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Testimony of Thomas N. Hansen

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Thank you very much Chairman Lampson, Vice-Chair Giffords, Ranking Member Inglis and distinguished members of the Committee and staff. My name is Tom Hansen and I am the Vice President of Environmental Services, Conservation and Renewable Energy for Tucson Electric Power, the second largest investor owned electric utility in Arizona. We serve the energy needs of nearly 400,000 customers in the Tucson area. It is always a great honor and pleasure to work with the members of Congress and their staff in exploring solutions to the energy challenges facing Americans today. The production of affordable, safe electricity from sustainable and secure sources in an environmentally appropriate manner is one of those challenges. I am here today to discuss with you one plausible solution to that challenge – a Solar Grand Plan.

My background includes the design, construction, operation or management of over 10,000 MW of generation capacity, comprised primarily of nuclear and coal power plants. Many of my solar advocate friends claim I am serving my penance for that background by working with solar energy. But I am proud to have played a role in developing the electric generation infrastructure that has served our society so well for many decades and will play a significant role in providing needed electricity for at least the next twenty years. Moreover, my background in the development of those traditional electric generation assets has given me a unique insight into the technical and operational characteristics of the next generation of power producing technologies. While many energy resources are sustainable and environmentally neutral, only solar energy can supply all of our projected

energy needs for the long-term future. Solar energy is abundant, ubiquitous, sustainable and sufficient to meet the total energy needs of the United States for centuries in the future. The January 2008 issue of Scientific American detailed a "Solar Grand Plan" that could realistically meet 69 percent of U.S. electric needs by 2050 while reducing electricity related greenhouse gas releases by nearly 50 percent. The same plan could satisfy 100 percent of our nation's electric needs by 2100. I am here today to discuss that plan with the Committee.

My enthusiasm for the Solar Grand Plan will likely become obvious throughout the course of this testimony. Nevertheless, I should point out that my comments do not necessarily represent the views of Tucson Electric Power. TEP has earned widespread recognition for its innovative solar power programs, and the company is committed to expanding its use of renewable power resources. But TEP has not taken a position on this particular plan for solar power development.

The Solar Grand Plan incorporates three core technologies that will be coordinated through smart grid technologies. The smart grid, which will be discussed in more detail later, would be a bi-directional quasi-real time communications and control system with interconnected energy sources, including traditional, wind, tidal, hydrokinetic, biomass and geothermal. It would connect with consumer electric devices – including plug-in hybrid electric vehicles – and incorporate predictive solar and wind forecasts of both short-and long-term time spans. While this system is incorporated in the Solar Grand Plan, the technology has enough flexibility to seamlessly integrate any traditional fueled or sustainable energy resource.

The three core components of the Solar Grand plan are:

- **Solar generation to refine the energy in the light rays of the sun into electricity.**
- **Energy storage to preserve energy from the sun or any other power source for later conversion into electricity.**
- **Electric transmission to link the solar generation and energy storage to consumers and their equipment.**

Discussion of each core component follows:

Solar Generation: **The solar generation component converts the energy of the sun's rays into the electric energy that will be stored or delivered to customers. Any of a wide variety of existing solar energy technologies will meet the requirements for this component of the Solar Grand Plan, as the final output of all solar electric technologies is effectively interchangeable. Fixed or tracking flat plate, crystalline or thin film photovoltaic (PV) modules with DC-to-AC inverters for interconnection to the electric grid are supported. Concentrating solar power (CSP) using trough, solar tower, dish/thermal engine, dish/PV engine or concentrated photovoltaic (CPV) technologies are all supported.**

Tucson Electric Power's solar development experience has demonstrated that deployment of a varied portfolio of solar technologies is needed for optimal solar generation economics, as each solar technology type is best suited for operation in a particular set of climatic conditions. For example: PV, which uses virtually no water in operation, is best suited to a geographic area with no access to water; solar trough technology, meanwhile, is appropriate for areas with readily available water and can be combined with desalination options to augment the local potable water supply. The Solar Grand Plan assumes the deployment of a combination of thin-film PV technologies (88 percent of the total) and solar thermal with storage technologies (12 percent of the total). Both technologies are commercially available and are in common use today, with a very good opportunity for future cost reductions.

The solar generation technologies envisioned in the Solar Grand Plan have a proven record of reliability and safety. Future challenges for these technologies include reducing their cost through development of larger-scale U.S. located manufacturing facilities, optimizing the balance of system component costs and standardizing installation code requirements. Solutions to these challenges include an extension of the federal Investment Tax Credit for solar energy systems, expanded support for research and development of new solar energy conversion technologies at federal laboratories and universities, continued support for the Solar America Initiative program goals, and expanded federal programs for education and outreach to the American people regarding developments in solar energy product commercialization.

Energy Storage: A core concept of the Solar Grand Plan is the need to store solar energy for use when the sun is not shining. By way of explanation, traditional electric generation is performed by technology that effectively refines a form of primary energy such as chemical energy in coal or nuclear energy in uranium into electricity. Instantaneous customer demand for electricity is met through the conversion of just the right amount of primary energy source to perfectly balance the supply of electrons with demand for those electrons at all times. A utility's ability to meet its customers' peak electric demand is a function of the maximum capacity built into the power plant.

Production of solar energy – effectively refining the energy of the sun into electricity – is a function of time of day, time of year and cloud cover as well as capacity of the plant. The energy of the sun at the earth's surface is not dispatchable, to use a traditional electric system term, as the utility has no direct control over increasing the sun's intensity. The addition of cost- effective, reliable, efficient, safe, environmentally compatible energy storage into a solar generation system would allow a utility to control output to support customer loads during times when the sun's energy is not available. Energy storage is needed on at least two different time scales: storing excess solar energy in one season for consumption a season or two later, and storage of daytime solar output for use at night.

Numerous energy storage technologies exist today, but only two are suitable for utility scale use. One of them, pumped hydro storage, retains energy in the form of potential energy in water stored at a high elevation. The energy is released when the water is allowed to flow to a lower elevation through a traditional hydro generator. The other option, compressed air energy storage (CAES), retains potential energy in the form of high-pressure gas in an underground cavern or pore structure. While pumped hydro requires a specific set of geographic surface features and a supply of water, the underground conditions that would allow CAES are available in nearly every state in the union and often are used today for natural gas storage. The same technologies used for developing natural gas storage would support CAES development. The compressors that would tap excess solar generation to pump air underground are available today, as are the combustors and expansion turbines needed to convert the energy in compressed air to electricity. Such generators effectively would employ a split-shaft combustion turbine, thus relying on the same technology used to generate power from fossil fuels today. Two CAES plants are operational today with

decades of operating experience, and other plants are in development for use in balancing the output of wind generation.

The Solar Grand Plan requires a total underground storage volume of less than 10 percent of the volume used today for storage of natural gas, a very feasible amount of underground development using existing technology. Surface disturbance area for CAES is very similar to that of natural gas storage, with an additional need for electric transmission access. Energy storage cycle efficiencies of CAES are around 80 percent using existing technologies. While existing CAES technologies use some natural gas to reheat the air prior to conversion of the stored energy back to electricity, adiabatic expansion turbines can be developed that will not require the use of natural gas during energy recovery. A comparison of CAES characteristics with those of other energy storage technologies typically associated with solar energy, such as batteries or flywheels, is very favorable for CAES. Existing battery technologies typically can support a limited number of storage cycle before they must be replaced. Meanwhile, storage of energy from one season to another in batteries or flywheels generally results in additional storage cycle losses dependent upon the duration. CAES can store energy with minimal loss for extended time periods, and capacity does not degrade with an increasing number of charge/discharge cycles.

Meeting all of the nation's electric needs with solar power would require a sizable volume of energy storage to manage the seasonal and daily variations of solar energy production. While this storage could involve pumped hydro, flywheels, super-capacitors or superconductive magnetic energy storage (SMES), CAES enjoys a significant advantage in that it relies on deep underground facilities. This reduces its impact on land use, limits direct human interaction with the stored energy and mitigates risk from attack by enemies of our country. While the Solar Grand Plan can use any type of efficient, low-cost energy storage system, CAES was chosen due to its existing commercial availability, relatively low cost and proven reliability in utility scale applications. Thermal energy storage in molten salts, a relatively new technology incorporated in plans for thermal solar generation plants, could become part of the Solar Grand Plan's short-term storage component if its reliability and cost effectiveness prove comparable to those of CAES.

Again, the Solar Grand Plan has sufficient flexibility to accommodate any new storage technology that can improve upon the reliability, efficiency, low environmental impact and cost effectiveness of CAES. Development of the energy storage system could be supported by federal Investment Tax Credits to reduce the effective initial cost to the owner of an energy storage facility; supportive capacity tariff rates from regional transmission organizations; and continued support of energy storage technology research and development, including additional funding for evaluation of geologic potential for CAES throughout the United States through the National Laboratories and universities. Favorable regulatory policy ensuring that the requirements of permitting a CAES facility are no more complex than permitting natural gas storage also would help reduce obstacles to development of the energy storage needed for the Solar Grand Plan.

Transmission: **The Solar Grand Plan includes a transmission component to collect and distribute the energy produced at the solar generation sites to the energy storage component and to energy-consuming customers throughout the nation. The Solar Grand Plan does not specifically mention support for wind, biomass, hydro, tidal, current and other forms of sustainable energy production. Nevertheless, it would provide a national transmission backbone – similar in nature, if not in scope, to the National Interstate Highway system – capable of carrying energy from any generation source. The use of high-voltage DC lines for the Solar Grand Plan would leverage proven technologies to significantly reduce the risk of technical problems. However, the development of a national electricity backbone to enable the delivery of energy produced anywhere in the U.S. to any other part of the country will require the same sort of sustained political will that supported the 35-year effort to complete the Interstate Highway System. Policy development will need to address the concerns of property owners, regional and state development priorities and special interests. We must seek to forge a coordinated set of transmission development incentives that will ensure the full acquisition of the right-of-way required for completion of the transmission backbone in a timely manner.**

Funding will be needed for research analysis and development of the specific right-of-way alignment for the transmission backbone system. Strategic "off-ramp" locations for interconnection to existing regional and local transmission systems will need to be determined through extensive review and analysis of existing available transmission capacity. Cost-effective solutions for transmission bottlenecks to ensure efficient transfer

of energy throughout the nation will need to be found through additional analysis by National Laboratories and universities in cooperation with regional transmission organizations and electric utilities. All of the high-voltage DC transmission technology exists now to make the transmission backbone a reality. Nevertheless, development of a national electric transmission backbone will be the most difficult component of the Solar Grand Plan to implement because of the need to resolve a myriad of permitting and regulatory issues.

Additionally, rules to allocate the system's costs to regions and various customer groups will have to be finalized prior to implementation of the transmission backbone. Technical advancements in high-temperature superconductors could make the regulatory challenges easier to resolve by providing an option for burying the transmission system underground in congested areas where overhead line extensions could be unacceptable. Federal Investment Tax Credits for companies investing in the transmission backbone would offer financial incentives for attracting investment in the transmission backbone system.

Smart Grid: **To maximize performance under the Solar Grand Plan, there is a need for a communications and control system to coordinate the solar generation, energy storage and transmission components. These so-called "Smart Grid" technologies include: advanced metering, meter database automation, quasi-real time bi-directional communications between customers and producers, direct load control, central distributed generation control and intelligent appliances.**

Customers will increasingly play a larger role in addressing the challenges of our energy future. Smart Grid technologies provide both customers and utilities with the tools to better manage the production, storage, delivery and use of electricity. In so doing, the Smart Grid changes the basic premise of electricity providers, transforming utilities from providers of am energy commodity to enablers of energy transactions. Under such circumstances, regulations to decouple commodity energy supply from utility revenue recovery will be an integral part of the development of the Solar Grand Plan.

Innovative rate incentives could be developed to make effective use of a nationwide Smart Grid. For example, owners of plug-in hybrid electric vehicles in New Jersey might be convinced to lend use of their cars' batteries to store solar energy produced in Arizona. Continued support of the National Laboratories for development and testing of Smart Grid

technologies and development of transaction manager grid control algorithms will enable the Solar Grand Plan technologies to become reality.

Other Considerations: **The Solar Grand Plan requires the commitment of fairly large tracts of land for the installation of solar generation, energy storage and transmission. Transmission and CAES storage facilities would be spread out across the country, mitigating their environmental impact on any particular region. However, the solar generation component is expected to be concentrated in the southwestern U.S. to tap promising solar energy resources in Arizona, New Mexico, Nevada, Texas and California. This could create concerns about the environmental impact of large sections of land being effectively covered with solar collectors. Placing a large percentage of our nation's solar generation assets in one geographic area also makes them more susceptible to damage from a single weather related event. Distributing solar generation systems over a wider area may reduce that risk of damage.**

Funding should be made available for evaluation of optimum solar generation area coverage factors, heat island creation, environmental mitigation, wildlife habitat impacts and beneficial land uses in harmony with solar collectors. We also would need to consider the societal impact of bringing a significant number of solar equipment installers to live and work in currently uninhabited areas of the desert southwest.

While the Solar Grand Plan envisions that most of our sustainable energy resources will be solar, the system would accommodate any generation resource – including our existing coal and gas fired power plants and nuclear facilities. As we transition to a new solar-based energy infrastructure, we must make accommodations for linking these existing resources into the national transmission backbone and incorporating their output into our energy storage plans.

Financial Support: **As with all energy project proposals, the Solar Grand Plan has a price. An estimated subsidy of $420 billion would be needed to support development of plan components from 2009 to 2020. After 2020, the plan should be financially self-supporting as the cost of solar power with storage drops below the price of energy that could be generated from proposed traditional power plants. At that time, the Solar Grand**

Plan infrastructure would provide an economic alternative to construction of those new plants, and funds for continued expansion of the system would come from the sources traditionally used for new power plants today.

A commitment to fund the solar generation portion of the Solar Grand Plan would encourage solar manufacturers to invest in new production factories in the United States. We will not fully reap the economic benefits of solar power development or achieve national energy security until the manufacturing of our basic energy Solar Grand Plan components occurs within this country. We will also not take full advantage of reducing our energy related expenses overseas if we are purchasing solar products produced in other nations.

Conclusion: The Solar Grand Plan is proposed to demonstrate that there is at least one feasible, affordable, realistic plan based on proven existing technologies that can transition our fossil and nuclear energy based electric energy production infrastructure into a sustainable energy production infrastructure. It is instructive that the Interstate Highway System had an initial cost of $425 billion in 2006 dollars, very close to the $420 billion of subsidies that would be needed to bring the Solar Grand Plan into reality.

The Solar Grand Plan strengthens our energy security by effectively storing electrical energy underground, as we have done with fuels at the Strategic Petroleum Reserve and at natural gas storage facilities. Energy security is further enhanced by geographic dispersion of the energy storage facilities and through redundancy in the transmission backbone right-of-way alignments. Just as the construction materials and route alignments evolved during the 35-year construction of the Interstate Highway System, the Solar Grand Plan will benefit from advancements in technology and regulations during its development. And just as it took the political will of Congress with strong support from the states to make the Interstate Highway System a reality, strong leadership, vision and the will of Congress in partnership with the states will be essential to implementing a long-term, reliable, sustainable, secure energy solution for our nation.

Chairman Lampson, Vice-Chair Giffords, Ranking Member Inglis and distinguished members of the Committee and staff. I want to thank your for this opportunity to address

the Solar Grand Plan and for your dedication to finding solutions to the energy challenges facing our future.