Written Statement of
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Mr. Chairman, thank you for this opportunity to discuss important issues related to the nation's energy policies to meet our energy demands for the future. I am the director of the National Renewable Energy Laboratory (NREL) in Golden, Colorado. NREL is the U.S. Department of Energy's primary laboratory for research and development of renewable energy and energy efficiency technologies. I am honored to be here, and to speak with you today.

We applaud the Committee for its continuing examination of solar and other sources of renewable electricity and fuels. If we are to ensure the nation receives the full range of benefits that renewable energy technologies can provide, we will need a carefully balanced blend of new technology, market acceptance and government policies. It is not a question of whether to rely solely on the market, or on new research, or on government action, as we work to solve our energy problems. To accelerate deployment of renewable energy technologies, we need to effectively combine all three.

It's also crucial that this mix of technology, markets and policies be crafted so that each works in conjunction with the others. The reality is that distinct renewable energy technologies – be they solar photovoltaic, solar thermal, wind, biomass power, biofuels or geothermal – are in different places in terms of their economics, technological maturity and market acceptance. While a broad range of policies are needed to spur on these varied technologies, the specifics of policies and incentives to be enacted ideally must be tailored to fit the unique requirements of each of the systems and devices we are seeking to deploy.

My testimony will address the Committee's Solar Discussion Draft, share with you related activities underway in the Solar Energy Program of the Department of Energy's Office of Energy Efficiency and Renewable Energy and provide some specific reactions to the draft from our laboratory's perspective. I should note that on behalf of DOE, the Administration has not had sufficient time to coordinate interagency views on the Discussion Draft, but the Department wants to provide some preliminary comments.

SOLAR POWER: CURRENT RESEARCH AND DEVELOPMENT PROGRAM AND POTENTIAL CONTRIBUTION TO THE NATION'S ENERGY PORTFOLIO

DOE's Solar Energy Program sponsors research, development, and deployment of solar energy technologies and systems that can help meet our Nation's electricity needs and reduce stress on our electricity infrastructure. The Solar Program supports research in photovoltaics (PV), concentrating solar power (CSP), and solar heating and lighting. Through the President's Solar America Initiative (SAI), a major effort within his Advanced Energy Initiative, the Solar Energy Program goal is to reduce the cost of solar photovoltaic technologies so that they become cost-competitive with other sources of electricity in all major U.S. markets by 2015.

The SAI is being implemented at a critical time in the evolution of the global solar market. Worldwide growth rates for photovoltaics have averaged well over 35% for the last 5 years, which means the amount of installed solar power doubles every 4 years or less. However, this rapid growth is from a very small base; PV still accounts for less than 1 percent of electricity generation worldwide. Presently, several nations—including China, Germany, India, Japan, South Korea, and Taiwan—are attempting to attain larger shares of the global photovoltaic market by making significant public investments to spur private industry. At the same time, technology improvements and state incentives are stimulating domestic demand for photovoltaic systems in the U.S. The Solar America Initiative will provide the investment needed to expand U.S. advantages in product design and manufacturing, assuring that American technologies play a leading role in the growing domestic and global markets for solar electricity.

The SAI provides a unique opportunity to focus our efforts on accelerating cost reductions and manufacturing scale-up of the domestic photovoltaic industry to capitalize on this opportunity.

As we work to increase our energy independence and reduce our impact on environmental resources, solar technologies offer an attractive carbon-free, pollution-free energy resource.

In Fiscal Year 2007, President Bush requested $148 million for SAI—a 78% increase over pre-initiative levels—and the significant Fiscal Year 2007 Congressional appropriation demonstrated that our nation's leaders are in agreement that developing cost-competitive solar technologies is an important priority. The SAI R&D efforts supported by this funding are expected to expand domestic installed PV generating capacity up to 10 GW by 2015. Beyond enabling increases in manufacturing capacity, these projects will help put U.S. industry on track to reduce the cost of electricity produced by PV – from current levels of $0.18 - $0.23 per kWh to $0.05 - $0.10 per kWh by 2015 – a price that is competitive in markets nationwide.

STATUS OF CONCENTRATING SOLAR POWER (CSP) MARKETS

Recent developments in the western United States illustrate the growing concern over greenhouse gas emissions, and consequently, a market climate that is open to further deployment of concentrating solar power (CSP) in that region of the country.

In September 2006, California enacted the California Global Warming Solutions Act of 2006, which requires the state to reduce its greenhouse gas emissions by 25 percent by 2020.[i] In March 2007, California and four other western states (Arizona, New Mexico, Oregon, Washington) announced the Western Regional Climate Action Initiative[ii] in which they agreed to work together to cut their states' greenhouse gas emissions. With the large solar resources available in the Southwest, CSP-generated electricity could play an important role in helping these states meet their emissions reduction goals. In the longer term, CSP-generated electricity could help all the states reduce their greenhouse emissions.

Solar energy is the southwest's most abundant renewable resource. In fact, California, Arizona, and New Mexico have enough combined solar energy to provide all the power needed by the entire country. CSP technology is the least expensive solar technology for providing large quantities of electrical power, and with sufficient storage, it can deliver baseload power. At a time when large quantities of carbon-free power will be needed; CSP power plants, constructed primarily of concrete, glass, and steel, can be quickly constructed and brought on line. The yearly CO_2 emissions from a 1,000 MW coal plant are approximately 2,300,000 tons. The yearly CO_2 emissions from a 1,000 MW CSP plant would be nearly zero (there may be some need for grid power during the operation of the plant). With access to adequate transmission, CSP could even provide inexpensive carbon-free electricity beyond the Southwest to other regions of the U.S.

In the U.S., nine CSP power plants totaling 354 MW have been operating reliably in California for over 16 years, and CSP seems poised to grow significantly in the state. Each of the three major California utilities (Southern California Edison, San Diego Gas and Electric, and Pacific Gas and Electric) have signed power purchase agreements for a CSP project or have indicated an intent of doing so. In August 2005, Southern California Edison (SCE) signed a power purchase agreement for 500 MW of CSP dish-engine systems on a 4,500 acre site near Victorville, CA, with an option to expand the project to 850 MW. In September 2005, San Diego Gas & Electric (SDG&E) signed a power purchase agreement for a 300 MW dish-engine project in California's Imperial Valley, with an option of expanding the project to 900 MW.[iii] In August 2006, the Pacific Gas and Electric Company initiated plans with Luz II, LLC, to purchase at least 500 MW of solar energy beginning in the spring of 2010.[iv]

The state of Nevada has put in place tax credits enabling the construction of a 64 MW CSP project near Las Vegas that recently came on line. Nevada Power will purchase the power from the plant. A 1 MW CSP system, completed in 2006, is operating in Arizona for Arizona Public Service. In addition, several other utilities, under the leadership of Arizona Public Service, are investigating the potential of forming a consortium that would buy power from a 250 MW CSP plant built in Arizona.

The southwestern states also have strong renewable portfolio standards (RPS) which require that a specific portion of a state's electricity consumption be met by renewable energy by a certain year. RPS' are chief among the state policies that promote renewable energy, and some even specify that a certain amount of power must come from solar energy.

CONCENTRATING SOLAR POWER TECHNOLOGY STATUS

As with all new energy technologies, cost is an issue. But CSP has an additional challenge: the technology requires scale to achieve its ultimate cost effectiveness. Couple the scale issue with high up-front capital costs and the investment risk is too large for current market conditions.

The Solar Program addressed the cost issue by commissioning a detailed technical analysis of CSP by an independent engineering firm and then having the analysis reviewed by the National Research Council. Sargent and Lundy (S&L) was selected to conduct this analysis on the basis, among other factors, of its independence from the CSP industry and its recognized performance in conducting due diligence studies for the fossil power industry. S&L estimated that the cost of CSP technology can be significantly reduced from 12-14 cents/kWh (as of 2003). Sargent & Lundey predicts projects ultimate costs for CSP troughs at 6.2 cents/kWh and power towers at 5.5 cents/kWh. Sandia and NREL (Sunlab) predict costs could be even lower.

Since the S&L report was completed in 2003, the experience gained from trough plants being built in the U.S. and Spain is enabling industry to lower their cost through mass production and building larger plants. Since the S&L report was written, the price of steel, concrete, copper, and other commodity materials have risen. Although the numbers, as of 2007, are low, the figure continues to show the potential for CSP cost reduction.

Because sunshine is most intense during the hot summer months when air conditioners are working the hardest, solar energy is a good match for a utility's peak load. With 3-5 hrs of storage, CSP is also a good match to a utility's intermediate load. After gaining market penetration within the intermediate and peak load markets, however, CSP could expand into baseload generation markets through the expanded use of thermal storage, thereby providing a renewable alternative to baseload coal power. CSP technologies convert solar energy into thermal energy which is then stored in large tanks. This is an efficient way of keeping the energy until it's needed, at which time the hot fluid, often a molten salt mixture, is pumped to a power block where it is converted to electrical power through a turbine.

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The Role of Thermal Energy Storage and Transmission Integration

The Discussion Draft language on thermal energy storage addresses an important issue related to the intermittent nature of solar energy and its impact on utilities. Adding thermal storage to concentrating solar power (CSP) plants enables solar energy to be provided any time, day or night, that power is needed. Thermal storage also has the potential for being low cost. An independent study by Sargent & Lundy concluded that CSP costs could be reduced to between 4.3 and 6.2 cents/kWh by 2020 for technology that utilizes thermal energy storage.[1]

The potential for low-cost and efficient thermal storage is one of the key long-term attributes of large-scale CSP technologies. Key advantages of thermal energy storage are:

- High Value Dispatch of Electricity: Without thermal energy storage, solar power is an intermittent power resource, dependent on when the sunshine. Thermal energy storage allows the collection of solar energy to be separated from the generation of electric power, providing the ability to dispatch generation when the value for electricity is highest.

- Firming Delivery for Solar Power: The ability to store energy and dispatch solar power when it is needed helps make solar power plants a more reliable or firm power resource for the utility. Firming of delivery is an important aspect of supporting the economics of solar power plants through utility capacity payments.

- Increasing the Annual Capacity Factor: Solar power generating systems without thermal storage achieve capacity factors in the range of 25-30%. With the addition of advanced, low-cost thermal energy storage, systems can be economically sized to allow capacity factors of 75% or higher. As a result, with the addition of thermal energy storage it is possible for solar power plants to operate at or near baseload conditions.

The ability of CSP technologies to store energy presents an opportunity for DOE to establish an R&D effort that focuses on a solar technology that can produce baseload power at about 5

[1] Assessment of Parabolic Trough and Power Tower Solar Technology Cost and Performance Foreecasts, Sargent & Lundy Consulting Group, SL-5641, May 2003.

cents/kWh. Such systems would include 13-17 hrs of thermal storage and would compete with the cost of power from coal plants using carbon sequestration technology. It is expected that an aggressive R&D program could achieve the cost goal by 2020.

The Discussion Draft also addresses transmission integration, an important issue for CSP plants. CSP works best where the sun is most intense and there are few cloudy days, so plants are often located in desert or semi-arid locations where few people live. Transmission lines are required to bring the power from these remote locations to urban load centers. Throughout the West, access to transmission is generally limited because many lines currently operate at or near capacity. While transmission is a problem for all new power generation, it is particularly difficult for solar because solar power plants need to be located where the solar resource is best and these are not always near existing transmission lines. Addition transmission lines could allow solar energy from the Southwest to provide up to 6,800 GW of electricity to the U.S.

POTENTIAL R&D AND MARKET STRATEGY FOR CSP TECHNOLOGY

During the last three years, representatives of the DOE and NREL solar programs have met with the energy and economic advisors to governors, energy regulators, state legislators, utilities, and other stakeholders in California, Nevada, Arizona, and New Mexico. These meetings were to provide the states the economic, environmental, and energy benefits of CSP. Each state expressed an interest in CSP, although their interest was tempered by the high cost of the technology. They were, however, encouraged by the Program's projections of significant cost reduction and also showed interest in finding ways to encourage the deployment of CSP in their states. Nevada subsequently implemented tax incentives that have led to the construction of a 64MW CSP plant outside of Las Vegas.

Utilities have demonstrated a serious interest in CSP for several reasons:

- The widespread availability of solar energy throughout the Southwest provides utilities with flexibility in locating CSP plants near existing or planned transmission lines.

- Placing CSP plants on the "right" side of congestion can reduce grid congestion and increase grid reliability.
- CSP electricity production aligns closely with periods of peak electricity demand, reducing the need for investment in new generating plants and transmission system upgrades.
- Thermal storage or the hybridization of CSP systems with natural gas avoids the problems of solar intermittency and allows the plant to dispatch power to the line when it is needed.
- Large centrally-located power plants are the types of systems that the utilities have operated for years and with which they are most comfortable.
- Once the CSP plant is built, its energy costs are fixed; this stands in contrast to fossil fueled plants that have experienced large fluctuations in fuel prices during the last several years.
- The economic studies performed by the states show that a relatively small up-front investment can result in downstream tax revenues for the state and local governments.

Utility representatives expressed particular interest in CSP because its ability to store energy enables solar power to be dispatched to the grid through their entire period of peak demand, or whenever else it is needed. CSP was also attractive to them because of its size (50-250MW), use of conventional steam turbine power blocks, and the ability to hybridize CSP plants with natural gas.

Utilities have indicated that even with storage and the other advantages mentioned above, it is hard for them to justify purchasing CSP power above 10 cents/kWh when they can buy less expensive wind power. In California, utilities can pass along the higher cost of renewable energy to their ratepayers as long as it's under about 10 cent/kWh. Reaching 10 cent/kWh is thus important for early market penetration. The federal investment tax credit is important because it does much to bridge the cost gap. It is also important for the cost of CSP power to be at 5-7 cents/kWh by 2015. So early market penetration of CSP could be driven by a long-term extension of the 30% investment tax credit for commercial solar technologies. But if the cost of CSP power is too high when the tax credit expires, the market will take a significant downturn or become completely stagnant. An objective of the DOE and NREL CSP R&D activities would be to decrease the cost of the technology in a timely enough fashion so the market remains healthy when the tax credits expire.

To achieve this objective, we must reduce CSP costs to provide intermediate power at 5-7 cents/kWh with 4-6 hrs of thermal storage. These activities would focus on developing the solar collector, receiver, and other components of trough plants to attain the system goal.

To reach the long-term objective of providing baseload power, we will need to establish feasibility, develop components, evaluate, and test new system concepts beyond the trough plant design. The concepts likely to be examined include power towers, distributed power towers, concentrating line focus receiver (linear Fresnel), and dishes w/storage. The criteria for developing these technologies will include a detailed analysis that defines the current state of the technology, the needed advancements in efficiency and cost of each component, the development and manufacturing pathways needed to achieve the goal, the time to achieve the advancements, and the ability of the industry partner to commercialize the technology.

THE PHOTOVOLTAICS R&D STRATEGY

Prior to January 2006, our research focused on technical progress through increasing the conversion efficiencies of solar cells and reducing the manufacturing costs of photovoltaic modules. Our national laboratories—NREL and Sandia—implemented this R&D, which included providing relatively stable funding to companies and universities, resulting in steady, incremental progress. Hundreds of individual projects were funded at the national laboratories, universities, and companies that generated continued interest in photovoltaics throughout the country.

But this picture changed after January 2006. We began with a change in program strategy, along with a fresh look at the solar energy industry by the investment community, and supportive policies from numerous state and local programs. The focus of our research shifted from technical progress on components to integrated PV systems. Under the new strategy, companies funded by SAI are expected to develop products for priority markets, and industry is expected to influence the research agenda for the national laboratories and universities.

Dramatic progress is anticipated from multiple competitive solicitations, coupled with an aggressive process to evaluate results and eliminate awardees showing less than substantial progress. The first set of large awards, called Technology Pathway Partnerships, will support multiple industry-led partnerships over the full value-chain, whereas smaller projects will target earlier-stage technologies. Public attention will be attracted to these high-visibility projects, with the intent of stimulating consumer interest and eliminating barriers to PV deployment.

Perhaps the most dramatic evidence of this new strategy was DOE's significant investment in a new funding opportunity for industry-led Technology Pathway Partnerships. Entrance criteria for commercial applicants included prototype components, pilot production demonstration, and an established business case. At the end of three year projects, awardees were expected to have commercial PV systems and subsystems with annual production of greater than 25 MW. These partnerships include collaboration with national laboratories, universities, and suppliers to focus on the development, testing, demonstration, validation, and interconnection of PV components, systems and manufacturing equipment. Through these efforts, the Partnerships are expected to reduce the installed cost to consumers to $0.05–$0.10 per kWh by 2015 – a price low enough to open up all major U.S. electricity markets.

Earlier this year, 12 Technology Pathway Partnership projects were selected to receive up to $168 million in DOE funding over the next three years, with the awardees contributing over 50 percent of the funding for these projects. Representing a broad cross-section of U.S. industry, the projects involve more than 50 companies, 14 universities, 3 non-profits, and 2 national laboratories in 20 states. The selected projects' leaders are Amonix, BP Solar, Boeing, Dow Chemical, General Electric, Miasole, Nanosolar, SunPower, United Solar Ovonic, Konarka, GreenRay and Soliant. This new portfolio continues our historical investment in thin films and increases support significantly for concentrator photovoltaics and crystalline silicon technologies. The portfolio is intended to deliver on the near-term potential in residential markets and commercial markets, which are targeted by 32% and 48% of the funding, respectively, with longer-term utility markets following at 20%.

In addition to the Technology Pathway Partnerships, DOE will be releasing a variety of other funding opportunities to round out the PV R&D pipeline. These opportunities will focus on developing new materials and processes for solar electric conversion, transitioning fundamental science studies into the fabrication of new PV devices, shortening the timeline for companies to transition pre-commercial PV module technologies into full-scale manufacturing, supporting university materials science and process engineering research and improving inverters and power electronics in distributed PV systems.

THE NREL PHOTOVOLTAICS R&D PROGRAM

The Solar Energy Research Institute (SERI), now NREL, was originally created to develop the technologies needed to foster a dynamic solar industry. Our Laboratory has succeeded in large part at fulfilling this charter and has been vital to the development of the PV industry. In recent years, this industry has seen dynamic change and significant growth—thanks to past R&D successes at NREL.

Importantly, this change has included the emergence of significant internal R&D at start-up and established companies, as well as a proliferation of PV research at university laboratories around the country. With the industry and academic elements of the domestic PV R&D community changing significantly, in early 2007 we began to reexamine our research strategy to ensure that it will be complementary and relevant in years to come.

During spring of 2007, we began formulating a new multi-year research plan—with associated personnel and equipment plans—that recognizes this changing market context and is being developed with input from industry and academic collaborators. This planning process is intended to ensure the long-term vitality of NREL's research and its mission to help foster and sustain a strong American industry.

The new plan resulting from this process will improve on the existing concept for managing NREL's PV R&D portfolio in several critical ways: (1) For a given technology development "roadmap," the plan will more explicitly link the parameters targeted for device performance or process development to the market impact they would make if commercialized (e.g., in terms of change to commercial module costs, manufacturing equipment capital cost, or manufacturing bills of materials); (2) It will specifically identify the conditions and parameters under which a given device technology or process will be sufficiently proven to be transferred via licensing or other means for commercialization; (3) It will exhibit changing priorities over time, as research tasks in various areas are planned to be completed and as new technologies emerge for further development; and (4) The plan will explicitly identify research tasks that will be performed in industry, academia, or other institutions that are relevant to the activities and outcomes of NREL research activities.

We are extremely excited about our progress thus far under the new strategic planning process. And we look forward to sharing the resulting R&D priorities and management procedures in October 2007, at the start of our next fiscal year.

PHOTOVOLTAICS PROGRAM OUTCOMES AND BENEFITS

Upon realizing the SAI goal, it is expected that roughly 2 million metric tons per year of carbon emissions will be avoided by 2015 and PV will provide approximately 5 GW of electricity generating capacity – displacing roughly the equivalent of 5 coal-fired power plants – enough to energy to power about 1.25 million households. This is equivalent to 10 times the amount of PV installed today.[2]

Distributed solar technologies will enable our ultimate goal of affordable zero energy homes and buildings which fulfills the President's Advanced Energy Initiative vision of changing the way we power our homes and businesses. Net-zero energy homes and buildings produce as much energy as they consume through improved efficiency combined with renewable energy, such as solar, providing needed power and offsetting any utility-provided energy over the course of a year. Optimizing the balance of energy efficiency improvements and solar PV will result in the most cost effective net zero energy home or building and connecting the solar PV system to the grid can allow customers to sell the excess solar energy back to the utility.

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[2] DOE's Office of EERE uses two energy-economy models—NEMS-GPRA07 and MARKAL-GPRA07—to estimate the impacts of EERE programs on energy markets as part of its annual benefits analysis. The NEMS-GPRA07 model is a modified version of NEMS, the midterm energy model used by the EIA. The MARKAL-GPRA07 model is a modified version of MARKAL, a model developed by Brookhaven National Laboratory.

Highly efficient buildings with distributed technologies reduce peak demand, and will ease the need for expensive new generating capacity, transmission and distribution lines as our economy grows. Building-integrated PV can make the buildings sector a source of energy diversity and low carbon electricity (the building sector currently accounts for 39% of U.S. energy use). Total energy use in the buildings sector is projected to increase an additional 30% through 2025, and we believe that solar PV can meet much of this demand.

As the Committee's Discussion Draft notes, educating energy consumers is critical to achieving the market goals I have previously indicated. One of the ways we educate Americans about the new choices they have in heating, cooling and powering their buildings is a unique project that encourages the development of zero energy homes called the Solar Decathlon. The Decathlon, sponsored by DOE, challenges schools of architecture and engineering to design solar powered, zero-carbon, self-sustaining houses from the ground up to see which house is the most aesthetically pleasing and which house performs the best. Twenty collegiate teams from the United States, Canada, Puerto Rico, Spain, and Germany will participate in this year's competition, which will be held on the National Mall from October 12-20, 2007. The public is invited to visit the solar village and tour the houses, which showcase the latest green building and energy efficient technologies.

BUILDING ON MOMENTUM: STRATEGY & PRIORITIES FOR 2007

During the first 18 months of the Solar America Initiative, DOE and NREL have worked together to implement a broad-reaching change in strategy with one clear purpose: to make PV technologies cost-competitive in all major domestic grid-tied markets by 2015. We emphasize that this change was not implemented simply for the sake of change. But rather, to take advantage of progress in module efficiency and fabrication principally achieved by industry, universities, and the national laboratories over the years. These successes form the foundation for the PV systems that we will be supporting in the future.

Priorities in 2007 include continuing to implement the funding opportunities described above. We will also establish the framework for additional university involvement in the Technology Pathway Partnerships and calibrate our Laboratory's research portfolio and future role. And finally, we will ramp-up our efforts in testing and evaluation of new product designs – an activity that is critical to assuring the reliability of the new products we are developing with industry.

SUMMARY: BALANCING SHORT AND LONG TERM R&D INVESTMENTS IN SOLAR POWER

To address our near term needs in solar power we need a national strategy that promotes the deployment of solar systems and processes that are ready to serve us today. At the same time, to address our longer term needs and achieve a significant contribution from solar power technologies, we must make a major new commitment to the research required to deliver the next, and subsequent, generations of CSP, PV and other new technologies.

The good news is that the United States can take back the global leadership it once had in the solar energy field – what is likely to be one of the most important new industries of this century – through investing wisely now and into the future. The timing is fortuitous, because by most accounts the next big market for global renewable energy in here in the United States.

Thank you.

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[i] "AB 32 Assembly Bill," California Legislature, Retrieved on September 31, 2006, from http://www.leginfo.ca.gov/pub/bill/asm/ab_0001-0050/ab_32_bill_20060831_enrolled.html

[ii] Western Regional Climate Action Initiative, Feb. 26, 2007. Retrieved on April 3, 2007 from http://www.climatechange.ca.gov/documents/2007-02-26_WesternClimateAgreementFinal.pdf

[iii] "SDG&E Signs Solar Power and Other Renewables Energy Pacts," San Diego Gas & Electric Press Release, September 7, 2005

[iv] "PG&E Announces Significant New Green Power," PG&E Press Release, August 10, 2006