuels/engine research and testing. Collaboration on siting of renewables on brownfields. Collaborating on renewable energy and energy efficiency initiatives in Puerto Rico and U.S. Virgin Islands. Collaborating to release the Fuel Economy Guide and keeping www.fueleconomy.gov up to date.
- **HUD:** Under a memorandum of understanding DOE works closely with HUD on energy retrofit efforts. This has included supporting HUD in the crafting of the new PowerSaver home loan program for energy upgrades and collaborating on healthy homes issues.
- **USDA:** Collaboration on biomass feedstock. Collaborating on the Biomass Research & Development Board. Collaboration on the pilot of the Home Energy Score.
- **DOI:** Collaboration on permitting and other regulatory issues associated with siting renewables and transmission lines. Co-funding hydropower, marine-hydrokinetic, offshore wind projects, and wind projects in the Great Lakes. Supporting alternative fuel and advanced technology vehicle use and visitor education in National Parks.
- **DOD:** Key collaborator on demonstrations and procurement. Collaborate on siting renewable energy projects in a manner compatible with military mission. Partner in development, demonstration, and deployment of new energy technologies. Collaborating on working groups with the Department of Navy on biofuels, energy efficiency and others. Co-developer of technology to power DOE's National Training and Education Resource. Implementing DOD Energy Strategies from OSD and each of the armed services.
- **USACE:** MOU on assessing renewable energy generation from Federal hydropower facilities and developing best practices to increase sustainable generation. Collaborating on permitting wind in the Great Lakes.
- **DOC:** The International Trade Administration, Office of Energy and Environmental Industries co-leads with EERE and works with other agencies to implement the Renewable Energy and Energy Efficiency Export Initiative. MOU with NOAA to enhance the accuracy, precision, and completeness of resource information for the effective deployment, the safe, reliable and sustainable operation and maintenance, and the efficient use of weather-dependent and oceanic renewable energy technologies and infrastructure.
- **CEQ**: Collaboration on permitting and siting renewables and transmission lines. Collaborating on the National Ocean Council. Partner in the Recovery Through Retrofit Initiative and on green school efforts.
- **NIST:** Partner on innovation in manufacturing and outreach to upgrade manufacturing enterprises.
- **SBA:** Partner in devoting $500 million per year for five years for energy saving activities through Small Business Investment Companies.
- **DOS:** Partner in planning U.S.-led clean energy initiatives for the Clean Energy Ministerial. Partner on clean Cookstoves Initiative. MOU to transform the way the Department of State practices energy management at diplomatic and consular missions overseas.
- **DOL:** Collaborating on developing Workforce Guidelines for Home Energy Upgrades. Partner on DOE energy efficiency training program accreditation and worker certification.
- **NEC:** Collaborating on Advanced Vehicle Working Group. Collaborating on the Energy Regional Innovation Cluster.
- **FTC:** Collaborating to revise Energy Guide label, and supporting greenhouse gas information inclusion in appliance labeling.

Conclusion

EERE's strategic priorities and R&D portfolio are designed to help put the U.S. on the path to meet its energy, environmental, and national security goals, and to ensure that U.S. businesses and U.S. workers enjoy the benefits of a rapidly growing national and international market for energy efficiency and renewable energy products and services. If we do not move boldly and quickly in these areas, this opportunity will be lost to foreign producers. The recent surge of private investment in domestic manufacturing of wind turbines, batteries, lighting products, and many other renewable energy and energy efficiency products in the U.S. gives us good reason for optimism. We can out-invent and out-compete any nation in the world, but only if we are willing to sustain the kinds of private/public partnerships that have driven so much of American innovation in the past – innovations that are now at the core of our economy.

Thank you very much, and I will be happy to answer any questions Members of the Subcommittee may have.

Appendix 1

RECENT EERE ACCOMPLISHMENTS

Biomass Program:

- Supported 29 innovative biorefineries, which are projected to contribute at least 100 million gallons of advanced biofuels by 2014, and for which each DOE dollar leverages $1.70 in private funding. Most of these biorefinery projects are either in construction or will be by the end of 2011.
- Validated sustained operations at a cellulosic ethanol biorefinery with 1.4 million gallons per year (MGY) capacity.
- Completed ethanol blend testing for vehicle model years 2001 and newer, supporting U.S. Environmental Protection Agency waiver decisions on E15 in 2010 (for model years 2007 and newer) and 2011 (for model years 2001 – 2006)
- Helped reduce feedstock logistics costs from $46 per dry ton to $38 per dry ton (on an oil-equivalent basis, about a $10 – 15 per barrel reduction in feedstock costs).

Building Technologies Program:

- Issued ten appliance standards since January 2009 that will save customers a projected $250-300 billion in electricity costs by 2030.
- Developed one of the largest gains in an energy efficiency standard within a single code cycle. Working with American Society of Heating, Refrigerating and Air Conditioning Energizers (ASHRAE) and the International Code Council, developed ASHRAE Standard 90.1-2010, representing a 30 percent improvement over the previous version and the 2012 International Energy Conservation Code (IECC), also representing a 30 percent improvement over the baseline codes (2006 IECC/AHRAE 90.1-2004).
- Worked with DOE Commercial Building Energy Alliances to develop innovative and high efficiency design specifications for 10-ton capacity commercial air conditioners (rooftop units) that will be used as the basis for procurement by building owners that are about 50 percent of the market for these units. These high-efficiency rooftop units are expected to reduce energy up to 50-60 percent compared with current equipment.
- Working with Whirlpool Corporation to develop 50 percent improvement (relative to Federal minimum standards) in energy efficiency performance in domestic refrigerators, with an estimated cost premium of less than $100.
- Supported research that led directly to a heat pump water heater (HPWH) introduced by General Electric in 2010. This created market ripple effects as A.O. Smith and Rheem met the competitive challenge with HPWH products of their own. The potential energy savings of these products is 0.7 Quads annually.
- Walmart announced this year that all new parking lots, whether domestic or international, would be required to use the DOE performance specification for solid state parking lot lighting.

Federal Energy Management Program:

- Catalyzed an all-time Federal record by facilitating $536 million in investment from federal energy savings performance contracts in FY 2010 that will result in guaranteed savings of over $1.1 billion over the contracts' lifetime.
- Leveraged $13 million in ARRA funds for technical assistance in support of renewable energy and energy efficiency projects with Federal agencies into an investment of $74 million.
- Assisted DOE in:
  - Reducing energy intensity by 17.7 percent (exceeding 2010 15 percent targeted reduction from 2003);
  - Reducing water usage by 12 percent since 2007 (exceeding 6 percent target); and
  - Obtaining 9 percent of electricity from renewables (exceeding 5 percent goal)
- Funded 119 technical assistance projects resulting in $122 million in project work in Federal facilities.
- Trained more than 10,000 federal employees through its First Thursdays Seminars on 6 topics in 2010.

Hydrogen and Fuel Cell Technologies Program:

- Awarded $42 million under ARRA to industry participants who provided approximately $54 million in cost-share funding.

- Supported projects that:
  - Reduced the cost of transportation fuel cells by more than 30 percent since 2008 and more than 80 percent since 2002 – to $51/kilowatt (assuming volume production).
  - Demonstrated 152 fuel cell electric vehicles and 24 hydrogen stations – these vehicles have traveled more than 3 million miles, demonstrating up to 2500-hour durability (more than 75,000 miles of driving), up to 59 percent efficiency (more than twice the efficiency of conventional gasoline engines), and a driving range of more than 250 miles. The Program also independently validated an additional vehicle to be capable of 430 miles on a single fill of hydrogen.
  - Improved the performance of stationary fuel cells, including development of a solid-oxide fuel cell for micro-combined heat and power applications with a 24 percent increase in system power density, which has enabled a 33 percent reduction in stack volume and a 15 percent reduction in stack weight.
  - Developed advanced gas diffusion layer manufacturing processes that have reduced cost by more than 50 percent and quadrupled manufacturing capacity since 2008.
  - Made several key advances in renewable hydrogen production technologies, including reducing electrolyzer costs by 80 percent since 2001 and 15 percent in the last year – to $350 per kilowatt (compared to 2012 target of $400 per kilowatt); and demonstrating potential to exceed the 10 percent solar-to-hydrogen efficiency target for photoelectrochemical hydrogen production (greater than 16 percent efficiency observed at lab-scale).

Geothermal Technologies Program:

- In partnership with TerraGen Power, a 2 megawatt low temperature bottoming plant was built and commissioned at Beowawe in northern Nevada. The plant thereby achieves a nearly 20 percent increase in electricial capacity – from about 12 megawatts to 14 megawatts.
- In partnership with Energent Corporation, DOE is developing and field testing a variable phase turbine that has the potential to generate 30% more power from low temperature geothermal resources than current state of the art power conversion technologies. The turbine system will lower the capital cost relative to other low temperature systems by using a liquid heat exchanger instead of a boiler and separator and by directly driving the generator, eliminating the need for a gearbox.
- Demonstrated that geothermal brine can be a source of lithium and other strategic minerals that can be used in batteries.
- Funded 24 resource exploration projects through ARRA to help confirm up to 400 megawatts of new geothermal resources by 2014 and reduce the risks and costs of geothermal exploration.
- Through an FY 2008 award, GE Global Research fabricated an electronics platform which can operate at 300˚C (approximately 570˚F). The technology can convert temperature to frequency without using active cooling or flasking technologies. The silicon carbide based tool will ultimately be able to measure pressure, fluid flow, and down hole tool orientation in addition to temperature.

Industrial Technologies Program:

- Partnered with Yahoo to create a data center operating with 25 percent less energy than conventional designs.
- Supported R&D required to prepare 220 new, energy-efficient technologies for commercial use.
- Provided energy savings assessments and plant optimization software tools and training to more than 33,000 industrial plants over the past ten years.
- Identified $1.6 billion in annual savings from energy assessments conducted at 970 large plants and 1,900 small- and medium-sized facilities through Save Energy Now Audits (as of Jan. 2011).
- 105 companies – including approximately 7 of the top 50 largest U.S. industrial energy consumers –have signed the Save Energy Now LEADER pledge to reduce their energy intensity by 25 percent or more in 10 years.

Solar Energy Technologies Program:

- Supported research through the Photovoltaic Incubator Program that resulted in the production of a world record 27 percent efficient single junction solar cell by Alta Devices.
- Supported research at the National Renewable Energy Lab that beat (by 6.5 percent) a previously held record by demonstrating an 18.5 percent efficient low-indium thin film (CIGS) solar cell.

- Leveraged $1.2 billion in private capital for solar energy start-ups from $59 million of DOE funding since 2007, through earlier rounds of the Incubator program.
- In April 2011, Solar Junction, a current awardee, was certified as having created a 43.5 percent peak efficiency solar cell, the world's most efficient to date.

Vehicle Technologies Program:

- VTP-sponsored R&D enabled engine manufacturers to improve diesel engine efficiency by 5 percent since 2002, which has saved 2.4 billion gallons of diesel fuel worth more than $7.6 billion – more than 60 times VTP's $123 million investment in commercial engine R&D from 1999 to 2007.
- Helped reduce the cost of PHEV Lithium-ion battery to $650 per kilowatt-hour, a 35 percent reduction from the 2008 baseline of $1000 per kilowatt-hour, and on track to reduce cost to $300 per kilowatt-hour by 2015.
- VTP and Argonne National Laboratory developed breakthrough battery technology that has been licensed to multiple users, including GM and its suppliers.
- VTP's Clean Cities initiative has enabled the replacement of approximately 2.4 billion gallons of petroleum since 1993. Through Recovery Act investments, Clean Cities deployed more than 9,000 vehicles that will displace an estimated 38 million gallons of petroleum per year, and installed more than 2,100 new fueling and charging stations.

Water Power Program:

- In partnership with industry, utilities, and city governments, seven new hydroelectric facility upgrades were launched – the first hydropower improvement projects undertaken in over 20 years.
- Funded development of an advanced hydroelectric turbine with dramatically improved fish passage rates without sacrificing power conversion efficiency. By the first quarter of FY 2012, Electric Power Research Institute and Alden Laboratory are expected to install, test and demonstrate that the turbine can generate energy with fish survival rates ranging from 98 percent to 100 percent.
- Awarded 27 cost-shared grants to marine and hydrokinetic technology developers to advance commercial readiness of this emerging technology sector.
- Conducting resource assessments to more precisely quantify the energy generation potential of all U.S. water resources, including conventional hydroelectric supplies as well as new resources derived from waves, ocean/tidal/river currents, and ocean thermal power.
- Executed a Memorandum of Understanding (MOU) between DOE, the Department of Interior, and the Army Corps of Engineers. This new approach to hydropower development aims to increase the production of clean, renewable power while avoiding or reducing environmental impacts and enhancing the viability of ecosystems. The federal agencies agree to focus on increasing energy generation at federally-owned facilities and exploring opportunities for new development of low-impact hydropower.
- Developed three state-of-the art marine and hydrokinetic (MHK) Technology Design Tools that simulate the behavior and performance of MHK device types in complex marine environments (covering tidal/ocean current, and wave resources). These models will identify key cost of electricity drivers and facilitate rapid design optimization and support detailed techno-economic assessment of MHK technologies that is required per Congressional direction.

Wind Power Program:

- Funded wave tank testing of innovative off-shore wind energy technologies by a University of Maine led consortium, resulting in the world's most comprehensive analysis of deepwater floating support structures to date.
- 25 percent of 695 patents assigned to leading wind energy organization cite one or more of the 112 DOE-funded patents or papers.
- Built the nation's first large wind blade test facility capable of testing longer blades than any other facility in the world. The facility has the capacity to test blades up to 90 meters in length, suitable for wind turbines up to 15 megawatts.
- Worked with several small wind industry partners to develop commercially available, award-winning small wind generation systems.

- Created a wind energy test facility at Clemson University that will enhance the performance, durability, and reliability of utility-scale wind turbines. It will feature power analysis equipment capable of performing highly accelerated life testing of land-based and offshore wind turbine systems rated at 5-15 megawatts.

Weatherization and Intergovernmental Program:

- In the first quarter of 2011, the Weatherization Assistance Program (WAP) supported nearly 15,000 jobs, and completed retrofits on more than 75,000 low income homes bringing the total number of homes retrofitted under the Recovery Act to more than 400,000. WAP continues to retrofit 25,000 homes per month.
- In first quarter of 2011, under the State Energy Program 118,000 new workers were trained.
- States upgraded 15,750 buildings (14,500 residential),and thousands of renewable energy systems were installed since passage of the Recovery Act through Q4 2010, including:
  - Nearly 2,500 solar photovoltaic systems with 25.5 megawatts of capacity;
  - Over 1,100 solar thermal systems with nearly 38,000 square feet of capacity;
  - Over 200 wind turbines with over 8.5 megawatts of capacity; and
  - Over 580 geothermal systems with over 2,800 tons of capacity.
- In the first quarter of 2011, Energy Efficiency and Conservation Block Grants (EECBG) recipients reported creating/retaining 4,494 jobs.
- Cumulative through March 31, 2011, EECBG recipients have reported the following progress on their grant-funded activities:
  - Energy-efficient traffic signals installed – 150,904
  - Energy-efficient streetlights installed – 68,199
  - Buildings Retrofitted – 17,692
  - Loans/Grants given (count) – 7,866
  - Loans/Grants given (value) - $402,825,916

Appendix 2

TRL Levels

1. **Basic Research:** Initial scientific research begins. Principles are qualitatively postulated and observed. Focus is not on applications.
2. **Applied Research:** Initial practical applications are identified. Potential of material or process to satisfy a technology need is confirmed.
3. **Critical Function or Proof of Concept Established:** Applied research continues and early stage development begins. Studies and initial laboratory measurements to validate analytical predictions of separate elements of the technology.
4. **Lab Testing/Validation of Alpha Prototype Component/Process:** Design, development and lab testing of components/processes. Results provide evidence that performance targets may be attainable based on projected or modeled systems.
5. **Laboratory Testing of Integrated/Semi-Integrated Components:** System Component and/or process validation in relevant environment.
6. **Prototype System Verified:** System/process prototype demonstration in an operational environment (beta prototype system level).
7. **Integrated Pilot System Demonstrated:** System/process prototype demonstration in an operational environment (integrated pilot system level).
8. **System Incorporated in Commercial Design:** Actual system/process completed and qualified through test and demonstration (pre-commercial demonstration)
9. **System Proven and Ready for Full Commercial Deployment:** Actual system proven through successful operations in operating environment, and ready for full commercial deployment.