UTILITY-SCALE SOLAR POWER: OPPORTUNITIES AND OBSTACLES

FIELD HEARING

BEFORE THE

SUBCOMMITTEE ON ENERGY AND ENVIRONMENT

COMMITTEE ON SCIENCE AND TECHNOLOGY

HOUSE OF REPRESENTATIVES

ONE HUNDRED TENTH CONGRESS

SECOND SESSION

MARCH 17, 2008

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UTILITY-SCALE SOLAR POWER: OPPORTUNITIES AND OBSTACLES

MONDAY, MARCH 17, 2008

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

The Subcommittee met, pursuant to call, at 12:30 p.m., in the Pima County Administration Building Hearing Room, 1st Floor, 130 W. Congress Street, Tucson, Arizona, Hon. Gabrielle Giffords [Vice Chairman of the Subcommittee] presiding.

BART GORDON, TENNESSEE
CHAIRMAN

RALPH M. HALL, TEXAS
RANKING MEMBER

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The Subcommittee on Energy and Environment

Hearing on

Utility-Scale Solar Power: Opportunities and Obstacles

March 17, 2008
12:30 p.m. – 2:30 p.m.
Pima County Administration Building Hearing Room, Tucson, Arizona

Witness List

Mr. Mark Mehos
Program Manager, Concentrating Solar Power Program, National Renewable Energy Laboratory

Mr. Tom Hansen
Vice President of Environmental Services, Conservation and Renewable Energy, Tucson Electric Power

Ms. Kate Maracas
Vice President, Arizona Operations, Abengoa Solar

Ms. Valerie Rauluk
Founder and CEO, Venture Catalyst, Inc.

Ms. Barbara Lockwood
Manager, Renewable Energy, Arizona Public Service

Mr. Joe Kastner
Vice President, Implementation and Operations, MMA Renewable Ventures LLC

FIELD HEARING CHARTER

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

Utility-Scale Solar Power: Opportunities and Obstacles

MONDAY, MARCH 17, 2008
12:30 P.M.–2:30 P.M.
PIMA COUNTY ADMINISTRATION BUILDING HEARING ROOM, 1ST FLOOR
130 W. CONGRESS STREET
TUCSON, ARIZONA 85701

Purpose

On Monday, March 17, 2008 the House Committee on Science & Technology, Subcommittee on Energy and Environment will hold a hearing entitled, *"Utility-Scale Solar Power: Opportunities and Obstacles,"* at the Pima County Administration Building Hearing Room, Tucson, Arizona.

The Subcommittee's hearing will explore the potential for utility-scale solar power to provide a significant fraction of U.S. electric generating capacity and the challenges to achieving this goal. The specific technologies to be discussed include solar thermal technology, concentrating photovoltaics and distributed solar power. Transmission, regulatory and financial issues will also be examined, along with a look at the government and private industry roles in the development of utility-scale solar power—and enabling productive partnerships between them.

Witnesses

- **Mr. Mark Mehos** is the Program Manager for the Concentrating Solar Power Program at the National Renewable Energy Laboratory. Mr. Mehos will provide an overall assessment of the available resource size for solar energy in the U.S. and an introduction to the known technologies that may take advantage of solar power on a large scale.
- **Mr. Tom Hansen** is the Vice President of Environmental Services, Conservation and Renewable Energy at Tucson Electric Power. Mr. Hansen will describe a "Solar Grand Plan" to provide more than half of the U.S.'s electricity from solar power by 2050.
- **Ms. Kate Maracas** is the Vice President of Arizona operations at Abengoa Solar. Ms. Maracas will describe the current state of solar thermal technology and the near- and long-term economic costs and benefits of large-scale solar power in general.
- **Ms. Valerie Rauluk** is the Founder and CEO of Venture Catalyst, Inc. Ms. Rauluk will describe the current state of distributed and concentrating photovoltaics and provide an assessment of how the marketplace for solar energy will change over the next 10 years.
- **Ms. Barbara Lockwood** is the Manager of Renewable Energy for Arizona Public Service. Ms. Lockwood will provide the perspective of utilities on the ability for large-scale solar power to be a significant competitor in the U.S. energy sector over the next 50 years.
- **Mr. Joe Kastner** is the Vice President of Implementation and Operations for MMA Renewable Ventures LLC. Mr. Kastner will describe his company's experience with installing and managing the Nellis Air Force Base solar array and ways to enable productive partnerships between government and renewable energy industries in general.

Background

An article in the January 2008 issue of *Scientific American* titled "A Solar Grand Plan" outlined a potential path to providing nearly 70 percent of U.S. electricity demand and 35 percent of its total energy demand, including transportation, with solar power by 2050. It is also estimated that if fully implemented, the plan would reduce U.S. carbon dioxide emissions to 62 percent below 2005 levels. Approximately $420 billion in various government subsidies from 2011 to 2050 would be required to fund the necessary infrastructure and make solar power cost-competitive.

Several types of technology would be needed to follow through on such a plan. Photovoltaics (PV), which convert sunlight directly to electricity, are the most familiar. Vast arrays of PV cells can be deployed in the Southwest covering multiple square miles to generate hundreds of megawatts of electricity per field. A variation on this technology, known as concentrating photovoltaics (CPV), uses lenses or mirrors to concentrate sunlight onto high-efficiency solar cells. These solar cells are typically more expensive than conventional cells used for flat-plate PV systems. However, the concentration decreases the required cell area while also increasing the cell efficiency. PV and CPV systems may employ any of a number of electrical energy storage technologies for use during periods of passing clouds or into the evening.

An alternate technology could also be used. Solar thermal technology produces electric power by converting the sun's energy into high-temperature heat with various mirror configurations. The heat is then used to power a conventional generator. Solar thermal plants consist of two parts: one that collects solar energy and converts it to heat and another that converts heat energy to electricity. Just as batteries may assist PV systems, molten salts and other forms of thermal energy storage technology allow this heat to be retained for later use in generating electric power.

An expansive new transmission and distribution system would be required for the remainder of the country to take full advantage of the immense solar resource in the American Southwest. A 2005 study commissioned by the Western Governors' Association estimated that solar energy from the Southwest alone could provide up to 6,800 GW of electricity to the U.S. To put this in perspective, the electric generating capacity of the entire country is currently about 1,000 GW. However, the existing system of alternating-current (AC) power lines would lose a significant fraction of its energy over long hauls so the Solar Grand Plan recommends building a new backbone of high-voltage, direct current (HVDC) power transmission lines and coupling this to sites near population centers that may utilize another form of electrical energy storage technology known as compressed air energy storage (CAES).

Under this scheme, electricity generated from solar power plants hundreds of miles away compresses air and pumps it into vacant underground caverns, abandoned mines, aquifers and depleted natural gas wells. The pressurized air is released on demand to turn a turbine that generates electricity, aided by burning small amounts of natural gas. Citing a study by the Electric Power Research Institute (EPRI) and the natural gas industry, the Plan affirms that suitable geologic formations exist in 75 percent of the country often close to metropolitan areas, and that a national CAES system would look similar to the current U.S. natural gas storage system.

The Plan assumes relatively small increases in PV solar-to-electric efficiency from 10 percent today to 14 percent in 2050 and increases in efficiency for solar thermal technology from 13 to 17 percent. The Plan also assumes significant reductions in installed cost and electricity price based on economies of scale reaching 5–9 cents/kWh. (Today's rates for these systems in the U.S. are 16–18 cents/kWh and average overall electricity rates are currently 5–15 cents/kWh depending on the region.)

Though not directly addressed by the Solar Grand Plan, one other method to generate solar power on a large scale is distributed generation (DG) which consists of smaller facilities on otherwise unused real estate (roof-tops and sites of 10 to 500 acres) located near the load demand and dispersed throughout many communities. DG systems typically produce under 20MW of power and may consist of PV and CPV components. By providing power near or directly at the point of use, DG may offer a more cost-effective near-term solution in many areas of the country.

Ms. GIFFORDS. This hearing will come to order. Good morning, everyone. It is my great, great honor and privilege to welcome you all this morning to a field hearing of the Subcommittee on Energy and Environment entitled “Utility-Scale Solar Power: Opportunities and Obstacles.”

I want to welcome everyone here to Tucson. I want to thank Chairman Richard Elías for having us here in the Supervisor’s Headquarters. Richard, where are you? Thank you so much for having us here today.

We also have with us Councilwoman Nina Trasoff. Thank you for all the work that you are doing, one of our local elected officials, I appreciate having all your support.

Rarely does a meeting in Congress go by when I do not have an opportunity to talk to my colleagues about how extraordinary southern Arizona is, and so that is one of the reasons why I am so pleased to have so many of our colleagues here with us today to enjoy this extraordinary part of the world that we call home.

Many thanks to my colleagues who are interested in utility-scale solar power for coming. All have given up time in their district work periods to be here in southern Arizona. We are honored to have Members from around the country with us today. I believe it is a testament to the high degree of energy and interest that we have in solar technology.

In particular, I would like to extend a very special welcome to the two most senior Members of the Science and Technology Committee. The Chairman of the Full Committee, Mr. Bart Gordon from Tennessee, unfortunately, was detained in Washington due to weather and mechanical problems with his airplane, but he is going to be joining us by telephone in just a few minutes.

But, I would like to thank Ranking Member, Mr. Ralph Hall from Texas. Ralph Hall has been on the Science and Technology Committee for 28 years, and also Energy and Commerce. So, we are very pleased to have him with us today.

Also with us is Representative Dan Lipinski of Illinois, Vice Chair of the Full Committee, Representative Jim Matheson from the State of Utah, thank you for coming, and Representative Harry Mitchell, a fellow Member of the Arizona Congressional Delegation, from Tempe, Arizona.

No one can remember the last time that we had so many Members of Congress in southern Arizona for an actual field hearing. So, I am particularly pleased that we are all here on a topic as important as solar energy.

I would like to extend a very warm welcome to our witnesses who are here today. We are glad that you are here to share in your expertise, to enlighten the Committee and members of the public about the experiences that you have and the thoughts that you have. It was challenging to only have six panelists when we have so many talented people that are experts in solar technology, but we are very pleased that you are here to join with us today.

We also have many smart and talented members of my Solar Advisory Committee that are in the audience today, and I want to thank you as well for taking this part of the world and making it so focused on solar energy and the possibilities that lay ahead of us.

Finally, a welcome to all the members as well, just of the general public, who are here because they care about what is happening with the future of energy technology, and again, I want to thank you, our Members today, but also watching live on the Internet, and we know we have a streaming video and we will capture that for people who are not able to participate.

In the Science and Technology Committee, it is common for our Chairman, Mr. Gordon, to refer to us as the Committee of big ideas. The notion is certainly well grounded from the history of the Committee. Just last week we celebrated 50 years of the Science and Technology Committee, with Bill Gates coming to talk to us. It is a Committee that oversaw the days of NASA and winning the space race, the wake of Sputnik, but the Chairman's statement is as much, I believe, about the future as it is about the past. It expresses a belief which I share, that the greatest days of American innovation are the days which lay ahead. So, in my view, it could not be more fitting for the Committee to turn its attention to solar power.

Solar power is a big idea, whose time has come. And, like the space program, solar is an idea that can shape our nation in significant and positive ways. In the coming months, in the coming years, we will face critical decisions on how to address climate change, reduce our dependence on foreign energy, and boost our economic competitiveness.

The beauty of solar power is that it offers an elegant solution to all three of these challenges. Imagine what it would be like if every time that it rained it rained oil, big black drops falling from the sky. Don't you think that we would find some way to run around with a big bucket and collect all of that energy that was falling from the sky? I know this sounds like an absurd picture, but the reality is that what we have outside today is something very comparable to that. Literally, we have useful energy pouring out of the sky, and nowhere does it rain sunshine with greater intensity and consistency than in the American southwest.

In fact, some studies show that there is enough sunshine in the southwest to power almost our entire nation. One of these studies was recently covered on—actually, was brought forward on the front cover of the *"Scientific American Magazine."* So, in other words, the southwest is home to a national treasure that streams from the sky almost every day.

That sounds like a good enough reason to start developing an effective solar bucket, and while we are at it, let us make it a really big bucket.

The focus of this hearing is not just about any kind of solar power, it is about utility-scale solar power. Utility-scale refers to large installations that can generate significant amounts of electricity for the grid, but with free fuel and, virtually, no pollution. Developing solar installations on this scale creates unique opportunities, but it also presents unique challenges.

So, we look forward today to hearing from our witnesses about both. Our goals in holding this hearing are to explore five key issues. First, the potential scale of solar power in America. Second, the current state of technology. Third, the benefits to our nation of embracing this energy source. Fourth, the obstacles to developing solar power in a big way. And finally, the policies that can help us overcome these obstacles.

The time for solar is now. Technologies are proving, the costs are falling, and the reasons to adopt it are compelling. We need to truly understand the potential of this energy source and how we can unleash it. So, that is what today's hearing is all about.

So, we should get started. Since we do not have Congressional hearings in Tucson every day, I want to briefly explain how we are going to proceed. First, some of my colleagues will make opening statements. Then we will have a chance to hear from each of the witnesses in turn. We ask our witnesses, because of our time consideration, to keep their testimony to five minutes, and we have our technology here on the table to indicate when your time is being close to up.

Then, following the witnesses, each Member will have five minutes to ask questions. Once all the Members have asked questions, if time remains we will have a chance to recycle and go back to the beginning.

I know that some of my colleagues have planes to catch, so we are planning on wrapping up around 2:30.

Now, following the conclusion of the formal hearing, I would like to take a short ten-minute break. I encourage people who are interested in the community to stay around, because we are going to ask our panelists to come on the dias and be able to directly answer your questions.

With that, I would now like to yield to Mr. Hall for his opening statement.

[The prepared statement of Acting Chair Giffords follows:]

PREPARED STATEMENT OF ACTING CHAIR GABRIELLE GIFFORDS

Good morning. It is my great privilege today to convene this field hearing of the Subcommittee on Energy & Environment, entitled *"Utility-Scale Solar Power: Opportunities and Obstacles."* I want to welcome everyone to Tucson.

Rarely does a hearing go by where I do not talk about Arizona so you can imagine what a pleasure it is to be able to show my fellow Committee Members why I am so proud of our community and the work we are doing together on Solar energy.

Many thanks to my colleagues from the Science and Technology Committee. They have all given part of their District work period to come to southern Arizona today.

We are honored to have with us Members from all over the country. This is a testament to the high level of interest in solar power, and to its relevance to the whole Nation.

In particular, I would like to extend a very special welcome to the two most senior Members of the Full Science and Technology Committee:

- The Chairman of the Full Committee, Mr. Bart Gordon, of Tennessee, who was unfortunately detained in Washington due to weather and mechanical problems with his airplane. He should be joining us by phone in just a bit. And
- The Ranking Member, Mr. Ralph Hall, of Texas.

Thank you both for coming.

Also with us today are:

- Rep. Dan Lipinski of Illinois, Vice Chair of the Full Committee,
- Rep. Jim Matheson from Utah, and
- Rep. Harry Mitchell, a fellow Member of the Arizona delegation.

No one can remember the last time that so many Members of Congress came together in Tucson for a Field Hearing. I am particularly pleased that we are here on such an important topic.

Thank you all for making the special effort to be here today.

I would like to extend a very warm welcome to our witnesses. We are glad you are here to share your expertise with the Committee. It was an incredible challenge to narrow our panel down to just six.

There are so many smart and talented people with important perspectives on these issues, including many members of my own Solar Advisory Council.

I wish we could fit them all at the witness table, but space and time constraints prevent us from doing so.

I thank all of these people for their important contributions to solar power and their work with my office on our solar initiatives. We value their expertise, and I will continue to seek their counsel and collaboration as we move forward.

Finally, a special welcome to all the members of the community who are here today. Thank you for your interest in this critical issue.

In the Science and Technology Committee it is common for our Chairman, Mr. Gordon, to refer to us as the "Committee of Big Ideas."

This notion is certainly well-grounded in history. Formed in the wake of Sputnik and initially charged with winning the space race, the Committee is now celebrating 50 years of promoting big ideas in American science and technology.

But the Chairman's statement is as much about the future as it is about the past. It expresses the belief—which I share—that the greatest days of American innovation lie ahead of us.

So in my view it could not be more fitting that the Committee is turning its attention to solar power. Solar is a BIG IDEA whose time has come.

And like the space program, solar is an idea that can shape our nation in significant and positive ways.

In the coming months and years, we will face critical decisions on how to address climate change, reduce our dependence on foreign energy, and boost our economic competitiveness.

The beauty of solar power is that it offers an elegant solution to all three of these pressing concerns.

Imagine what it would be like if every time it rained, it rained oil—big, black drops falling from the sky. Don't you think we'd find a way to catch some of that bounty from the heavens? I think we'd be running around with big buckets, scooping up every available drop.

As absurd as that picture may be, with solar energy we have something just as good—useful energy that is literally pouring down from the sky.

And nowhere does it "rain" sunshine with greater intensity and consistency than in the American Southwest. In fact, some studies show there's enough sunshine in the Southwest to power almost our entire country! One of these studies was recently reported in a cover story in *Scientific American.*

In other words, the Southwest is home to a national treasure that streams from the sky almost every day. That sounds like a good reason to get serious about developing an effective solar bucket.

And while we're at it, let's make it a big bucket. The focus of this hearing is not just any kind of solar power, it is utility-scale solar power.

Utility-scale refers to large installations that can generate significant amounts of electricity for the grid, but with free fuel and no pollution.

Developing solar installations on this scale creates unique opportunities, but it also has unique challenges. We look forward to hearing from our witnesses today about both.

Our goals in holding this hearing are to explore five issues:

- the potential *scale* of solar power in America
- the current state of solar *technology*
- the *benefits* to our nation of embracing this energy source
- the *obstacles* to developing solar power in a big way, and
- the *policies* that can help us overcome those obstacles.

The time for solar is now: technologies are improving, costs are falling, and the reasons to adopt it are increasingly compelling.

We need to truly understand the potential of this energy source, and how we can unleash it. That's what today's hearing is about.

Mr. HALL. Thank you very much, Madam Chair, and I am honored to be here.

What she did not tell you is that I am the oldest guy in the United States House of Representatives, and that makes me the dean. I am 84 years old, but I was running at 5:45 this morning, two to three miles every morning. I am trying to stay young to keep up with my grandchildren. I get a little sick of some of them telling old man jokes, Madam Chair, about me. The latest one was that a woman's husband was about to quit golfing because he was 92, and he could not see where the ball was going. And, she hated to see him leave golf and be at home all the time. She said, well, my brother is 94 and he does not golf but he likes exercise. He has wonderful vision and he can see, I will bet he could tell you where your ball went. And, they worked that out. That following Monday out on the golf course he hit that ball, and it was way up in the air. He said, Orville, are you watching it? He said, yeah, I am watching it. He said, is it still up there? He said, yeah. Can you see it? Yeah, I can see it. Has it hit yet? He said, yeah, just hit. He said, where did it go. And, he said, I cannot remember.

So, us senior Members have problems of all kinds. But in this campaign—I just won the primary election, and the *"Dallas News"* called me an old geezer. And I made the argument, Madam Chairman, that it does not hurt to have—I do not recommend a whole floor of old 84-year-old guys or women, but it does not hurt to have one old geezer up there. And, I had all kind of call-ins and letters and everything, and finally the guy that won the contest told me my motto should be, "Win One for the Geezer," and that is what we did.

But, I am glad and honored to be here with you in Tucson, and this very important hearing on solar energy. I am anxious to listen. I am here more to listen than I am to talk. The longest speech I will make is one that I will be reading to you right now in a few minutes.

I just want to say that I have often said that our country needs to become more energy independent, and to do that we need to use all the forms of energy. Americans, we have many forms of energy, and we just passed an energy bill a year and a half ago that had some incentive for every form of energy. And, energy is important, it is important in that if we solve our energy problems we also solve our war problems, because energy or lack of energy is the cause of most wars. It is the causation of it.

Japan did not dislike this country. Cordell Hull and Henry Stimson had cut their oil off. They had 13 months of national existence with no oil. So, we had to know they were going to break out and go south into Malaysia or somewhere. That was an energy war, it was not because they did not like us. Japan today is probably the best friend we have in the world, the best partner we have, I think. And, I would like to see them arm again, because they know how to deal with the Chinas, and the Koreas, and all that, but that is not what we are here about today. We are here about energy, and, of course, when George Bush, the elder George Bush, sent 450,000 youngsters to Iraq ten or 11 years ago, that was to keep a bad guy named Saddam Hussein from getting his foot on half the known energy in that part of the world. That was an energy war, in my opinion.

And, that is how important this hearing is, and solar is such an important part of energy. A balanced solution can reduce our dependence on foreign sources of energy, and that is one thing we really need to do, to make our air and water cleaner, most importantly, a viable solution reduces the cost of energy for Americans so that their economy can continue to grow.

As demand rises by an estimated 40 percent in the electricity sector by 2030, we are going to need solutions that keep America economically prosperous and competitive. As is evident here in the desert of the American southwest, the sun provides an abundant source of energy. Citizens have been using this source for years to power many small and some large-scale projects and devices. And, an entire small community of astronauts live on the International Space Station that is run entirely on solar energy. Yet, solar energy makes up a very small proportion of our overall consumption picture, only 0.4 percent of global energy demand is met by geothermal solar and wind energy combined.

In the United States, statistics by the Department of Energy from 2004 indicate that solar energy accounted for one percent of the total U.S. energy consumption, and 0.2 percent of our electricity generation.

Part of the reason this resource is not widely used is that sunlight is not constant, it is not focused. The amount of energy generated depends on the time of day, location, and weather conditions. In order to use solar energy for stable grid operations, we need better storage techniques. To this end, I introduced a bill last year, the *Energy for America Act,* which included the provision permitting research and development and demonstration of energy storage technologies for electricity transmission and distribution. I am pleased that this provision was included in the energy bill signed into law last year.

So, Madam Chair, I look forward to hearing this testimony today by this very esteemed panel of individuals, on how America can better harness the power of the sun to generate more utility-scale power that lowers the cost to taxpayers and consumers.

We write law up there. We write the law, but we write it based on people that know more about what we are talking about than we do, and that is this panel and people just like you. We will take your testimony, the rest of this committee, and the rest of Congress will have the opportunity to read it. Some of them will read it, but it can be the major part of a bill that would be introduced later, probably by Madam Chair with many of us being her co-sponsors.

With that, I thank you, and I yield back my time.

[The prepared statement of Mr. Hall follows:]

PREPARED STATEMENT OF REPRESENTATIVE RALPH M. HALL

Thank you. I am pleased to be here today in Tucson, Arizona for this important hearing on solar energy and I want to thank Rep. Giffords for organizing this gathering.

I have often said that America needs to become more energy independent, and to do that we need to use *all* forms of energy. Americans currently have, and will continue to need, reliable and affordable domestic energy. Citizens are rightfully concerned about rising energy prices and protecting the environment. A balanced solution reduces our dependence on foreign sources of energy while also making our air and water cleaner. Most importantly, a viable solution *reduces* the cost of energy for Americans so that our economy can continue to grow. As demand rises by an estimated 40 percent in the electricity sector by 2030, we will need solutions that keep America economically prosperous and competitive.

As is evident here in the desert of the American Southwest, the sun provides an abundant source of energy. Citizens have been using this source for years to power many small and large-scale projects and devices. Indeed, an entire small community of astronauts live on an International Space Station that is run entirely on solar energy. Yet, solar energy makes up a very small proportion of our overall consumption picture. Only 0.4 percent of global energy demand is met by geothermal, solar, and wind energy *combined.* In the U.S., statistics by the Department of Energy from 2004 indicate that solar energy accounted for one percent of the total U.S. energy consumption, and 0.2 percent of our electricity generation.

Part of the reason this resource is not widely used is that sunlight is not constant and focused. The amount of energy generated depends on the time of day, location, and weather conditions. In order to use solar energy for stable grid operations, we need better storage techniques. To this end, I introduced a bill last year, the *Energy for America Act,* which included a provision promoting the research, development, and demonstration of energy storage technologies for electricity transmission and distribution. I am pleased that this provision was included in the Energy Bill signed into law last year.

I look forward to hearing the testimony today by this esteemed panel of individuals on how America can better harness the power of the sun to generate more utility-scale power that lowers the cost to taxpayers and consumers.

I yield back the balance of my time.

Ms. GIFFORDS. Thank you, Mr. Hall.

I would now like to yield to the Chairman of the Science and Technology Committee, Mr. Gordon, who will offer his opening remarks (by phone).

Chairman GORDON. Thank you.

I am disappointed as to the mechanical problem that I cannot join all of you in southern Arizona today, but I want to thank you, Representative Giffords, for taking the lead and putting together this important hearing, and I want to thank my colleague, Old Geezer, and the other colleagues there, for being on the scene, and I know you are going to be bringing back a good report for us.

It is obvious that solar energy has the potential to provide a significant amount of power in Arizona, and I look forward to learning more about how states that do not get quite as much sun, like my own State of Tennessee, might be able to benefit from the tremendous resource we have in the southwest.

And again, I would point out that in 2006 Germany installed about seven times more solar power than the entire U.S., and that Germany's solar resources are roughly equal to Alaska's. So, I know that we can be doing much more to utilize the sun's energy.

It is clear that a major component of any scheme to use solar power on a large scale has to be energy storage. So, I am encouraged by the grand solar plan that Mr. Hansen will be describing. Additionally, further development in advanced batteries will also be a critical part of the distributed generation system that Ms. Rauluk will talk more about.

I am pleased about the bipartisan work last year on the energy storage, which had official contributions in this area from both you, Madam Chair, and Mr. Hall, as it was introduced in the latest energy bill and became law in December.

An improved transmission system is also needed, especially, if we ever expect to get a large fraction of our energy from remote regions where renewable resources, like solar and wind, are concentrated.

I am also concerned about the nexus between water and energy, something that we are going to be looking into more this year on the Committee. While regular solar panels do not need much water, except to clean them on occasion, some estimate that solar thermal technology uses more water than a typical coal plant. So, it is important that while we move forward we take the whole picture into account, and do everything we can to avoid trading one big problem for another.

And, I am excited about the opportunities that large-scale solar power present to create thousands of new green jobs, and reduce our dependency on old sources of energy. Our committee will continue to do everything we can to help overcome the barriers to getting us there.

Representative Giffords, thank you again for your strong leadership to promote solar energy, and thanks to this distinguished panel of witnesses for being here today.

I yield back my time.

[The prepared statement of Chairman Gordon follows:]

PREPARED STATEMENT OF CHAIRMAN BART GORDON

Thank you, Congresswoman, for taking the lead in putting together this important hearing. It is obvious that solar energy has the potential to provide a significant amount of power right here in Arizona, and I look forward to learning more about how states that don't get quite as much sun, like my home State of Tennessee might be able to benefit from the tremendous resource we have in the Southwest.

Then again, I could point out that in 2006, Germany installed about seven times more solar power than the entire U.S., and that country's solar resources are roughly equal to Alaska's, so I know that we could be doing much more to utilize the sun's energy.

It's clear that a major component of any scheme to use solar power on a large scale has to be energy storage. I am encouraged that the Grand Solar Plan that Mr. Hansen will describe would make use of compressed air and thermal energy storage technologies.

Further developments in advanced batteries will also be a critical part of the distributed generation systems that Ms. Rauluk will talk more about in just a few minutes. I'm proud that our committee's bipartisan work last year on energy storage, which had essential contributions in this area from both you and Mr. Hall, was included in the latest energy bill that became law in December.

An improved transmission system is also needed especially if we ever expect to get a large fraction of our energy from the remote regions where renewable resources like solar and wind are concentrated.

Our current system of power lines isn't robust enough to carry large amounts of power from these centers to consumers everywhere. Too much energy would be lost over the long distances between generation and delivery of power.

Studies by Oak Ridge National Laboratory show that new high-voltage direct current lines lose far less energy than existing transmission lines over the same distances. They may also be more reliable and cheaper to build. I look forward to hearing more about the prospects for making these kinds of changes to our electric grid system from this panel.

And I am also concerned about the nexus between water and energy. While regular solar panels really don't need much water except to clean them on occasion, some estimates show solar thermal technology using more water than a typical coal plant.

It is important that, moving forward we take the whole picture into account and do everything we can to avoid trading one big problem for another.

I am excited about the opportunities that large-scale solar power presents to create thousands of new green jobs and reduce our dependence on foreign sources of energy. Our committee will continue to do everything we can to help overcome the barriers to getting us there.

Representative Giffords, thank you again for your strong leadership to promote solar energy, and thanks to this distinguished panel of witnesses for being here today.

Ms. GIFFORDS. Thank you, Mr. Chairman.

Next, I would like to yield to Representative Harry Mitchell, for his opening statement.

Mr. MITCHELL. Thank you, Madam Chair.

I would also like to thank Chairman Gordon and Congresswoman Giffords for organizing this field hearing.

As a fellow freshman Member of Congress, from the sunny State of Arizona, Ms. Giffords and I have a unique perspective on how to address our nation's energy crisis.

We are lucky here in Arizona to enjoy over 300 days a year of sunshine. We have a real opportunity to brighten our state's future by investing in solar energy research and technology.

As solar technology advances, I believe that Arizona will be a leader in clean alternative energy production. Refocusing our energy production on alternative sources such as solar is critical for our national security and the environment.

Moreover, investing in solar energy is vital to Arizona's economy. Recently, Arbengoa Solar, and Arizona Public Service, announced exciting plans to develop the Solana Generating Station, and that is a 280 megawatt solar thermal energy plant, right here in the southwest. This will be the world's largest solar power plant. Solana will not only be a leading source of emission-free electricity, but it will also start significant development for Arizona.

However, the Arbengoa and Arizona Public Service executives have candidly told us that the Solana project will not happen without the extension of essential solar tax credits.

I am proud of the work that we have done in Congress to make sure that utility-scale solar projects, in particular, like Solana, continue to benefit from solar tax credits.

Recently, I voted for, and the House passed, the *Renewable Energy Conservation Act,* which would extend the 30 percent investment tax credit for solar energy property for eight years, through 2016. For the first time, public utilities would also be able to claim this investment tax credit.

I remain committed in doing what I can do in Congress to encourage further development and production of solar energy, and I would also like to thank two people from my district who are here to testify today. Barbara Lockwood is the Manager of Renewable Energy for Arizona Public Service, and Kate Maracas is the Vice President of Arbengoa Solar's Arizona Project. Both Arizona Public Service and Arbengoa are leaders in utility-scale solar energy and are working together to develop the Solana plant.

I look forward to hearing more about what we can do to establish Arizona's reputation as the Solar State, and I yield back the balance of my time.

Ms. GIFFORDS. Thank you, Mr. Mitchell.

I would like to yield a few minutes to Representative Matheson for his opening statement.

Mr. MATHESON. Well, thank you, Madam Chair. I will be very brief, because I am looking forward to hearing from the panel. But, I just do want to emphasize that the Science Committee is a very bipartisan committee in the House of Representatives. It is a committee that usually takes on a longer-term view on issues, and I think the issues before the Science Committee are really the issues that matter when you look out a couple of generations from now.

Congresswoman Giffords, you have been a leader in advocating the solar energy issue. You are a great Member of the Science Committee, and I am really impressed with how you have brought this hearing together today, and I just want to acknowledge that in your freshman term you have already established yourself as a real champion for this issue, and I will yield back my time.

Ms. GIFFORDS. Thank you, Mr. Matheson.

Representative Lipinski.

Mr. LIPINSKI. I just want to very briefly say, back in 1980 I was in 8th grade. We had a science fair. I did a science fair project on solar energy. It seems like in the—well, soon afterwards, we stopped having much interest in solar energy. It seemed like 30 years ago that was the emerging energy technology, where we had all these concerns about high gas prices, what is going to happen with oil, our oil supply, but here we are 30 years later, it feels like we are in the same place.

It is very important that we do not make mistakes now that we made back then. So, that is why I am very happy that Congresswoman Giffords is holding this hearing today. You know, having this many Members of Congress come out to a field hearing just really shows how important the issue is, and the role that Congresswoman Giffords is playing here—you know, this is a freshman Member of Congress—to have all this out here.

As Vice Chairman of the Science Committee, I think this is just a fantastic opportunity that we have here today. This is critical for the future of our country, and it is very important, critical for southern Arizona, certainly, and I look forward today to hearing from all the witnesses here today, and making sure that we do everything we can at the federal level so that we can take advantage of what is available, what solar energy makes possible for us.

And, I know Congresswoman Giffords is going to be a leader in Congress in doing that.

So, I yield back.

Ms. GIFFORDS. Thank you, Mr. Vice Chairman.

[The prepared statement of Mr. Smith follows:]

PREPARED STATEMENT OF REPRESENTATIVE ADRIAN SMITH

Thank you, Madame Vice Chairwoman. Nebraska is a state blessed with many natural resources, not least of which is sunshine. I have long held, and continue to believe, the United States needs to explore a diverse array of energy technologies.

Solar energy is one of many technologies which hold exciting potential. It is one of our most ubiquitous and reliable resources. Although there are challenges associated with capturing and storing solar energy, they are not insurmountable. I believe solar energy will play an important role in our future energy security.

I support policies which encourage innovation, research, development, and investment in renewable energy. We need to encourage long-term investments in solar energy, as well as wind energy, biofuels, nuclear power, and hydro-power. Our own domestic oil and gas resources should not be overlooked.

Thank you, Madame Vice Chairman, and I look forward to working with you to further policies which will promote research, development, and investment in solar technologies and other energy resources, leading to better energy security and national security for every Nebraskan and every American.

Ms. GIFFORDS. Now we would like to hear from our panelists, our witnesses. We are going to start, with just a couple brief seconds of introduction. We are going to hear from Mr. Mark Mehos, who is the Program Manager for the Concentrating Solar Power Program at the National Renewable Energy Lab in Colorado. So, thank you so much for being here.

We are going to hear from Mr. Tom Hansen, who is Vice President of Environmental Services, Conservation and Renewable Energy, at Tucson Electric Power, also featured in the *"Scientific American Magazine"* article, so great to have you here as well.

Ms. Kate Maracas is the Vice President of Arizona Operations at Abengoa Solar. We have heard a lot about your company and the proposed project. We are excited that you are here today as well.

Ms. Valerie Rauluk is the Founder and CEO of Venture Catalyst, Inc. She is a passionate supporter of solar energy, but also speaks on behalf of the business community as well. So, Ms. Rauluk, thank you for being here.

Ms. Barbara Lockwood is the Manager of the Renewable Energy for Arizona Public Service, APS, thank you for coming down from Phoenix, we welcome you.

And finally, Mr. Joe Kastner, the Vice President of Implementation Operations for MMA Renewable Ventures, LLC. We are so pleased to have you in southern Arizona. Thank you so much.

As I said earlier, our witnesses will have five minutes to present your oral testimony. Your written testimony will be inserted into the record, and when we are finished with the witnesses' testimony, remember that we will take turns asking questions of our witnesses.

And, we will begin with you, Mr. Mehos, please.

STATEMENT OF MR. MARK MEHOS, PROGRAM MANAGER, CONCENTRATING SOLAR POWER PROGRAM, NATIONAL RENEWABLE ENERGY LAB, COLORADO

Mr. MEHOS. Okay, thank you, Madam Chairman, thank you Members of the Committee, for giving me the opportunity to speak today. I did provide written testimony and ask permission to provide a Power Point oral presentation. Much of my information is better viewed than discussed.

So, I was asked to present information on, basically, some background on utility-scale solar power. I will do that. At NREL we have done a lot of analysis on the overall resource side for utility-scale solar generation in the U.S., especially with an emphasis on the southwest.

I was asked to present information on what the Federal Government can do to facilitate deployment, and finally, what can the Federal Government do to kick start utility-scale solar.

Real quickly on some background of utility-scale solar technologies. When we talk about utility-scale solar we are really talking about two different markets, solar with storage, which we call dispatchable generation, which I will discuss in a little bit, and solar without storage or, basically, non-dispatchable, meaning that it will generate electricity when the sun is shining.

On the dispatchable storage, we are really talking about three categories of technologies, and there are variations within these that I do not have time to discuss, but there's the parabolic trough up on the top of the screen, the power tower over to the lower left, and finally the linear fresnel, which is an upcoming technology over on the lower right. Each of these technologies are thermal-based technologies, which means they use concentrated sunlight to generate heat that can then be converted to electricity using conventional steam sites.

The solar without storage, or what we call the non-dispatchable technologies, are just that. They are, basically, they cannot use storage, and there is three technologies that can fall into this category, the dish engine, which is on your upper, or on the lower side of the screen now on your left, concentrating photovoltaic technologies, which is in the middle, and then finally flat plate PV technologies, just like those that are on the home, but in a much larger scale for utility-scale applications.

On the top, most of these are built in very large installations, on the order of 50, 100, 200 megawatts. People are even talking about much larger installations. Their economies of scale forced them toward that side. On the lower part of the screen, the non-dispatchables, typically, those are much smaller-scale technologies, on the order of kilowatts to tens of kilowatts, which can then be gained together to the similar 100 megawatt plants for large utility-scale applications.

So, I talked about the dispatchable technologies. Why do we, or why do utilities, like dispatchable power? Primarily, what we do with dispatchable power, is we collect a lot of that energy that is shining on our collectors during the daytime, we store a lot of that energy, or most of that energy, and we distribute that energy over a larger period of the day. So, what does that do for us? It gives us a much higher value for that energy collected. If we were just dispatching during the peak times of the day, that is a very high value period, certainly, but especially in the southwest when people come home and they turn on their air conditioners, and their TVs, and everything else, that peak load really does go throughout later into the evening and even into the night. And so, we are allowed to take on that higher value production later into the day, not just during the daytime. It also allows us to lower the cost of the technology, basically, taking what amounts to be a fairly high capital cost for any solar technology and amortizing that high capital cost over a larger number of hours, instead of operating annually at 25 percent of the year, we can operate up to 50 percent or even 70 or 80 percent of the year. So, it allows you to really take that energy and lower the cost, due to that larger amortization.

Okay. So, you asked the question regarding what is the resource potential, so at NREL we have done a significant amount of analysis using geographic information systems as a start, to try to screen where the most economical locations for large-scale solar can make sense.

Up in the upper left-hand corner, I show the unfiltered solar resource, basically, the darker red spots are where the highest solar resource exists. But, if I take this entire southwest region and compare that southwest region to anywhere else in the world the southwest is as high or higher than anyplace else in the world as far as its solar resource.

But, that is not all we need to look at. We need to look at other exclusions that can lower the economic value of that. The first thing we want to do, on the upper right-hand corner, is to exclude those areas that have a lower solar resource. We picked six hours, six kilowatt hours per meter squared per day, not that in the long-term you could not build economic plants, but we were looking more in the near-term.

On the lower left-hand corner, we start looking at land exclusions. This is utility-scale solar. Typically, plants can be as large as one square mile, for the APS plant three square miles, so we are looking at large tracts of land that we are not going to build in wilderness areas, we are not going to build in urban areas, and so we take those types of exclusions, and that is the lower left-hand corner.

Finally, because we are trying to minimize costs for constructing the plant, we are looking at fairly flat land. That does not have to be the case for some technologies, the most aggressive case is in the lower right-hand corner where we have looked at just one percent slope land.

So, when we do that, and we look at that fairly aggressive filtering scenario, we still have 11 times the current U.S. generating capacity, just in that small percentage of land that is left over. The current U.S. capacity is about 1,000 gigawatts, and I am showing a solar capacity with those lands of 11,000 gigawatts of potential.

Okay. So, you asked what can the Federal Government do to support this technology. I should say on that last map there are a couple items in my written testimony. One is, a lot of that land that I showed, while a lot of that lies on private lands, much of that lies on federal lands, on Bureau of Land Management lands, on Defense lands, so there is an effort within the Department of Energy to try to open access, to try to reduce barriers to permitting, for example, to putting some of these large scale solar plants on federal lands. And so, the Federal Government can continue to support that effort.

Also based on that map, much of that solar resource, while it is located near existing load, located near existing transmission, much of that transmission is constrained, and so to the degree that the Federal Government can support regional efforts to try to extend that transmission into these high-value areas, whether it is solar, or whether it is wind, or other renewable resources, please continue that effort.

Probably one of the most important near-term issues facing large-scale solar is the extension of the 30 percent investment tax credit. So, this is a quick example of the cost reduction associated with going from a 10 percent permanent investment tax credit to the 30 percent investment tax credit, basically, about a 15 percent reduction in cost, which does not seem like an awful lot, but this technology is right on the margin, as I will show in a second, that 15 percent reduction in cost to make or break these systems.

So, this is a curve based on a regional deployment system model developed at NREL, that competes solar technologies, wind technologies, against conventional technologies. I will not go into detail, but without an extension of the existing 30 percent investment tax credit, in other words, just the 10 percent investment tax credit, we see very little new penetration of utility-scale solar technology in the near-term. You do see it come on line in the long-term, as conventional costs start to rise, and as our costs start to reduce based on the R&D that happens within the laboratory system.

If you do extend that 30 percent tax credit by eight years, and it is important to note that a two-year extension does nothing, and eight-year extension will allow, according to our models, and we hear this out in the public sector, quite an increase, up to 20 gigawatts in the near-term of this technology. So, the extension of the tax credit is extremely important.

This just gives you a more visual representation of that, without the extension of the tax credit, and our model does go to 2050, but this is the nearer-term look. You will get some initial penetration that is basically driven by some of the State portfolio standards, and that initial penetration will probably happen 10 or 15 years from now, but you will get some initial penetration, and this, basically, the colors show capacity in megawatts. So, low penetration.

If you were to extend this investment tax credit by eight years to 2020, in this case I am showing the data, then you are looking at significant penetration in Arizona, in California, down in Texas, New Mexico, Colorado, all of these states driven, primarily, by the extension of this tax credit.

You asked what would be needed to kick start utility-scale solar. Right now, within the DOE program, utility-scale solar is about $30 million, primarily, focused on concentrating solar power of $170 million budget, which is mostly photovoltaic and distributed generation.

NREL and Sandia, at the request of DOE, did an exercise to see what could happen to accelerate utility-scale solar, and we estimated about $50 million per year to achieve accelerated goals. Those accelerated goals included being competitive in intermediate load markets by 2015, a five-year acceleration of the current goal, and to be competitive in carbon-constrained base load markets by 2020, which was not a goal previously at all.

To achieve those goals, there needs to be R&D emphasis on advanced thermal storage systems, and higher temperature systems, primarily, the troughs and the tower systems, which are the systems that are high temperature and allow for thermal storage.

I believe that's the end of my presentation.

[The prepared statement of Mr. Mehos follows:]

PREPARED STATEMENT OF MARK MEHOS

Madame Chairman, thank you for this occasion to present and discuss information related to opportunities and obstacles for utility-scale solar power. I am the Manager of the Concentrating Solar Power Program at the National Renewable Energy Laboratory (NREL). NREL is located in Golden, Colorado, and is the U.S. Department of Energy's primary laboratory for research and development (R&D) of renewable energy and energy efficiency technologies. I am honored to be here and to speak with you today.

I truly believe that solar power—both concentrating solar power and photovoltaic technologies—can provide a significant level of generating capacity in the United States if cost goals established by the U.S. Department of Energy (DOE) can be achieved. Reaching these goals will require a carefully balanced blend of DOE and industry sponsored R&D and government policies.

Introduction to Solar Technologies

Solar energy can be converted into electricity by means of photovoltaic (PV) or concentrating solar power (CSP) systems. Photovoltaics is the technical word for solar panels that create electricity. Photovoltaic material converts sunlight directly into electricity through a device called a solar cell. When sunlight strikes a solar cell, electrons are dislodged, creating an electrical current that can be captured and harnessed to do useful work.

Solar cells are connected together electrically to produce modules, and modules are mounted in PV arrays that can measure up to several meters on a side. **Flat-plate PV** arrays can be mounted at a fixed angle facing south, or they can be mounted on a tracking system, allowing the array to follow the sun in one or two axes to capture more sunlight over the course of a day. About 10 to 20 PV arrays can provide enough power for a household. However, for large electric utility or industrial applications, hundreds or thousands of arrays can be interconnected to form a single, large "utility-scale" PV system.

Higher efficiency solar cells, because of their high cost, are better suited to operate under concentrated sunlight. **Concentrating photovoltaic** (CPV) collectors use lenses or mirrors as optics to focus the sunlight onto the high-efficiency cells. The main idea is to use very little of the expensive semi-conducting PV material while collecting as much sunlight as possible with lower-cost concentrating optics. CPV systems are being considered primarily for utility-scale applications.

CSP technologies use concentrating optics to generate high temperatures that are typically used to drive conventional steam or gas turbines. Due to economies of scale, CSP is generally considered a central-generation technology, rather than a source of distributed generation.

The three main types of concentrating solar power systems are parabolic trough systems, power tower systems, and dish/engine systems. Variants of these systems are also being considered, such as the linear Fresnel reflector system, which uses flat, rather than parabolic, mirrors to concentrate the solar thermal energy.

Parabolic trough systems concentrate the sun's energy through the use of long, linear parabolically curved mirrors. The mirrors track the sun, focusing sunlight on a receiver that runs along the focal line of the trough. A heat-transfer fluid, typically a synthetic oil, flows through the receiver, rising in temperature as it flows along the length of the collector. The hot oil is then used to boil water in a conventional steam generator to produce electricity. Alternatively, water can be boiled directly in the receiver using a direct-steam receiver. A key advantage of parabolic trough systems is that they can use thermal storage, giving the systems the flexibility to dispatch electricity coincident with peak utility loads, which often occur late in the evening. Many systems in Spain, as well as the system announced by Arizona Public Service last month, will make use of this feature. Parabolic trough systems are currently the most commercially developed technology.

A **power tower** system uses a large field of mirrors, called heliostats, to concentrate sunlight onto the top of a tower, where a receiver is located. This focused sunlight heats a working fluid such as molten salt or water/steam flowing through the receiver. Similar to oil in a parabolic trough receiver, the salt in a tower receiver is used to generate steam (using heat exchangers) to generate electricity through a conventional steam generator. As with trough systems, tower systems can be integrated with thermal storage. Future low-cost storage options should allow both troughs and towers to operate competitively in the near-term in intermediate load markets and in the future in base load markets, offering a potential alternative to coal-based generation.

A **dish/engine** system uses a mirrored dish, similar to a very large satellite dish. The dish-shaped surface collects and concentrates the sun's heat onto a receiver, which absorbs the heat and transfers it to a gas within a Stirling engine or gas turbine. The heat allows the gas to expand against a piston (in a Stirling engine) or to power a turbine to produce mechanical power. The mechanical power is then used to run a generator or alternator to produce electricity.

Resource Potential for Solar Energy in the United States

A 2005 study commissioned by the Western Governors' Association (WGA) looked at the solar resource and suitable land available in seven southwestern U.S. states, including California, Arizona, Nevada, Utah, Colorado, New Mexico, and Texas. Analysis using Geographic Information Systems (GIS) determined optimal CSP sites with high economic potential by excluding regions in urban or sensitive areas, regions with low solar resource, and regions where terrain would inhibit the cost-effective deployment of large-scale plants. Even with this high level of exclusions, the WGA solar task force calculated a capability of generating up to 6,800 gigawatts (GW) using CSP technologies—almost seven times the current electric generating capacity of the entire United States. The WGA study found that, with a build-out of only two to four GW of CSP, the technology will be competitive with conventional natural-gas-fired combined-cycle plants with a cost approaching 10 cents per kilowatt-hour.

The southwestern United States is not the only area with great potential for CSP. Projects are under way in Spain and Northern Africa, with additional projects planned for Israel, the Middle East, Northern Mexico, and Australia. In total, more than 60 utility-scale CSP plants are under development worldwide, primarily driven by policies favorable to large-scale deployment of the technology.

Two questions are now addressed that relate to the role of the Federal Government in the success of utility-scale solar projects in the Untied States.

The first question is: How can the Federal Government facilitate the deployment of utility-scale solar projects?

At the request of the U.S. Department of Energy, NREL analyzed the impact of policy (both State and federal) and R&D on the penetration of utility-scale solar generating systems in the southwest United States. The Renewable Energy Deployment System (ReEDS) model, developed at NREL, was used to estimate the U.S. market potential of wind and solar energy for the next 20 to 50 years. The model competes these technologies against the more-conventional generation technologies of hydro, gas-combustion turbine and combined-cycle systems, coal, and nuclear. Future sequestration technologies are also included within the ReEDS model.

Results from the model indicate that utility-scale solar technologies can produce nearly 120 GWs of capacity in the Southwest by 2050. Significantly more capacity is possible if dedicated transmission can supply generation to load centers located outside the Southwest. However, a key outcome of the analysis is that initial market penetration is extremely dependent on the continuation of the existing 30 percent investment tax credit (ITC). According to the analysis, without an extension of the ITC, new capacity will be delayed about 10 to 15 years—until lower CSP generation costs resulting from R&D and international market development allow CSP technologies to compete against future conventional plants.

The Federal Government can facilitate the deployment of solar power plants by providing access to land. Utility-scale solar projects require considerable acreage. The 280-megawatt (MW) Arizona Public Service project mentioned earlier will cover three square miles. That is nearly 2,000 acres to produce the power for 70,000 homes. The Federal Government owns large tracts of land in the West. Doing an environmental study of those lands and streamlining the process by which industry can lease tracts found suitable for solar power projects will shorten the time it will take to build projects on these lands.

Finally, the Federal Government can support efforts to relieve transmission congestion throughout the West. Existing transmission lines are operating at near capacity. New lines must be built to bring power from solar plants located in the areas where the solar resource is best, often in remote sunny regions. Our transmission grid is like our highway system, but without the interstate highways. An "interstate" grid system would facilitate the transmission of solar power from the Southwest to load centers throughout the United States. As described earlier, the United States has an enormous solar resource. Once we reduce the cost of the technology, the next challenge will be to distribute the electricity produced to the people who need it.

A second questions is: How does the level of federal investment required to "kick start" utility-scale solar compare with that required by other technologies seeking government support?

NREL scientists are studying a number of renewable energy technologies. The country is entering a period where it must start making the transition to new sources of energy. DOE and NREL are pursuing a portfolio approach of technologies—such as solar, wind, biomass, hydrogen, and geothermal—that could play a role in the future. All these technologies have the potential to become cost competitive with fossil generation.

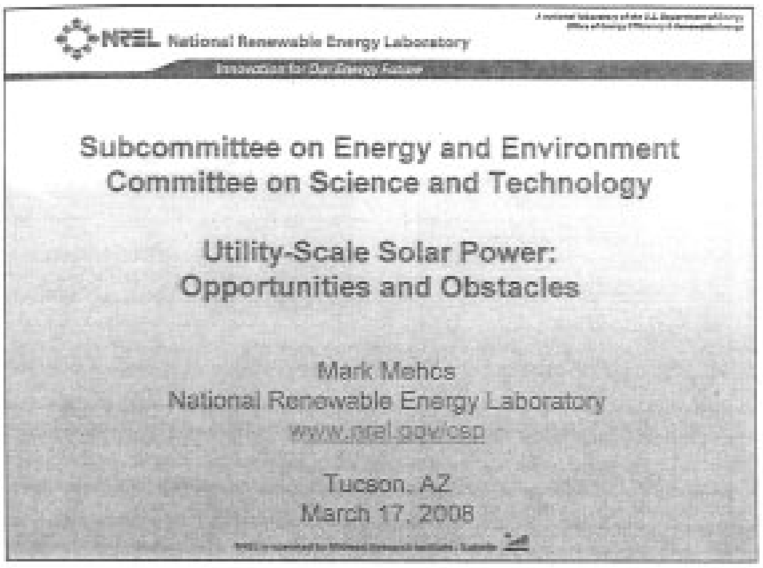
The price tag of utility-scale solar projects is large. For example, the 280-MW plant mentioned above will cost more than a billion dollars. Fortunately, the Federal Government does not need to contribute directly to cover the cost of these plants. The southwestern states have established renewable portfolio standards that have created the market for utility-scale power plants. Some states have established price guidelines by which they recognize that they will initially have to pay more for the renewable power. The additional costs are passed along to the rate payers. Thus, the bulk of the cost for establishing cost-effective utility-scale solar power is being borne by the states. If the Federal Government were to decide that utility-scale solar power was important, then they could partner with the states, which have already kick-started utility-scale solar.

Most of the money appropriated for solar energy R&D focuses on residential and commercial applications. Utility-scale solar receives about $30 million out of a total solar budget of $170 million. To meet the goals mentioned earlier, the DOE estimates that this funding would need to be doubled. Researchers at NREL work closely with the CSP industry and universities to develop new technologies that are more efficient and less costly. A study commissioned by DOE several years ago showed that reducing the cost of solar technology depends about 45 percent on R&D and 55 percent on actually building solar projects. This combination of R&D and deployment could well bring the cost of solar power into alignment with fossil generation in the intermediate power markets. And with low-cost storage, the overall cost may also align with future baseload power markets if carbon constraints are considered.

Summary

Addressing our near-term needs in solar power will require a national strategy that promotes the deployment of solar systems and processes that are ready to serve us today. At the same time, addressing our longer-term needs and achieving a significant contribution from solar power technologies will require a major new commitment to the research needed to deliver the next—and subsequent—generations of CSP, PV. and other new solar technologies.

Thank you.


NREL National Renewable Energy Laboratory
Innovation for Our Energy Future
Subcommittee on Energy and Environment
Committee on Science and Technology
Utility-Scale Solar Power:
Opportunities and Obstacles
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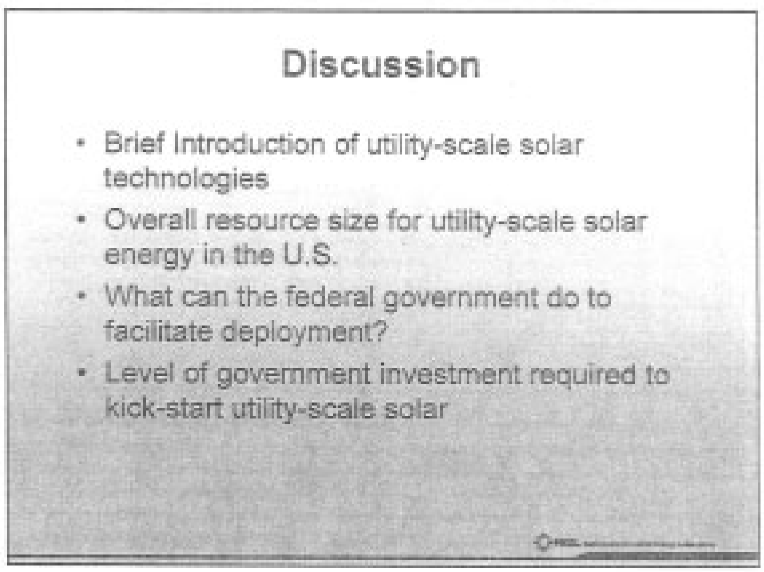
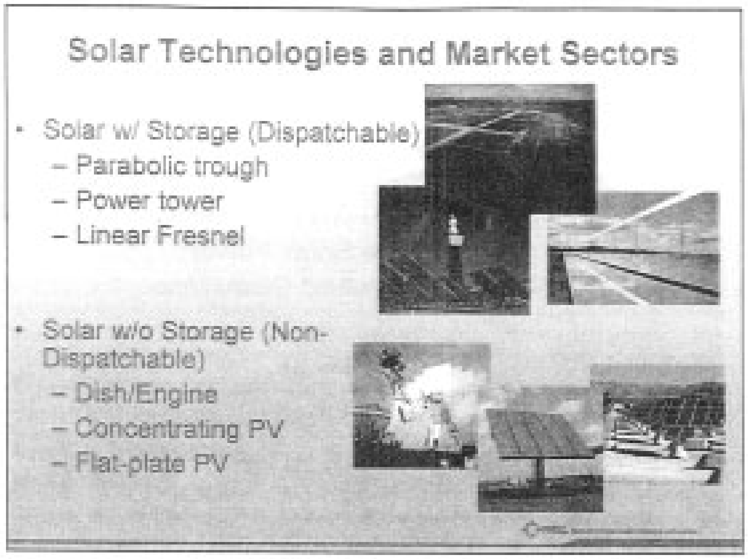
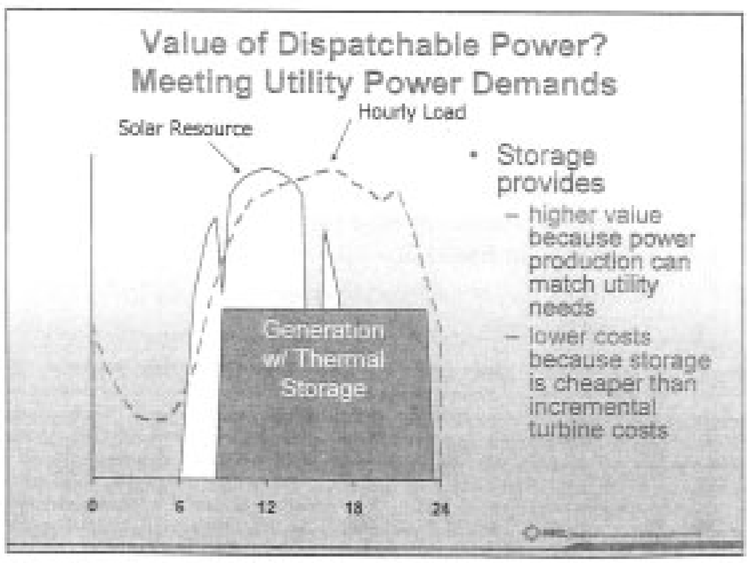
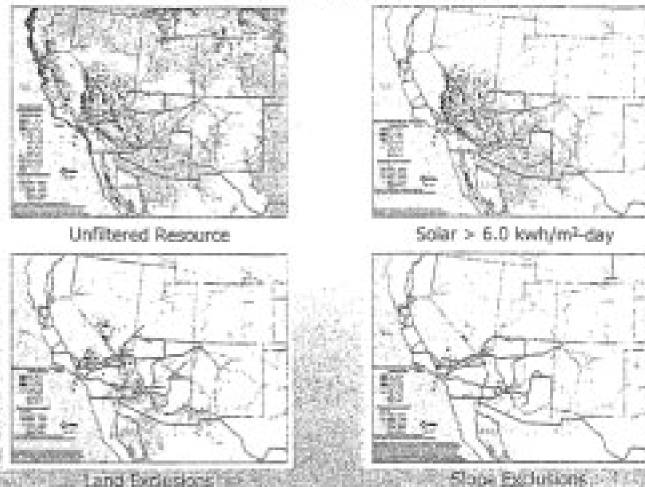

Discussion
• Brief Introduction of utility-scale solar technologies
• Overall resource size for utility-scale solar energy in the U.S.
• What can the federal government do to facilitate deployment?
• Level of government investment required to kick-start utility-scale solar


Solar Technologies and Market Sectors
• Solar w/ Storage (Dispatchable)
– Parabolic trough
– Power tower
– Linear Fresnel
• Solar w/o Storage (Non-Dispatchable)
– Dish/Engine
– Concentrating PV
– Flat-plate PV


Value of Dispatchable Power?
Meeting Utility Power Demands
Solar Resource
Hourly Load
Generation w/ Thermal Storage
0
6
12
18
24
• Storage provides
– higher value because power production can match utility needs
– lower costs because storage is cheaper than incremental turbine costs

GIS Solar Resource Screening Analysis

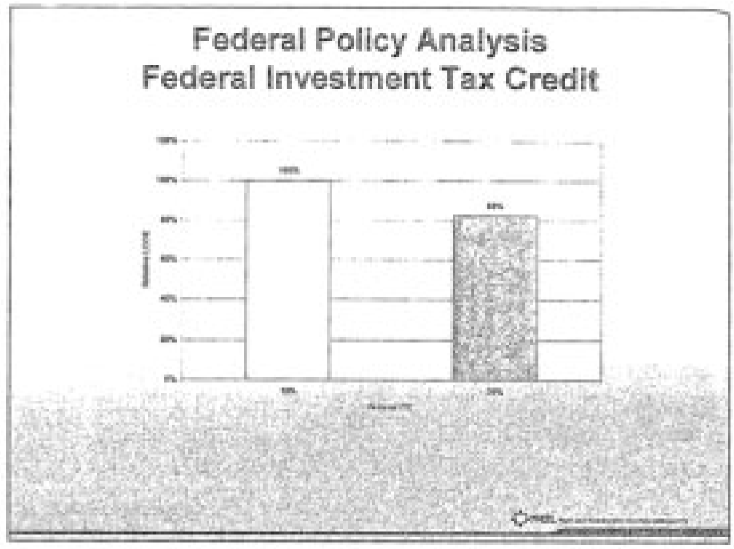


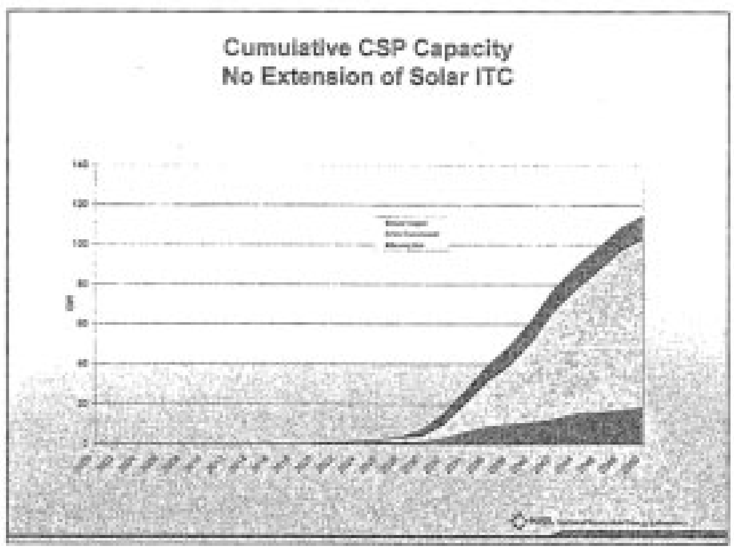
Resulting CSP Resource Potential

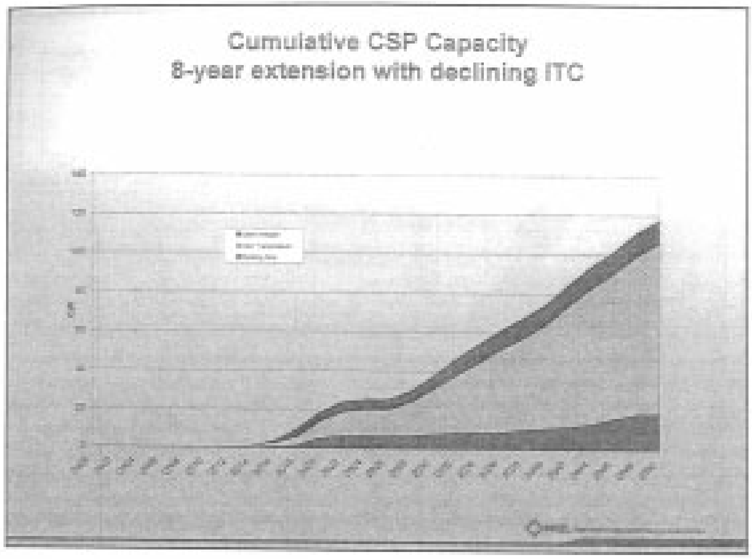
State	Land Area (mi²)	Solar Capacity (MW)	Solar Generation Capacity GWh
AZ	13,613	1,742,461	4,121,268
CA	6,278	803,647	1,900,786
CO	6,232	797,758	1,886,858
NV	11,090	1,419,480	3,357,355
NM	20,356	2,605,585	6,162,729
TX	6,374	815,880	1,929,719
UT	23,288	2,980,823	7,050,242
Total	87,232	11,165,633	26,408,858

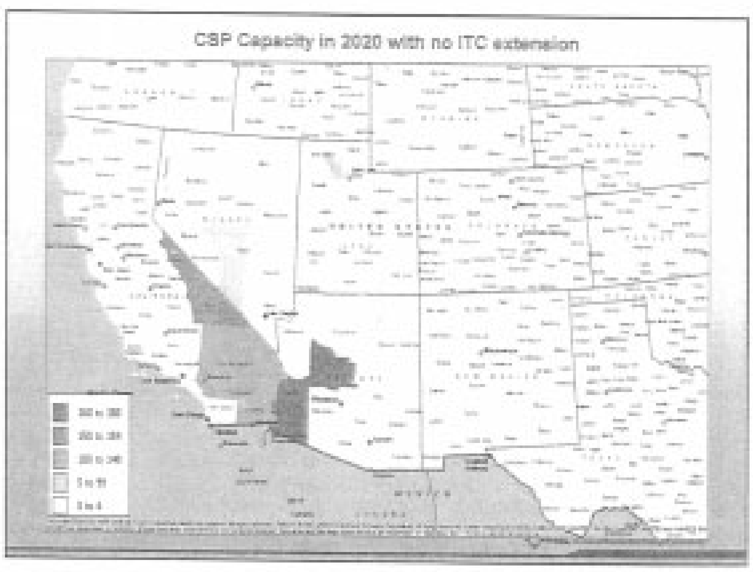
[illegible]

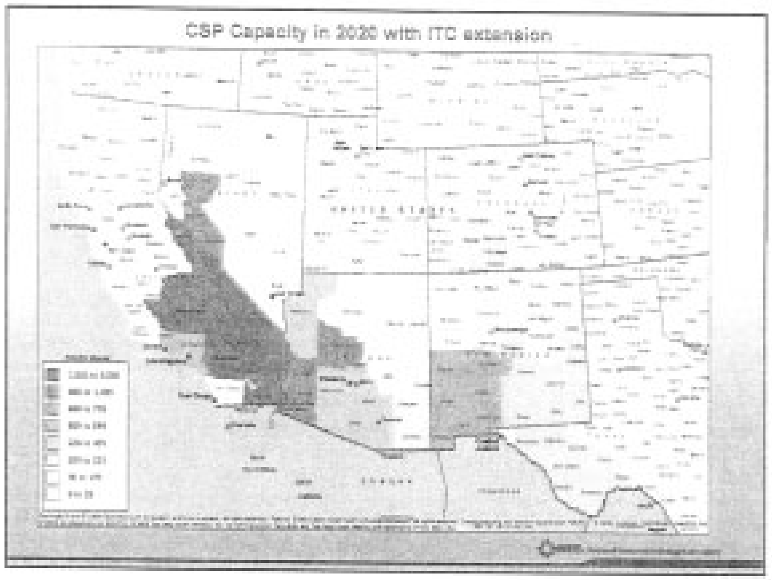
Current total nameplate capacity in the U.S. is 1,000GW w/ resulting annual generation of 4,000,000 GWh


Federal Policy Analysis
Federal Investment Tax Credit


Cumulative CSP Capacity
No Extension of Solar ITC

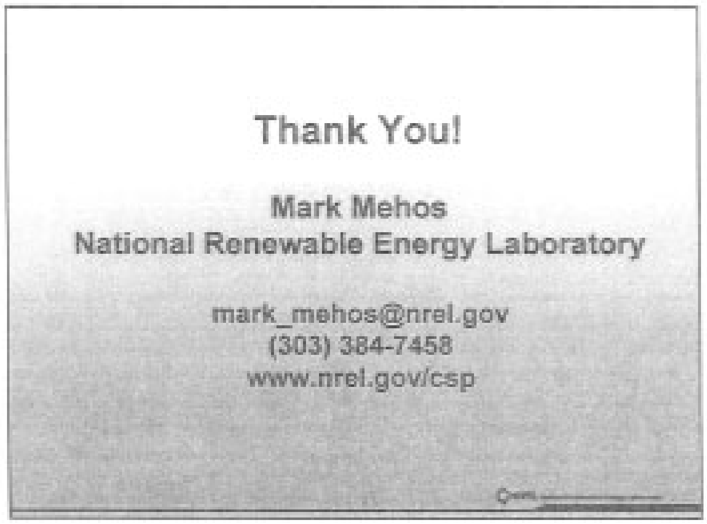

Cumulative CSP Capacity
8-year extension with declining ITC


CSP Capacity in 2020 with no ITC extension



Kick Starting Utility-Scale Solar

- Current utility-scale solar budget is $30M (out of $170M overall budget)
- NREL/Sandia exercise for DOE estimated $50M/year to achieve accelerated goals:
  - Competitive in intermediate load markets by 2015
  - Competitive in carbon-constrained baseload markets by 2020
- R&D emphasis on advanced thermal storage systems and high-temperature parabolic trough and tower systems.



BIOGRAPHY FOR MARK MEHOS

M.S., Mechanical Engineering, University of California at Berkeley
B.S., Mechanical Engineering, University of Colorado

Principal Program Manager—Concentrating Solar Power, NREL

Mark has been with NREL since 1986. He has led the High Temperature Solar Thermal Team at NREL since 1998 and has managed the Concentrating Solar Power Program since 2001. The emphasis of NREL's High Temperature Solar Thermal Team is the development of low-cost, high-performance, and high-reliability systems that use concentrated sunlight to generate power. He has participated on and conducted analysis for several task forces including New Mexico Governor Richardson's Concentrating Solar Power Task Force and the Solar Task Force for the WGA Clean and Diversified Energy Initiative. He is currently the leader for the "Solar Thermal Electric Power Systems" IEA SolarPACES task. In addition to his current work, he has managed and performed technical work within NREL's CSP analysis, advanced optical materials, solar photocatalysis and dish/Stirling R&D activities.

Ms. GIFFORDS. Thank you, Mr. Mehos.

Mr. Hansen, please.

STATEMENT OF MR. THOMAS N. HANSEN, VICE PRESIDENT, ENVIRONMENTAL SERVICES, CONSERVATION AND RENEWABLE ENERGY, TUCSON ELECTRIC POWER

Mr. HANSEN. Good afternoon, Chairwoman Giffords, thank you for the opportunity, thank you, distinguished Members of the Committee, for the opportunity to be here today to discuss with you what I consider a very important solution and a plausible solution to our energy challenges for the future, the "Solar Grand Plan," as described in the "Scientific American" issue in January of 2008.

While many energy resources are sustainable and environmentally neutral, only solar energy can supply all of our projected energy needs for the long-term sufficient needs to meet our long-term needs in the United States for centuries to come.

The January, 2008 issue of *"Scientific American Magazine"* details that "Solar Grand Plan," and it could realistically provide 69 percent of U.S. electric needs by 2050, and 100 percent of U.S. electric needs by the year 2100.

I should point out that my comments do not necessarily represent the views of Tucson Electric Power (TEP), although I'm employed by TEP these comments are based on my thoughts and my development of a totally alternative energy system over the last decade. So, TEP has not, at this point, taken a position on this "Solar Grand Plan."

The three core components of the "Solar Grand Plan" are first, solar energy installations, of course, to convert the sunlight into electricity. The second component, and a very important component, is energy storage. We need to be able to store that energy from the sunlight to make it dispatchable for periods when the sun is not shining. And finally, electric transmission, in order to bring the power from the southwest, or from other sources, be they hydro sources, or hydro kinetic, ocean sources, wind sources, throughout the United States, to the customers and to the energy storage sources.

The "Solar Grand Plan" assumes the deployment of a combination of thin film photovoltaic technologies, about 88 percent, and thermal storage, thermal solar technologies, including thermal storage, about 12 percent. These technologies have a proven record of reliability and safety, and that is what I want to emphasize, the "Solar Grand Plan" uses proven technologies that are in existence today. They are a little more expensive than traditional technologies, but they are proven. They do work.

The production of solar energy is a function of the time of day, time of year, and cloud cover. We need to have storage to be able to mitigate those intermittencies to provide utilities with a tool to make consistent dispatchable electricity. Solar energy has been developed, the modules themselves, the solar collectors of the thermal solar systems have been developed to a very high degree of reliability. What we need now is an effort to provide that storage, and to link the storage elements together with transmission opportunities.

One great reason that we would propose using compressed air energy storage is because it is under ground. It uses the same technologies as have been used to develop natural gas storage, and, in fact, only uses about 10 percent of the capacity that has been used already to develop natural gas storage in the United States. Energy storage under the ground makes it more secure, makes the opportunity to have it widely disbursed, providing better opportunities for energy security in the United States in the future.

Finally, the transmission component. In order to tie everything together, to make the opportunity to move electricity, just as we have in the United States with our interstate highway system, we need to have an interstate transmission system. This will probably be, while it is, again, one of the more technically, easily implemented elements, it will be probably the most challenging element from the standpoint of regulations and the ability and need to work together with stakeholders from states, at the federal level, and local level, to be able to implement putting in these right-of-ways for transmission systems.

There are other technologies as well that need to be developed. The smart grid technologies, as we heard, are a very important part. They make the glue, if you will, to tie all the pieces together. But, much, again, of that work has been done already. These are nascent technologies, but they do exist. They are not far fetched, this is not non-existent technology.

With all energy project proposals there is a price. This program should take, we estimate, about $420 billion, but think of it as another opportunity, another alternative, to carbon collection and storage. As we start looking at alternatives towards our energy future, we need to weigh the different alternatives. Carbon collection and storage is one opportunity, but so we feel is also the "Solar Grand Plan."

And finally, the "Solar Grand Plan" strengthens our energy security by effectively storing electrical energy under ground, just as we have done with fuels at the Strategic Petroleum Reserve and at natural gas storage facilities.

And, just as it took the political will of Congress, with strong support from the states, to make the interstate highway system a reality, so it will take strong leadership, vision and the will of Congress, in partnership with the states, to make this become a long-term, reliable, sustainable, energy secure solution for our nation.

Madam Chair, I thank you for the opportunity to visit with you today, and I look forward in the future to questions.

Thank you.

[The prepared statement of Mr. Hansen follows:]

PREPARED STATEMENT OF THOMAS N. HANSEN

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, supercapacitors 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.

BIOGRAPHY FOR THOMAS N. HANSEN

Education:

Lehigh University, BSEE, 1971

Major—Electrical Engineering/Computers, Hardware and Software Design

- Minor—Physics

Stanford University, MSEE, 1972

Major—Electrical Engineering/Computers, Hardware and Software Design, Laser Design, Inertial Navigation Design

Minor—Geophysics

Work Experience:

Tucson Electric Power Company—1992–Present

Vice President, Power Production—1992–1994

Vice President, Technical Adviser—1994–2006

Vice President, Environmental Services, Conservation and Renewable Energy—2006–Present

Guiding the development of the Renewable Generation Portfolio of Tucson Electric Power, including 11 MW of renewable generation capacity of which six MW is solar. Currently Arizona's largest single utility renewable generation fleet.

Alamito Company/Century Power—1984–1992

Superintendent of Operations, Springerville Generating Station—1984–1986

Plant Manager, Springerville Generating Station—1987–1988

Vice President, Operations, Springerville Generating Station—1989–1992

Bechtel Power Corporation—1972–1984

Senior Field Engineer, Navajo Generating Station—1972–1976

Start-Up Engineer, Cholla Generating Station—1977

Assistant Electrical Superintendent, Coronado Generating Station—1976–1980

Electrical Superintendent, Palo Verde Nuclear Generating Station—1981

Project Field Engineer, Springerville Generating Station—1981–1984

Career includes the design, construction, operation or management of over 10,000 MW of electric generation capacity in the western United States.

Affiliations Present/(Past):

EEI Renewable Energy Working Group—Chair, 2 yrs.

Arizona Governor's Renewable Energy Working Group—1 yr.

International Energy Agency Solar Energy Task 8 Committee Member and U.S. representative—2 yrs.

(WGA Clean and Diversified Energy Advisory Committee Solar Subcommittee Member—1 yr.)

(Utility Photovoltaic Group Board—Member, 3 yrs.)

Professional Licenses:

Registered Mechanical Engineer—Arizona

Registered Electrical Engineer—Arizona, California

Publications:

"Energy Pay-Back and Life Cycle CO_2 Emissions of the BOS in an Optimized 3.5 MW PV Installation." J.E. Mason, V.M. Fthenakis, T. Hansen and H.C. Kim. *Progress in Photovoltaics,* May 6, 2005.

"Photovoltaic Pourer Plant Experience at Tucson Electric Power." Larry Moore, Hal Post, Tom Hansen and Terry Mysak. *2005 ASME International Mechanical Engineering Congress,* November 2005. IMECE2005–82328.

"Environmental Portfolio Standard Meeting Solar Electric Generation Goals: The Utility View." Presented October 25, 2002 in Phoenix, Arizona at the Arizona Corporation Commission.

"More Solar for Less $." Presented October 3, 2003 in Scottsdale, Arizona at UPEX 2003: Solar Power Experience Conference.

"The Systems Driven Approach to Solar Energy: A Real World Experience." Presented October 15, 2003 in Albuquerque, New Mexico at the Sandia Laboratories Solar Power Conference.

"The Promise of Utility Scale Solar Photovoltaic (PV) Distributed Generation." Presented March 2, 2004 in Las Vegas, Nevada at the Power-Gen Renewable Energy 2004 Conference.

"Utility Scale Photovoltaic (USSPV) Distributed Generation." Presented April 5, 2004 in Phoenix, Arizona at the Arizona Corporation Commission.

"Springerville Generating Station Solar System: A Case Study." Presented October 19, 2004 in San Francisco, California at the Solar 2004 Conference.

"Utility Scale Photovoltaic Generation: Broccoli for Utilities—A New Generation Financing Paradigm." Presented October 27, 2005 in Phoenix, Arizona at the Arizona Corporation Commission.

"Utility Scale Photovoltaic Generation: A New Opportunity." Presented November 8, 2005 in Denver, Colorado at the Rocky Mountain Electric League Fall Conference.

Ms. GIFFORDS. Thank you, Mr. Hansen.

Ms. Maracas.

STATEMENT OF MS. KATE MARACAS, VICE PRESIDENT, ARIZONA OPERATIONS, ABENGOA SOLAR INC.

Ms. MARACAS. Thank you. Chairwoman Giffords, Members of the Committee, and staff, I, too, would like to express my appreciation for the opportunity to talk about this very important subject today. Thank you.

I am the Vice President of Arizona Operations for Abengoa Solar, and we are a very large company based in Madrid, Spain. Abengoa employs over 23,000 people worldwide, and we have presence in more than 70 countries. Right now, we have about 40 people in the U.S. and Spain, who are dedicated to improving the technology and developing solar technology in the sunny southwestern states.

In December of 2007, last year, the U.S. Department of Energy selected us for three R&D projects aimed at improving solar parabolic trough technology, which you saw in Mr. Mehos' presentation. And recently, as we have already talked a little bit about, we have announced an agreement with Arizona Public Service to build, own and operate the 280 megawatt CSP, or concentrating solar plant called Solana.

APS will purchase all of the output of the plant, and I think as Congressman Mitchell already mentioned, if the plant were in operation today it would be the very largest in the world.

So, with over 500 megawatts of large-scale solar power plants in operation, development and construction in the U.S., Spain, Algeria, and Morocco, I think our company is notably one of the largest providers, leading providers of large-scale solar technology today. And, with that position in mind, we are grateful to be part of this important dialogue and discussing the role that CSP and other large-scale solar technologies can play in helping build our nation's energy resource portfolio.

We will also be talking about the opportunities for removal of obstacles or barriers that could get in our way, and could otherwise prevent us from leveraging this very abundant resource, which as we heard comes in buckets from the sky. I like that analogy, I think it is a good one.

I have been asked to address a few topics today, and they include, one, the efficacy of large-scale solar power as a significant component of the U.S. generation fleet, and barrier reduction opportunities for achieving this potential. Two, the near and long-term economic impacts of large-scale solar deployment. And third, the role of government in advancing solar thermal technologies.

In the interest of time and efficiency, I will probably skip the third one, because I really cannot add anything to what Mr. Mehos has already commented, and I certainly concur with his remarks.

On the subject of large-scale solar generation as a viable option for providing significant contributions to our power needs, my view is, certainly, that large-scale power facilities not only have the potential to become a leading part of our national resource portfolio, they are also among the smartest options that we can exercise, particularly, in a business-wise context.

Further, I see today's family of CSP technologies as an important mainstream option for utility resource plans, and I will explain the reasons for those thoughts momentarily. Just one minute I will spend, before I get there, though, on the distinction in technologies. Mr. Mehos already pointed out some of the few, but the family of solar and thermal CSP technologies is growing rapidly and there is an increasing number of technologies that are becoming part of the solar thermal or CSP family. These technologies are advancing rapidly in the marketplace, but there are two basic categories of technology that I would like to distinguish.

One is the category of photovoltaic or PV technologies, and those are the technologies that convert the sun's energy directly into electricity by virtue of a photo electric reaction that occurs on a semiconducting material. And, when a concentrating mechanism such as a lens is used on conjunction with those PV cells then we have a large-scale technology known as high concentration photovoltaics or ACPV, and this becomes a member of the utility-scale solar family, as I mentioned earlier, and you saw an illustration of one of those technologies on Mr. Mehos' slide.

But, the solar thermal category, which is kind of the work horse of the large-scale family, is a bit different, in that it uses the sun's heat to produce steam, which in turn becomes the working agent in a conventional ranking cycle, the very familiar thermodynamic process that converts heat to energy in a common steam plant. So, this is very familiar, tried and true, mature technology.

The significant difference between our kind of solar steam plant and natural goal or coal steam plants is that there is no fossil fuel combustion or associated carbon emission to use in creating the mechanical energy that in turn spins the turbine, and then transfers mechanical energy to an electric generator.

So, most of my remarks today are with the large-scale solar technologies in mind.

And then, returning to my comment that CSP is a business-wise decision, I can offer that at Abengoa Solar we talk with many, many utilities in our sunny southwestern and western states, and they are beginning to articulate large-scale solar in a different way. It is no longer just something that we have to do for compliance anymore. It is no longer something that our utility colleagues talk about as an R&D endeavor or an experiment, it is something that they consider a wise part of the their future resource planning options.

When we talk about advanced coal technologies, which are not terribly mature yet today, and what are the other options that could compete as we are thinking about rapidly-growing demand in service areas, you probably will hear from Ms. Lockwood today about the rapid growth that APS is experiencing in our state.

When you look at natural gas volatility risks, and the increasing likelihood of some kind of carbon regulation or carbon tax, then utilities are really beginning to think of it differently. Although, as Tom says, everything has a price, there is a slight premium today above conventional generation costs for CSP or large-scale solar generated electricity, but that cost gap is closing and I think Mark's slides illustrated that very well. As natural gas prices rise, as other costs go up, and as carbon regulation becomes more imminent the gap is closing. Our costs will come down.

Utilities are increasingly viewing CSP as a wise bet against fuel price volatility and open-ended carbon liability.

APS, our first large-scale CSP customer in the U.S., has, in fact, been very, very forward thinking about the role that CSP will play in their future resource portfolio, and I will let Barbara talk about that in just a little bit. But, I will say that APS has really been a leader among a group of very proactive utilities who are thinking about this in a very different way today.

And, the final portion of this first topic that I have been asked to address relates to those barriers that could stand in the way of large-scale solar deployment, and I will just be very simplistic about this. In my mind, there is no barrier whatsoever related to technology. Yes, indeed, there is room for improvements in cost, and performance, and efficiency, and R&D should continue, but in terms of will technology be the barrier that prevents us from going forward, it most definitely will not.

In my view, the greatest barrier to increased deployment of solar generating facilities is, indeed, political rather technical, and you know where I am going with this, I am going to be talking about the ITC, the lack of an enduring tax credit, the 30 percent solar investment tax credits that we have talked about briefly already, is really the biggest hindrance that we see today in large-scale solar.

The ITC has been in place since the passage of the Energy Policy Act in 2005, but it has, since its enactment it has really just been kept on life support with one or two-year extensions at a time.

As Mark said, these one or two-year extensions do large-scale projects really no good, in fact, they do a disservice, because it prevents us from developing a longer extension through Congress that could help create the certainties that capital markets need to lend money on these large projects. The duration of one or two years, which is shorter than the project development time for a large-scale solar plant, means that we really must see a long-term extension, at least eight years of the ITC, in order for this industry to move forward.

As Congressman Mitchell mentioned, we have been very candid about the fact that the Solana Generating Station in the Gila Bend area of Arizona cannot happen without it, without the eight-year extension.

So, for these reasons I guess I will just say, ITC, ITC, ITC over and over again, and I would urge Congress to extend this important measure for an eight-year period, through bipartisan support of the Renewable Energy and Energy Conservation Tax Act of 2008 which passed through the House last month.

On the subject of near and long-term economic impacts of large-scale solar deployment, I can draw observations from a very large body of credible research that has been done over the last several years on this topic, and I will speak as a member of the Western Governors' Solar Task Force—or the Western Governors' Association Solar Task Force, as a member of that group I participated in a comprehensive effort to analyze the role that solar energy could play in helping the Governors meet an ambitious goal of deploying 30,000 megawatts of clean energy in their 19 states by 2015.

So, our task was to understand what is the actual resource potential, what is the market potential, how does that match up with demand for energy, what is the industry's capability to gear up and build projects and deliver energy through solar resources, and also to understand the barriers to deployment, and then finally, what will this effort pay back in terms of economic benefits.

On the topic of economic impact, we examined over a dozen economic studies that had been done since 2004, all by credible investigators, State governments, national labs, universities. In fact, three of those studies were supported by Mark's institution, the National Renewable Energy Laboratory, and these three looked specifically at CSP, Concentrating Solar Power plants, and in a variety of different scenarios and assumptions about different growth patterns, and sizes of deployments and so on, they looked at what would be the impacts in terms of private investment in the state, permanent and temporary job creation, indirect and direct effects, and so on.

And, we convened—these studies were conducted for Nevada, for New Mexico, and for southern California, and so the assumptions were all different, as I mentioned, different sizes of economies, and different scales and so on, in order to just understand, in a general sense, what does CSP or large-scale solar deployment really mean, in terms of just kind of generalization across the board, what does one gigawatt, 1,000 megawatts of CSP actually do to our economies. So, we convened an expert panel of economists to generalize these impacts, and our findings were that for every gigawatt of CSP added to the state's economy the deployment would yield $3 to $4 billion of private investment in the state, 3,400 to 5,000 construction jobs, and up to 200 permanent solar plant jobs, many of those in rural areas where we typically are trying to attract economic development, a $1.3 to $1.9 billion, 30-year increase in tax revenues, and that is after any tax incentives or other incentives are given to the project developers, and between $4 and $5 billion in increased gross State product. And so, a general rule of thumb for one gigawatt of CSP. These are enormous positive impacts that can occur.

Clearly, the findings indicated that the broader incorporation of large-scale solar plants into the U.S. generation fleet, not only produces those economic impacts, but also the benefits of sustainability and energy independence, as Mr. Hansen spoke about.

Finally, on the role of government advancing solar technologies, as I said, I will defer. I think those points have already been made very well. I will say that the thing that government can do for this technology, in addition to what Mr. Mehos mentioned, and issues that will help us site and facilitate permitting, solve transmission congestion problems and so on, we have to help CSP learn to walk on its own, and, in fact, we very much hope it learns to run.

Thank you very much.

[The prepared statement of Ms. Maracas follows:]

PREPARED STATEMENT OF KATE MARACAS

Mr. Chairman, Vice Chairman Giffords, Members of the Committee, thank you for the opportunity to testify today. I am the Vice President of Arizona Operations for Abengoa Solar Inc., a U.S. division of Abengoa, which is based in Madrid, Spain. Abengoa employs over 23,000 people worldwide, with presence in more than 70 countries. Abengoa Solar has a team of approximately 40 people in the United States and Spain dedicated to researching, developing and improving solar technologies. In December 2007, the U.S. Department of Energy selected Abengoa Solar for three research and development projects to improve solar parabolic trough technology. And recently, we announced an agreement with Arizona Public Service to build, own and operate a 280 Megawatt (MW) Concentrating Solar Power, or "CSP" plant in western Arizona. APS will purchase all of the output of the plant, known as the Solana Generating Station. If in operation today, Solana would be the largest solar power plant in the world.

With over 500 MW of large-scale solar power plants in operation, development, and construction stages in the U.S., Spain, Morocco, and Algeria, Abengoa Solar is notably one of the world's leading providers of large-scale solar technology solutions today. With that position in mind, we are especially grateful for the opportunity to be a part of this important dialogue about the role that CSP and other large scale solar technologies can play in our nation's energy resource portfolio, and the opportunities for removing obstacles that could prevent us from leveraging our very abundant and sustainable solar resource.

I have been asked to address a few topics today, and they include:

(1) The efficacy of large-scale solar power as a significant component of the U.S. generation fleet, and barrier reduction opportunities for achieving this potential;

(2) Near- and long-term economic impacts of large-scale solar deployments; and

(3) The role of government in advancing solar thermal technologies.

I will attempt to address these topics, in that same order.

On the subject of large-scale solar generation as a viable option for providing significant contributions to our nation's power needs, my view is that large-scale solar power facilities not only have the potential to become a meaningful part of our national resource portfolio; they are also among the smartest options we can exercise—particularly in a business-wise context. Further, I see today's family of CSP technologies as an important "mainstream" option for utility resource plans. I will explain the reasons for those thoughts momentarily, and before I do, a brief discussion about the distinction between large-scale solar generation and CSP in particular is worthwhile.

The family of solar thermal and CSP technologies is growing rapidly. An increasing number of technology approaches to solar thermal generation is advancing in the market place. I would like to clarify that there are two very basic categories of solar electricity generation. One is the category of photovoltaic, or "PV" technologies—those that convert the sun's energy directly to electricity by virtue of a photo-electric reaction that occurs on a semi-conducting material. When a concentrating mechanism such as a lens is used in conjunction with PV cells, the technology is known as High Concentration Photovoltaics, or "HCPV." Because the lenses add great efficiency to the PV cells' production capacity, HCPV is currently being developed as a utility-scale solar option.

The solar thermal category is a bit different, in that it uses the sun's heat to produce steam, which in turn becomes the working agent in a conventional Rankine Cycle—the very familiar thermodynamic process that converts heat to energy in a common steam power plant. The significant difference is that a solar thermal plant requires no fossil fuel combustion or associated carbon emissions to create the mechanical energy that spins a turbine, which in turn transfers mechanical energy to an electric generator.

Most of my remarks today contemplate thermal CSP technologies, although Abengoa Solar also views HCPV as a very promising technology in the near horizon.

Returning to my comment that CSP is a "business-wise" decision, I can offer that Abengoa Solar Inc. holds discussions with many utilities in our sunny western and southwestern states, and an increasing number of our utility contacts articulate that they no longer view CSP as *just* an option for Renewable Portfolio Standard (RPS) compliance, or as an experimental R&D endeavor. Rather, our utility colleagues consider their future resource planning options in the context of advanced coal technology and emission constraints, natural gas price volatility risks, and the increasing likelihood of carbon emission costs in the form of externalities or direct taxation. Although there is a slight premium today above conventional generation costs for CSP-generated electricity, the cost gap is closing as fossil fuel prices increase and carbon regulation becomes more imminent. With today's promise of dispatchable solar plants made available through advanced commercialization of Solar Thermal Energy Storage (TES) technology, utilities increasingly view CSP as a wise bet against fuel price volatility and open-ended carbon liability.

Arizona Public Service, our first large-scale CSP customer in the U.S., has in fact been very forward thinking about the role of CSP in their future resource portfolio. APS is a leader among a group of proactive utilities in our nation who very definitely view CSP as a viable part of a low-risk resource portfolio, and as a mainstream element of their growing generation fleet.

The final portion of this topic that I have been asked to address relates to those barriers that may stand in the way of large-scale solar deployments. There is no question in my mind that technology is not a barrier. While there is room for cost and performance improvements that will occur with technology advancements, economies of scale, repetition and associated learning curve improvements, the greatest barrier to increased deployment of solar generating facilities is indeed political rather than technical. While federal support of R&D must continue, the single most significant hindrance to broader deployments of CSP facilities in the U.S. is the lack of an enduring tax credit which is essential to the financial viability of CSP installations today. The 30 percent federal Investment Tax Credit, or "ITC," has been in place since passage of the *Energy Policy Act 2005.* But since its enactment it has been kept on life support with one- or two-year reauthorizations at a time. The short lifespan of the ITC does not stimulate the deployment of large, capital-intense solar generating stations, which require three to four years to build. Further, the large institutional entities required to provide construction and operating capital for these projects cannot operate with the uncertainty of an expiring tax credit whose duration is shorter than a project development period.

In summary, are there technology improvements to be achieved for large-scale solar through R&D? Absolutely. Are the barriers to meeting more of our nation's energy needs through solar energy production related to technology? Absolutely not. The single most important barrier to achieving our solar potential is the lack of a policy framework that is sufficiently robust to stimulate solar deployments in a meaningful way. We, our industry colleagues, and our consumers urge Congress to extend the federal ITC for an eight year period through bipartisan support of the *Renewable Energy and Energy Conservation Tax Act of 2008* that passed in the House last month.

On the subject of near- and long-term economic impacts of large-scale solar deployments, I can draw observations from a large body of credible research that has been done over the last several years. As a member of the Western Governors Association's Solar Task Force, I participated in a comprehensive effort to analyze the role that solar energy could play in helping the Governors meet their goal of deploying 30,000 MW of clean energy in their 19 states by the year 2015. Our task was to understand the resource potential, the market potential, the industry's capacity, the barriers to deployment, and the economic impacts that would result. On the latter topic, we examined over a dozen economic studies conducted since 2004 by credible investigators such as universities, national laboratories, and State governments. In fact, three of those studies, supported by the National Renewable Energy Laboratory (NREL) examined the economic impacts that could be expected as a result of increased deployment of CSP plants in particular. The studies contemplated a variety of CSP plant growth and scale scenarios, and the changes to be expected in terms of job creation, net Treasury gains, Gross State Product, and private investment.

We convened an expert panel of economists to generalize these impacts across different State economies, and across different assumptions used among the studies.

Our findings were that for every one Gigawatt (GW) of CSP added to a state's economy, the deployment would yield:[1]

- $3–$4 billion private investment in state;
- 3,400–5,000 construction jobs; up to 200 permanent solar plant jobs, many in rural areas;
- $1.3–$1.9 billion 30-yr. increase in State tax revenues; and
- $4–$5 billion increase in Gross State Product.

Those figures represent net effects, even after any tax credits or economic incentives are utilized to stimulate industry development. Clearly, the findings show that broader incorporation of large-scale solar plants into the U.S. generation fleet not only produces the benefits of sustainability and energy independence, it also pays back in very significant, positive economic impacts.

Finally, on the role of government in advancing solar thermal technologies, it is clear that the private sector cannot achieve a "Grand Solar Plan" alone. The market penetration of any new technology, product, or service traditionally follows a pattern of growth in market adoption, followed by declining prices and higher margins that result from economies of scale. Large-scale solar generation is no different in that regard. What is different, however, is that the capital commitments required to bring large-scale solar plants to market are very large, and the risk of investing in such markets with the hope that demand will follow is too high for private sector entities to bear alone. This condition describes the very traditional role that government has played in numerous examples of infrastructure development and market stimulation actions.

The government's role in solar power thus far has been both push and pull. By that I imply that the creation of demand for clean solar energy in the market place must come from both mandates and incentives. Twenty six states, including Arizona, now have Renewable Portfolio Standards that require increasing portions of delivered electricity to be derived from renewable energy resources. The RPS frameworks are a very good start, but only speak to half of the push-pull equation. Governments must also step up to the plate to incentivize market activity, and so I repeat here that a vitally important role for the Federal Government will be to extend the ITC for eight years so that large solar power plants can be financed and be economically viable. Recalling my comparison to other new technologies, products, and services in the marketplace, CSP will also grow up and learn to walk on its own.

On a final note, I will comment that we are very pleased to see the serious commitment to solar energy R&D that both the President and Congress have demonstrated in recent years. While I noted earlier that technology itself is not a barrier to large-scale solar power production, the efficiency and performance improvements that will be accomplished through R&D will continue to be an important part of ongoing cost reductions that will help large-scale solar generation to walk on its own. In fact, we hope it learns to run.

Thank you very much for the opportunity to share our perspective on this important topic.

BIOGRAPHY FOR KATE MARACAS

Kate Maracas is the Vice President of Abengoa Solar's Arizona Operations, where she focuses on infrastructure development to support the siting of Concentrating Solar Power (CSP) plants within Arizona. She has more than 25 years of energy industry and consulting experience in areas including engineering, environmental management, and renewable energy. Her career emphasis over the last several years has been in large scale solar generation. Kate actively participated with the Western Governors' Association Solar Task Force in developing its report and recommendations for solar market expansion in the western region, and continues to work on legislative and policy efforts to advance CSP deployment. Kate holds a Graduate Certificate in International Business from the Thunderbird Graduate School of International Management, and a Bachelor of Science Degree in Electrical Engineering from Arizona State University. Ms. Maracas currently serves as an ap-

[1] The assumptions here are:

- A state economy (GSP) of $250B (a median range across states);
- Only direct jobs—no manufacturing or other indirect jobs are considered here;
- Investment represents only direct capital associated with the plant and assets;
- GSP increase includes indirect and induced effects.

pointee of Governor Janet Napolitano on Arizona's Solar Energy Advisory Council, and chairs the CSP committee of the Governor's Council.

Ms. GIFFORDS. Thank you, Ms. Maracas.

Ms. Rauluk, please.

STATEMENT OF MS. VALERIE RAULUK, FOUNDER AND CEO, VENTURE CATALYST INC.

Ms. RAULUK. Thank you, Madam Chair, Chairman Gordon, and distinguished Members of the Committee, Representatives Lipinski, Matheson, Mitchell, and Ranking Minority Leader Hall. I would also like to thank my colleagues regarding the insights I will share with you. Please note that Venture Catalyst is solely responsible for the opinions expressed. Thanks to Arizona Research Institute for Solar Energy, AzRISE, the University of Arizona, Joe Simmons and Ardeth Barnhardt, my colleagues at Sun Edison, Jigar Shah, Howard Green, Colin Murchie, and my colleagues at Raytheon Missile Systems, John Waszczak and Thomas Olden.

Venture Catalyst has been engaged in commercialization of solar energy technology for the last ten years, primarily, under contract with the U.S. Department of Energy, Sandia National Labs, and the National Renewable Energy Laboratory. We have also worked with regional and national solar energy companies in thermal and photovoltaic technologies, from residential to utility-scale markets.

Although fundamentally agnostic when it comes to solar technologies, I will address specific preferences based on risk factors and maximized benefits.

Here is what I hope to cover, opportunities, obstacles, critical factors in the first 10 years.

The "Grand Solar Plan" is possible with the right investment structure and technology portfolio. The path to progress for achieving that goal is a going-forward focus on Distributed Solar Photovoltaic, DGPV, I hope to use that, DGPV, throughout here.

Given the dominance of PV in the "Grand Solar Plan" and the 3,000 megawatts of solar thermal projects in the pipeline, a similar commitment to PV should be made. At present, 800 megawatts of PV have been cumulatively developed.

But most importantly, the DGPV focus offers the greatest flexibility for resolving the biggest obstacle to achieving the plan financing. Strategically targeted DGPV development offers all of the investor groups the best return on their investment, especially, the rate payers, and I am going to talk about that in a little more detail in a minute.

A couple critical factors for success on the path to progress. First of all, productively framing the concept of utility-scale solar. The second, continuing technical improvements, and third, structuring the investment for fairness and maximized benefit.

I want to talk a little bit about the different technologies and the different formats. You have already seen the difference between PV and solar thermal, I want to go into that.

There is two major development formats for solar energy. One is the central station format, and the other is the distributed format.

This is an example of solar thermal projects, which because of economies of scale limitations are to date developed in large-scale central station format.

The title of this image is “Perfection.” This is one of the many formats that solar photovoltaic projects can take, a utility-scale project in a distributed generation DG format. It does not require transmission and the associated costs considered connected to the distribution part of the electric power grid. Strategically located PV installations within the distribution grid can provide benefits above and beyond the value of clean green peak power, benefits that can extend the life of power infrastructure and increase the reliability of the local grid.

This is another picture of that same installation of an 8.4 megawatt in southern Colorado, and you can see the substation in the background there.

Here is another way to deploy DGPV, and it has actually been the major development mode for PV to date, and that is roof-top installation.

I would like to offer the following definition of utility-scale solar energy and call out the key factors, large scale, lower cost, higher reliability, and benefits across customer classes.

Here are a couple examples, two to 20 megawatt solar farms strategically located in the low pockets, one to five megawatt solar farms on the roof tops of schools, reducing school energy expenditures, and putting solar energy into the grid in the summertime for the rest of the community, and also, of course, the one to five megawatts in commercial government installations, similar to what I showed you before.

Critical factor 2, solar energy technology is ready right now. You have heard that from several of the speakers. PV, in particular, has, and continues to achieve, incremental improvements across the entire value chain. Additionally, major advances are coming out of Arizona laboratories in the next three to 10-year term, specifically, in the area of PV, concentrated PV, or CPV, and high-concentrated PV, or HCPV. A solar focus on the PV family of technologies will help harvest additional economic benefits for Arizona and Arizona rate payers, and you will have to pardon my specific interest in Arizona.

A major obstacle to PV deployment has been the conflict with preserving utility revenues. By means of both product design and regulatory rules and policy, the industry is actively addressing this conflict. A commitment to large-scale DGPV programs would accelerate the resolution.

Financing, financing, as I have said, is a major obstacle to making this happen.

We are asking the Federal Government, and local government, private capital, and, most importantly, the rate payers, from whence the utility renewable energy investment dollars comes from, are all the people involved in this transaction.

We are asking rate payers, I think this is the most important thing that you need to think about as we structure this, we are asking rate payers to contribute to solar energy investment at the same time they are being asked to pay for fossil fuel increases. By developing many solar projects across numerous communities, more rate payers will experience the direct benefits of economic development and increased power security and reliability. PV, CPV, HCPV, because of greater scalability, flexibility, and modularity, can be deployed more easily across a range of situations.

Regulatory obstacles, we know what has to be done, and have developed and implemented best practices in key regional U.S. markets. We need to nationalize those practices for a more rational and effective market. I would concur with many of the things that people have said already, the ITC is very important, and nationalizing some of these best practices is very important as well.

Incentive design, in general we need to reallocate our incentives away from fossil fuel and to solar energy, and we know there are some best practices on how to design that.

So, for the first 10 years, my recommendation is reallocate investment to the highest benefit, lowest-risk installations, and that is DGPV, and to aggregate smaller projects in a systematic program to reduce risk while delivering the cost of scale. And, I believe that this will effectively stretch public investment, and it will reduce performance and project risk.

In the second five years, I would see that we would integrate higher-volume concentrated PV and high-concentrated PV as the cost effectiveness and reliability of those technologies come on line, and begin a second phase of solar thermal development if feasible or necessary.

So, in conclusion, the path to progress for the Grand Solar Plan, make balanced, judicious, timely technology choices, structure the investment for fairness and efficiency across all of the investment groups, and match the 3,000 megawatt solar thermal projects in process with 3,000 megawatts of photovoltaic projects.

Thank you for this opportunity to testify, and thank you for your leadership in this critical issue, and especially, Chair, Congresswoman Giffords, I really appreciate your leadership here. It has made a very big difference in Arizona.

Thank you.

[The prepared statement of Ms. Rauluk follows:]

PREPARED STATEMENT OF VALERIE RAULUK

Madame Chairman, Members of the Committee, distinguished guests I am honored to offer my testimony concerning Utility Scale Solar Power. My comments will address the following:

1. Grand Solar Plan as a viable option. The technical & regulatory obstacles.
2. Current solar energy market and expected changes over the next 10 years.
3. Current regulatory environment and incentive structures conducive to large scale solar development & recommended improvements.
4. Distributed PV and concentrating PV compared with solar thermal technology. Areas of government research that can play a critical role not met by private sector. Other recommendations and priorities.

1. The Grand Solar Plan as a viable option. The technical & regulatory obstacles.

The Grand Solar Plan calls out a vision of nearly 70 percent of our electricity generation from solar energy by 2050. It also calls for a technology mix of five times as much solar photovoltaic ("PV") as solar thermal. This vision is highly probable, with the right development framework and investment incentives.

Additionally, the Grand Solar Plan calls out for a development format of large-scale remote solar energy generation, compressed air storage, and direct current transmission. My colleagues at the University of Arizona have convinced me that compressed air storage and direct current transmission are more than science fiction, although there is much that needs to be assessed for both approaches to be viable. It is important to note that designing, financing and implementing a large-scale adoption of such strategies is no minor feat. As such, I would see, from my experience and understanding of technology adoption cycles, that such approaches will not be available for commercial adoption for 10 or more years. Other witnesses could clarify the risks, timing and benefits better than I. Beginning the process of assessing and designing such approaches is useful, but I would caution that we focus on the approaches that can deliver large amounts of market driven solar generation into the mix quickly, with the lowest risk and the greatest benefits.

As you will see, my comments focus on the first ten years of a Grand Solar Plan. The first steps will be difficult. Large amounts of investment capital from public and private sectors will be needed. And the skeptics concerning solar energy and its primary role in the greening and cleaning of our energy system will be numerous and loud. That is why in the first years, we should focus on efforts that lower risk and maximize the benefits.

In addressing the technical and regulatory obstacles to achieving the Grand Plan the following critical factors will be addressed.

- Critical Factor #1—Productively framing the definition of "utility scale solar" and supporting with regulatory requirements.
- Critical Factor #2—Technology improvements, including improvements in business model.
- Critical Factor #3—Effectively structuring the multi-billion dollar investment to be made by rate-payers, investors and the government.

Critical Factor #1—Productively framing the definition of "utility scale solar" and supporting with regulatory requirements

Although the Grand Solar Plan does not make specific recommendations regarding the development format, it seems to imply, with the recommendation for large scale storage and specialty transmission, that solar energy should be developed under the model of the last 50 years: large scale, remotely located, dependent on extensive transmission for delivery to consumers. This is commonly referred to as the "central station" model.

There is a more market driven way to develop solar energy and the successes of the last few years highlight the approach. That approach consists of smaller generation facilities, on otherwise unused real estate (roof-tops and sites of 10 to 500 acres of land, two percent to 80 percent of a square mile), located near the load demand, and dispersed throughout many communities. That approach is called distributed generation or "DG."

DG is not only a path of more rapid, less risky development, it is also the path for a more robust power network. There is an inherent resiliency in networked systems where resources are at the point of use (like the Internet) instead of a hub and spoke development (like the land-line telephone system). This resiliency can be enhanced with the addition of small scale, on-site intelligent controls and storage, increasing reliability and dependability and improving the fit between resource generation and needs across the local grid. When developed in a strategic and coordinated fashion, DG can delay or eliminate the need for distribution and transmission infrastructure investment.

Although DG includes very small generating systems, much larger DG systems (up to 20MW in a single location) can be clearly characterized as "utility scale" as can a systematic aggregation of many smaller generators. Utility scale can be more productively thought of as any project/program offering high volume, lower-cost, reliable, and dependable renewable energy for 20 years plus at fixed prices for large numbers of customers. Utilizing this more expansive definition of utility scale offers more options for maximizing solar energy deployment at the best cost-benefit trade-off, starting now.

Examples are:

- 2 to 20MW solar farms, strategically located in load pockets to strengthen the grid and increase community energy security in case of transmission failure.
- 1 to 5 MW solar farms on the roofs of our schools, reducing school budget exposure to volatile and rising energy prices for 20 years and pumping solar power into the grid for community use during the summer days when community demand is most pressing.
- 100kW to multiple megawatts on commercial, government, industrial sites/buildings.

In Arizona alone, an immediate potential of multiple gigawatts of solar energy systems are available. With expected cost reductions, 65 GW of solar energy could be developed in the U.S. over the next ten years (U.S. Department of Energy. Solar America Initiative, *http://www1.eere.energy.gov/solar/solar_america/*).

Central station development has its attractions. It feeds into the 'bigger is better' syndrome. Bigger means more attention. Bigger means larger development fees. Usually bigger means cheaper. But what a great deal of research has shown, is that bigger, especially when it comes to power plants, can often be riskier: longer construction periods, higher financing cost, longer delays before a system is producing and selling energy to end-users, to name just a few.

Bigger also usually means more remotely located from where the consumers are, a distance that results in additional costs for transmission: wheeling charges, transmission investment and public approval (nobody seems to want transmission lines in their backyards), and transmission losses. And last, but not least the security exposure of having a critical resource like power, vulnerable to hundreds of miles of difficult to protect delivery infrastructure.

Removing the Obstacles

Since nearly all of our existing power generation is central station, and a considerable amount of central station solar power is in the early stages of development, our focus going forward should be to diversify our resource portfolio and focus on solar DG installations.

Regulatory

Regulatory obstacles to this path are fairly straightforward and in fact, many states have established law, policy and procedure to remove them. That is how 300MW of solar energy got developed last year. But the patchwork has prevented a truly vibrant and efficient market for solar energy. Efforts at the federal level to establish the following best practices will accelerate the development of solar energy.

Level the playing field for incentives, subsidies and financing

Establish incentives at the federal level that match the incentives given to fossil fuels. Structure for rapid and long-term deployments with declining levels of support to encourage systematic and focused cost reduction across the whole value chain. Reward system performance and support system diversity,

Net Metering

Require full retail value for all solar energy produced by customers without restrictions on size, or special fees and tariffs.

Standard & Fair Interconnection Standards to the Grid

Interconnection standards set the rules and fees for connecting a customer generator to the grid. The standard should encourage the development of customer systems, while maintaining the safety and integrity of the grid. A fair and reasonable standard has been broadly vetted and adopted in the leading renewable energy states and should be adopted nation-wide.

Solar Fair & Friendly Rates & Utility Revenue Practices

Properly designed rates can support investment in solar energy and wise use while maintaining utility profits.

Critical Factor #2—Technology improvements, including improvements in business model

Technical

Cost and efficiency, especially of components have been perennial obstacles to widespread use of solar energy. Both of those concerns have been and are being addressed with incremental improvements. In addition, major improvements are possible in the in the six- to 15-year time frame as research and development initiatives currently in process begin focused commercialization.

Two areas of consideration that have not received as much attention in the past are storage strategies and intelligent control technologies that facilitate integration of renewable energy into the grid. Storage is important for solar energy. It expands its flexibility by extending access to the power produced during sunlight hours. Storage schemes can be grand and large, like compressed-air energy storage. Because of scale and site limitation this approach is not being actively integrated into deployment projects. Other forms of storage such as flow batteries, inverter based micro storage, and flywheels are being considered. The storage industry is currently at a stage of development very similar to where PV was less than 10 years ago. Low volume market demand has meant low volume manufacturing and all of the cost premiums that entails. Properly incentivized storage options will bring investment and scale to its manufacture with the concomitant cost reduction. From the perspective of solar energy deployment in the near-term, these forms of storage should receive both research and incentive support, while core research continues on large scale, big bite strategies that will not be functionally available for five to ten years.

Intelligent controls are especially useful to maximize the potential benefits of DG deployment to the grid. Such controls could allocate generation resources across a distribution node to maximize value. Many of these controls are inverter based and would require software and minor hardware additions and modifications, a low cost solution with significant benefits. In addition to technical changes (including modifications of UL 1741), these benefits could be best achieved through a development mechanism of aggregating individual DG sites. There are some fundamental business model improvements that need to be made to integrate DG into the existing utility business model in a way that protects revenues and existing asset base.

Technical Improvements in business model

One of the most important innovations supporting rapid deployment of solar energy has been the technical advance in business models. The solar industry's explosive growth in the last few years has been directly related to the development and use of the solar power purchase agreement (PPA). In 2007 over 50 percent of the national nonresidential market for solar electric power was developed under PPAs, up from 10 percent in 2006 ("Solar Power Services: How PPAs are changing the PV Value Chain," Greentech Media, February, 2008). The solar PPA essentially finances the up-front capital cost and offers customers the output from PV systems at or below the cost of fossil fuel generation. The solar PPA developer monetizes the federal and local tax credits, facilitates utility incentives and renewable energy credit sales, and designs and implements all business processes to minimize and absorb the risk that the customer would otherwise be forced to assume. These risks include: financial, technology, system performance, construction and regulatory. With discipline and innovation, PPA developers have improved and enhanced the solar photovoltaic transaction across the entire value chain, bringing greater profitability and lower prices to the market place.

It was this customer-centric focus, at a time when customers were reeling from rate increases and pricing volatility that resulted in such an expansion of system installations. The solar PPA using PV technology, offers two financial risk reduction strategies for customers: capital acquisition and future price protection. Under the solar PPA, the developer monetizes all of the incentives and tax credits and through aggregation, secures private sector project financing. Because of the nature of PV technology, especially minimal operations and maintenance requirements once installed, and long-term predictable performance output (PV panels have warranties of 25 years), PV can offer firm prices under contract for 20 years. This means an effective 20-year hedge against rising fossil fuel prices for the customer. It is this hedge against rising electric power prices fueled by resources with uncertain and volatile pricing that has made the PV PPAs so successful.

The next generation of solar PPAs, currently entering the market continues this customer-centric focus, but with the addition of utility-centric features. The recent success of solar thermal technologies in the market place (3,000 MW of solar thermal contracts have been initiated with construction expected to be complete in the next three years) highlights the importance of utility-centric features. Solar thermal is a traditional steam turbine electric power generation process, fueled primarily by solar collectors instead of coal, natural gas or nuclear reaction. The familiarity helps many utility executives more readily consider the solar thermal option. But since the approach incorporates a traditional power block, it shares many of the risks and inefficiencies of indirect, multi-stage conversions of energy: large scale, remote location, transmission dependent, multi-year construction, and big impact financing, performance, and operation risks. For these reasons and more, it is not a technology choice and a development approach that can be relied upon to deliver large volume, rapid deployment of solar energy in the first phase. Large scale, strategic, and multi-year development of solar energy in the distributed generation format, especially in the next 10 year period is essential for achieving the goals of Grand Plan for Solar Energy.

Solar energy is a disruptive technology. Disruptive technologies by definition create risk. But disruptive technologies, like the automobile that replaced the horse and buggy, can offer massive improvements in quality of life and prosperity. What mitigates that risk and transforms it into opportunity is the right technology of doing business, the right business model. Such a model must be both customer-centric and utility-centric. Utility revenue and the remaining life of the massive investment made by investors and rate-payers in conventional generation, power distribution and transmission assets must be protected and maximized as best possible while incorporating solar technologies. But not at the expense of future competitiveness and resiliency.

A major obstacle to massive solar energy deployment, in addition to cost and efficiency, has been conflict. Innovations in the solar PPA, coupled with other innovations in power financing entering the marketplace, are designed to end the current conflict between distributed generation and utility revenue protection while establishing more effective and fair financing for rate-payers. It is in our interest to end the conflict. Much can be gained from strategic deployment of DG: improved system reliability, reduction or elimination of transmission & distribution expenditures, reduction of local congestion, voltage support, low cost to no cost for non-participants, and reduced subsidies. Deploying and integrating generators, smart meters and intelligent controls, energy efficiency, virtual net metering, green tariffs and effective storage will permit greater control of load and generation. It is important to note how great the need is for strengthening and hardening our power grid.

> ". . .the United States has three times as many power outages of the United Kingdom and over 30 times as many power outages of Japan. Both Japan and the United Kingdom have achieved this reliability in part by investing in 21st century distributed generation technologies-distributed solar, combined heat and power, fuel cells, energy efficiency measures, and other customer-centric market solutions. (as quoted in "The Materiality of Distributed Solar, "Jigar Shah, Apt, Jay & Lave, Lester & Morgan, M. Granger. (2006). Power Play: A More Reliable U.S. Electric System. *Issues in Science & Technology. http://findarticles.com/p/articles/mi_qa3622/is_200607/ai_n17174065*)

Finally, just as "simple, easy" is a useful guiding principle for technologies and technology systems, it is a good design principle for business models as well. "Solar PPA 2.0" can reduce and eliminate the need for complex and copious regulations, mandates and other policy requirements.

Critical Factor #3—Effectively structuring the multi-billion dollar investment that will be made by rate-payers, investors and the government.

The solar energy investment envisioned by the Grand Solar Plan is significant and such an investment should be fair to all investors and maximize both direct and indirect benefits. Because solar energy financing consists of several mechanisms: tax advantages, utility sector incentives payments, and private capital different investor groups are coordinated in the transaction. Fairness would recommend that all investors receive benefits that justify the investment made. The federal investment for solar is no different than investments made over the last 100 years for general public access to energy and electric power. From 1943 to 1999 $151 billion was spent by the Federal Government for support to nuclear power, $145.4 billion; solar energy, $4.4 billion; and wind, $1.3 billion. ("Federal Energy Subsidies: Not All Technologies are Created Equal," Marshall Goldberg, Renewable Energy Policy Project, Research Report July 2000, No. 11). Clearly, for solar energy to become more broadly available, restructuring of the federal energy investment must be made.

The rate-payer contribution is the area of greatest concern for assuring fairness. At the current level of financing for a residential rate-payer, usually less than $50 per year, when some rate-payers benefit more than others, although contributing benefits for all, there is less need for concern. But for the kind of investment that the Grand Solar Plan would entail, spreading the benefits across all rate-payer classes and all communities is crucial. The DG development approach can distribute the benefits across a broader range of rate-payers and communities.

But the fairness issue still remains. Not all rate-payers are in a position to invest in solar energy systems even with the tax credits and utility incentives available. The new funding mechanisms must be designed so that those who can directly benefit, contribute greater investment. Recent developments in PPAs for the DG market can increase the fairness, if the directive to support utility scale coordinated DG development is made.

2. The current marketplace for solar energy and expected evolution.

The current solar energy market has been dominated by DG deployment of PV, although 3,000 MW of solar thermal projects are expected to be built in the next few years. PV deployment over the next five years is conservatively projected to increase 35 percent annually. Worldwide 2007 deployment was just under 3 GW and is expected to increase to 11 GW by 2012. US deployments of approximately 300 MW (SEIA as reported by the *Wall Street Journal* 1/18/08) are conservatively expected to grow in excess of 35 percent annually (internal proprietary analysis). The U.S. market is commonly considered to be the next high growth solar market, anticipating greater consolidation of political will and the necessary regulatory framework at the U.S. federal level.

PV is on track for delivering promised cost reductions. Incremental improvements in silicon pricing, silicon utilization and overall system costs are expected to decrease annually at a consistent, but modest level. This is independent of any major game changing technology or manufacturing process coming on-line. There are cost, performance and manufacturing processing improvements in the pipeline, but it is uncertain when, and at what scale they will enter the marketplace. Commercialization is a highly uncertain process and although it is clear that more attention and investment has been directed toward PV improvements across the entire value chain, it is unclear how soon those improvements will be translated into value.

The Grand Plan calls out thin film and expected cost reductions. In general, I am in agreement, though my colleagues at University of Arizona have pointed out some of the fundamental resource issues from both a supply and a toxicity perspective, with the cadmium telluride cells. They and others are working on next generation materials with great promise that avoid supply and toxicity concerns, but again, there are uncertainties concerning time to market.

The greatest concern in the next three to five years may be financing. Solar energy financing comes from multiple sources (federal, utility rate payers and private capital). Difficulties in any of the sectors will constrain the total financing. In particular, without new approaches to utility contributions, in the current near-recessionary (recessionary) environment, there will be limits to how much of a cost burden can be placed on the rate-payer.

PV and HCPV technologies should and will dominate development in the next ten years, especially in a DG format. With all the talk of large-scale projects and exporting to the rest of the country, it would make sense to take care of the domestic needs of potential power exporters first and then use the fixed cost clean power to build generation for export.

The Grand Solar Plan suggests equal development on a GW basis for each technology for the next ten years. On that basis alone, with 3,000 MW of solar thermal in process, the focus for the next five to 10 years should be on PV deployment, especially in the DG development model (PV because it is scalable, modular and flexible can be developed in a central station format or distributed format).

Another way to think about it is to emphasize the technology that offers the "two-fers" or perhaps more elegantly "positive externalities." These are other positive benefits that come from the technologies, independent of clean, cost-effective energy generation. Economic development and job creation is essentially the same for each technology, more maintenance jobs for solar thermal, more flexible job experience for PV. Solar thermal is not less expensive than PV, and there is evidence that it is more expensive when comparing scale to scale. Other features and comparisons will be discussed later.

PV is scalable and flexible and it can be developed across a whole range of sizes from a few kilowatts to 50+MW on rooftops and ground mounted, using land that may not have any other productive use. Developed near to the customer demand, transmission costs can be saved. Larger numbers but smaller installations spread across more communities could be deployed, permitting more people and more communities to participate in the economic benefits of a large infrastructure development campaign. Large scale DG deployment also offers additional reliability as has been noted above.

Scale development of any solar technology has the potential to bring cost down, from component manufacturing to installation practices to financing and other transaction costs. Utility scale solar thermal provides component scale benefit solely to utility scale solar thermal. Because the same components are used in PV small scale to utility scale, any wins in the PV area have benefits across the whole range from utility scale down to the small systems on homes or for remote emergency applications.

For the next three to five years it is critical that we allocate solar energy investment to the highest benefit lowest risk installations. That would suggest a predominant role for DG, where the rate-payer investment can be more effectively stretched with private capital, and where the investment has the biggest return to rate-payers: near the load, dispersed throughout communities, benefiting more communities. Larger investments, with longer construction periods, greater cost of construction exposure, higher technology and performance risks, are less beneficial under the current constrained conditions. Since PV can go to scale in a DG format (5 to

20MWs) and at the higher MW level, deliver price breaks equal to or below the current cost of large scale solar power, it is prudent to focus on PV technology and DG scale.

As presented in the technology obstacles above, DG presents difficulties for utilities concerning revenue loss. With the entry into the market place of means to address those concerns, large volume strategically developed and integrated DG projects utilizing PV technologies will dominate in the next 5 years. In the second five, CPV and HCPV advances in scalability will support additional DG and more cost effective central station from regions like Arizona that have good solar resource and available land.

3. Current regulatory environment and incentive structure & large-scale solar development.

Key to large scale development in the near-term is the extension of the Federal Investment Tax Credit, standard interconnection and net metering at the federal level, support for solar energy on federal lands and protection for the key solar energy financing mechanism to date, the Power Purchase Agreement ("PPA").

The rationale for the first two issues have been offered and discussed above. Support for solar energy development on federal lands could be in terms of multipliers for requirements for federal agencies to deploy solar energy on-site and other federal lands as was done in EPACT 2005 (energy production is doubled for accounting purposes), and in reducing the administrative burden for long-term leases, etc. The fourth issue, protection for the PPA, like standard interconnection and net metering has been addressed in many states, but not all. This requirement concerns the ability of PPAs to be offered by solar energy developers without the burden of excessive and unnecessary regulatory requirements and approval. Federally preempting state attempts to prohibit or restrict on-site generation could consist of the following:

> "Provision of electricity from equipment which uses solar energy to generate electricity shall not be considered a sale of electricity for the purposes of any federal, State, or local regulation governing sales of electricity or regulating utility service, provided the sale is to serve load on the premises where the system is located, or on contiguous property."

4. Distributed photovoltaics, concentrating photovoltaics, solar thermal technology comparisons, R&D funding & Congressional actions.

Solar energy consists of two kinds of approaches: capturing the sun's photons (solar electric, photovoltaics, "PV") and capturing the sun's heat (solar thermal). These approaches can be developed in two formats: central station and distributed generation ("DG"). Central Station consists of large scale (20MW to GW, multiple square miles), remotely located, and connected to the grid via transmission lines and infrastructure for distances up to hundreds of miles. Distributed generation ("DG") consists of micro generators of hundreds of watts up to 20MW and can be located near the consumer demand. DG does not require transmission infrastructure, and is delivered to the end-user directly through the service panel or in larger systems of multiple megawatts by means of distribution lines and equipment.

Capturing the sun's heat requires components and equipment that is different depending on whether the developed in central station or DG format. Capturing the sun's photons, depends on similar components regardless of small scale or large-scale development. (This is particularly true for PV. For concentrating and high concentrating PV, smaller scale may not be effective).

Utility scale solar thermal approaches include parabolic troughs, power towers, and other systems. Most systems concentrate the sun's heat and focus that heat on production of steam to turn electric generators that then produce electricity.

PV, concentrating PV ("CPV" to 100 equivalent suns) and high concentrating PV ("HCPV" in excess of 100 suns) all use semi-conductor material that when exposed to the photons of the sun, directly produce electric current. The concentrating technologies, by means of special lens, dishes and reflective surfaces, effectively multiply the potential electric current from the photon energy of the sun (some proposed CPV systems are hybrids and use heat for energy production, but they are exceptions). Such systems require tracking and sophisticated thermal management. The complexity is offset by the potential to substantially increase the 10 percent efficiency of PV to 20 to 40 percent. As sophisticated tracking and thermal management technologies from other industries, especially the defense industry, migrate to the CPV and HCPV arena, these complexities could be profitably managed. As experience increases the certainty regarding performance, CPV and HCPV can become more viable, especially those that lend themselves to a scalable, modular and flexible development profile. (*Please see pictures of systems following the text*).

A key consideration for assessing the functionality and finance-ability of a technology, is how quickly and efficiently it can be deployed. Finance-ability requires long-term dependable production, either low cost or reasonably predictable operation and maintenance costs, and other minimized risk factors. The following table summarizes risk factors for PV and solar thermal. Due to the limited deployment of CPV and HCPV technologies, the risk analysis was not meaningful.

Risk Factor Reduction	PV	Solar Thermal
Fast, simple installation	Yes	No
Modular, scalable, incremental installation	Yes	No
Flexible installation (central station, DG, combination)	Yes	No
Low Operations & Maintenance cost	Yes	No
Faster, less production impacts from O&M	Yes	No
Greater cost reduction 2009 to 2015	Yes	No
Storage can be added at any time	Yes	No
Not dependent on fossil fuel support	Yes	No
Little water needed	Yes	No
Economic Development	Yes	Yes
Dispatch-ability (with storage addition)	Yes	Yes
Cost effective at smaller project size & lower capital requirements	Yes	No

There is a feature of solar thermal that may make it more advantageous and that is storage. Adequate storage increases the dispatch-ability and value of solar energy generation. Large-scale storage for solar thermal, supported by fossil fuel generation, is purported to be farther along in the development and reliability cycle than large-scale storage options for PV. Several proposed projects with storage features are expected to be completed in the next three years and will clarify.

Development Format: Central Station and Distributed Generation

PV (and CPV and HCPV) can be developed in a DG or central station format, though nearly all developments to date have been in a DG format. Utility scale solar thermal requires a central station format. As has been discussed, there are many advantages to DG, as summarized below:

Benefits Central Station & Distributed Generation	DG	Central Station
Direct customer hedge value	Yes	No
Direct customer access to benefits, more customers benefit	Yes	No
More communities have access to economic development	Yes	No
Strengthens Grid Reliability	Yes	No
Increases Energy Security	Yes	No
Allocates Costs more directly	Yes	No
Reduces transmission costs	Yes	No
Reduces need for transmission investment	Yes	No
Relieves Distribution Congestion	Yes	No
Reduces need for distribution investment	Yes	No
Multiple financing opportunities (asset based, tariff based etc.)	Yes	No

Other Regulatory & Incentive Mechanisms

Pricing Carbon Emissions

Currently, pricing carbon emissions has been done indirectly, through an assumed green value attributed to generation from renewable sources. How these attributes are valued and bought and sold is dependent upon the regulatory framework adopted by the state where the project is located. Establishing market based pricing mechanisms at the national level, by means of carbon taxes and/or carbon trading would be very productive and supportive of rapid and efficient deployment of solar energy. Among other positive results would be a reduction in transaction costs.

Setting Standards & Mandates

Although market driven strategies are always to be preferred on core resource issues, standards and mandates are often prudent and necessary to achieve certain objectives. The electric power industry is a regulated monopoly and does not operate in an environment where competitive alternatives can be easily presented and adopted. This is especially true in a market where many of the negative costs have not been systematically included, as is true for electric power. A national requirement or standard for renewable energy deployment could be helpful.

Summary of Federal Research & Development Support and Regulations

Research & Development

1. Storage *Large scale and small scale: batteries, inverter based, flywheels, compressed air storage.*
2. Intelligent Controls for Grid Integration
3. Value and Integration of Distributed Generation
4. Photovoltaic Materials, *including CPV and HCPV*

Regulations

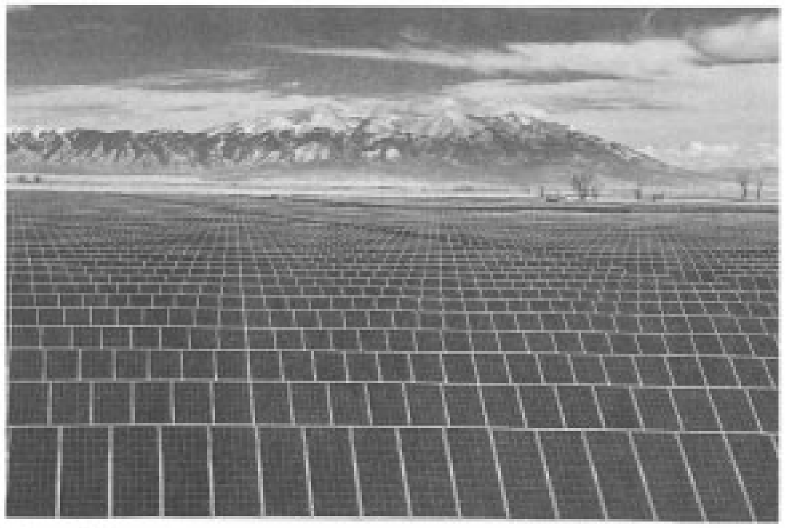
1. Extension of Federal Investment Tax Credit
2. Federalizing Standard Interconnection, Net Metering, and PPA protection
3. Access to federal lands for solar energy deployment
4. Pricing Carbon Emissions
5. Setting Renewable Energy Requirements

In conclusion, we are walking a tightrope of opportunity in the decisions we will make on cleaning and greening our electric power system. And the consequences of making a large, monolithic bad choice are no longer minor. At the end of the day, it all comes down to limiting our risk. Our choices must reflect a hard-nosed look at the risk, no matter how brutal the facts are.

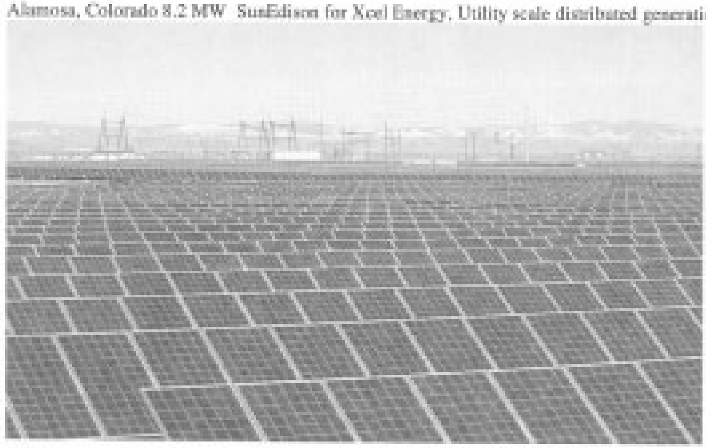
Thank you Madame Chairman and the Members of the Committee for the opportunity to share these observations and opinions with you.

Thanks to my colleagues at Arizona Research Institute for Solar Energy, AzRISE, University of Arizona (Joseph Simmons, Ph.D., Ardeth Barnhardt); SunEdison (Jigar Shah, Greg Ashley, Colin Murchie, and Howard Green), and Raytheon Missile Systems (John Waszczak, Ph.D., and Thomas Olden) for their insights in preparing this document.

Venture Catalyst Inc. is solely responsible for the opinions expressed here.



Alamosa, Colorado 8.2 MW SunEdison for Xcel Energy, Utility scale distributed generation.

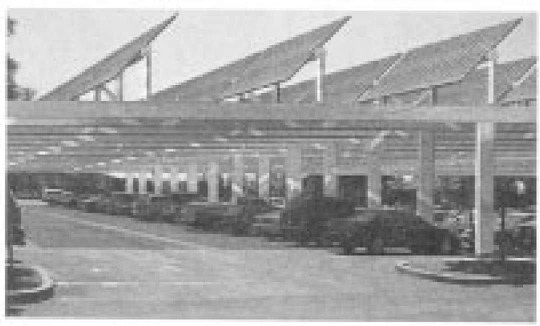


Connected to substation on the distribution network in the background.

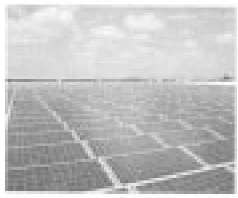
Solar thermal parabolic trough system.

Solar thermal power tower installation.

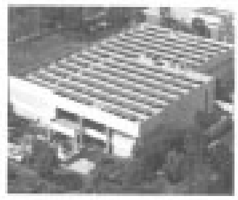
Typical roof mounted PV installation.



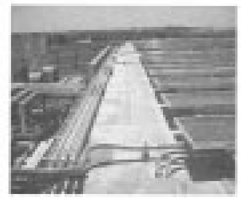
DG PV on carport structure.



Seagull Lighting [2 facilities, 1MW]

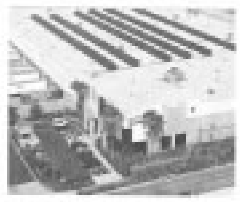


Sicor Laboratories (404kW)

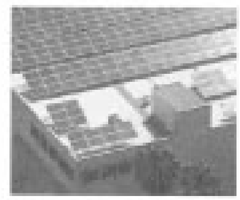


Cal Food Distributor (1.2MWs)

ICU Medical (475kW)



Staples Ontario, CA; Rialto, CA (560kW)



Sure Save Storage (888kW)

DG PV roof-mounted.

Utility Scale Solar Power Opportunities and Obstacles

Valerie Rauluk
Venture Catalyst Inc. [illegible] [illegible]

U.S House of Representatives Committee on Science and Technology, Subcommittee on Energy and Environment

March 27, 2008

Agenda

- Opportunity
- Obstacles
- Critical Factors
- The first Ten Years

Conclusions:

Path to Progress for the Grand Solar Plan

- Make balenced, judicious and timely technology choices.
- Structure the contribution of all investors for fairness and efficiency.
- Match the 3,000 MW Solar Thermal projects in process with 3,000 MW Solar Photovoltaic projects.

3

Opportunity

- Solar energy supplies over 35% of electricity and 69% of our energy needs by 2050 (3,500 GW), dominated by solar electric photovoltaic ("PV") technologies.
- Solar energy development brings 12 jobs per MW (35 million +).
- Solar energy development increases energy security.
- Arizona is a key nexus for solar energy deployment and solar energy innovation and manufacturing.

4

Obstacles

- Financing – structuring the investment and investment environment to support solar energy deployment.
- Legal/ Regulatory

Critical factors

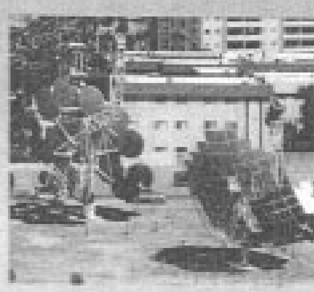
- Critical Factor #1: Productively framing the definition of "utility scale solar".
- Critical Factor #2: Technology improvements, including improvements in business model.
- Critical factors #3 – Effectively structuring the multi-billion dollar investment to be made by ratepayers, private capital and the government.

First, a framework…

- Technology Type
  - Solar Thermal
  - Solar Photovoltaic ("PV")
- Development Format
  - Central Station
  - Distributed Generation ("DG")

7

Capturing the sun's heat and/ or light

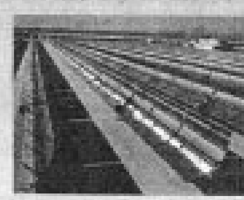


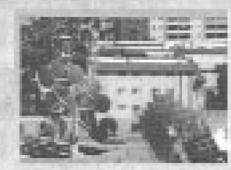
8

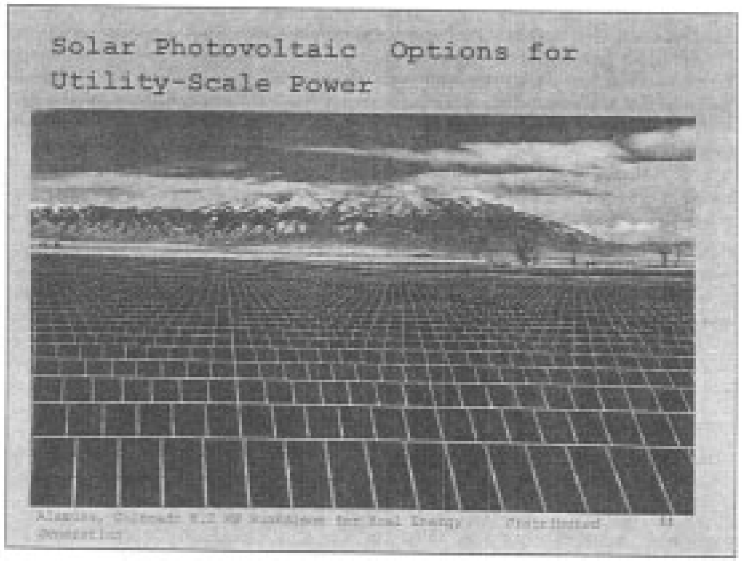
Electric Power Generation Development Format

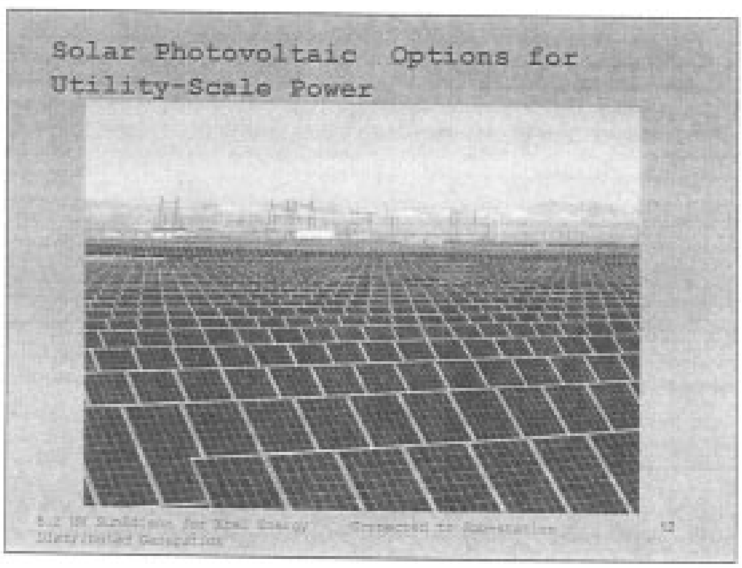
- Central Station
  - Large scale, remote locations, connected to transmission infrastructure
- Distributed
  - Large (up to 20MW) to small scale connected to distribution network near customer load

Solar Thermal Options for Utility-Scale Power

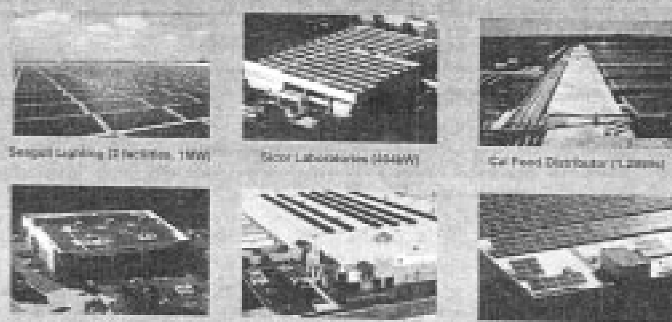





Solar Photovoltaic Options for
Utility-Scale Power


Solar Photovoltaic Options for
Utility-Scale Power

Solar Photovoltaic Options for Utility-Scale Power



Seagull Lighting (3 facilities, 1MW) — Sicor Laboratories — Cal Food Distributor — ICU Medical — Staples Ontario, CA; Rialto, CA — Sure Save Storage

13

Utility scale solar energy

- Any project/ program offering high volume, lower-cost, reliable, and dependable solar energy for 20 years plus at fixed prices for large numbers of customers.

14

Utility scale solar energy

includes:

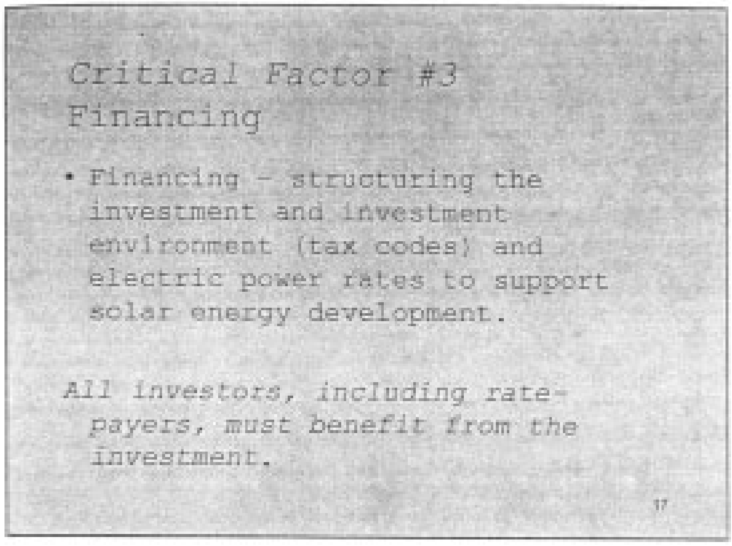
- Larger DG systems (up to 20MW in a single location)
- Systematic, strategic aggregation of multiple small generators.
- Examples:
  - 2 to 20MW solar farms, strategically located in load pockets to strengthen the grid and increase community energy security in case of transmission failure.
  - 1 to 5 MW solar farms on the roofs of our schools, reducing school budget exposure to volatile and rising energy prices for 20 years and pumping solar power into the grid for community use during the summer days when demand is most pressing.
  - 100kW to multiple megawatts on commercial, government, industrial sites/ buildings.

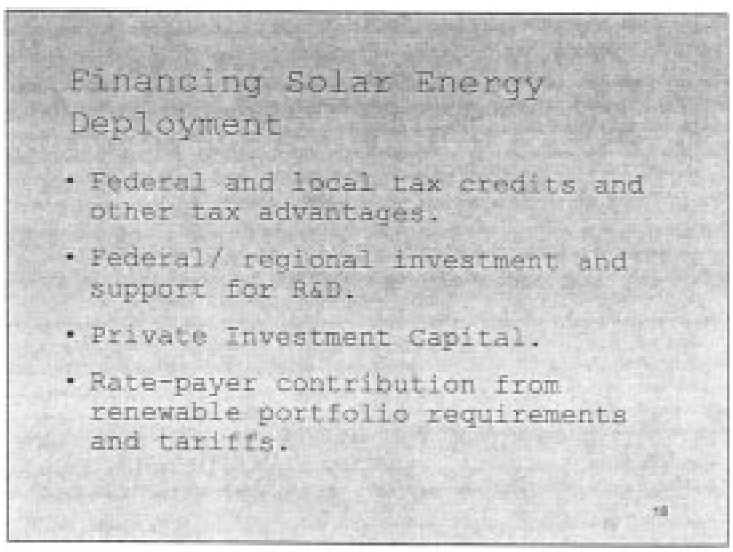
15

Critical Factor #2
Technology Advances

- Solar energy is ready today.
- Component, materials and business model improvements will incrementally reduce costs and improve efficiency.
- Major improvements could come as current research gets fully commercialized in the 5 to 10 year time frame.
- Resolving conflict with preserving utility revenues and assets as solar technology is deployed.

16


Critical Factor #3
Financing
• Financing – structuring the investment and investment environment (tax codes) and electric power rates to support solar energy development.
All investors, including rate-payers, must benefit from the investment.
17


Financing Solar Energy Deployment
• Federal and local tax credits and other tax advantages.
• Federal/ regional investment and support for R&D.
• Private Investment Capital.
• Rate-payer contribution from renewable portfolio requirements and tariffs.
18

Rate-payer Contribution

- Maximizing rate payer benefits
- Rate payers will be asked to pay for the solar investment while at the same time paying for the increasing costs of fossil fuels.
- Economic development: jobs, manufacturing, and harvesting value of regional intellectual property.
- Distributing the economic development and other benefits across communities and customer classes—with large scale, systematic and strategic development of *distributed* solar PV/ CPV/ HCPV.

19

Regulatory Obstacles

- Level the playing field for incentives, subsidies and financing
- Net Metering
- Standard & Fair Interconnection Standards to the Grid
- Solar Fair & Friendly Rates & Utility Revenue Practices
- Protection from unnecessary state regulation concerning Power Purchase Agreements
- Pricing negative externalities: Carbon taxes and/ or carbon emissions trading

20

Regulatory Obstacles

- **Level the playing field for incentives, subsidies and financing**
  - Establish incentives at the Federal Level that match the incentives given to fossil fuels.
  - Structure for rapid and long-term deployments.
  - Declining levels of support encourage systematic and focused cost reduction across the whole value chain.
  - Reward system performance and support system diversity.

21

First ten years

- Strategic, distributed solar PV in Arizona of 2 to 5 Gigawatts.
- United States 65 GW.

US Department of Energy. *Solar America Initiative*, http://www1.eere.energy.gov/solar/solar_america/

22

First five years

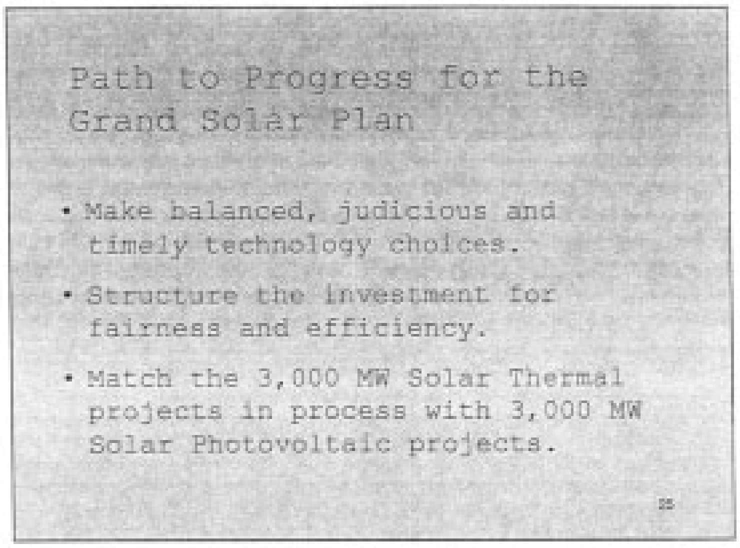
- Allocate investment to the highest benefit lowest risk installations (DG PV)
- Aggregate smaller projects in a systematic program to reduce risk, while delivering the lower costs of scale.
  - Effectively stretch private capital investment.
  - Reduce project and performance risk.
  - Spread the benefits across more communities with multiple projects.

23

Second five years

- Integrate higher volume deployment of Concentrated PV ("CPV") and High Concentrated PV ("HCPV") in DG format for regional use and central station for export.
- Begin 2nd phase of solar thermal development *(if feasible)*.

24



BIOGRAPHY FOR VALERIE RAULUK

Valerie Rauluk Founder and Chief Executive Officer of Venture Catalyst Inc. ("Vecat"), a consultancy based in Tucson, Arizona, specializing in financing and community development. Emphasis in the last 10 years has been sustainable energy deployment, especially solar energy commercialization and financing. These activities were conducted under contract with the United States Department of Energy, National Renewable Energy Lab, Sandia National Labs, Arizona renewable energy vendors, and SunEdison, LLC. Ms. Rauluk has been in the development business for nearly thirty years, guiding products, services, programs and projects from concept to full operation. Educated at the University of Chicago and New York University, she served as an investment banker in New York during the 1980's, where she worked in mergers, acquisitions, leveraged buy-outs and industrial revenue bonds. Her experience also includes economic development for New York City minority businesses.

Ms. GIFFORDS. Thank you, Ms. Rauluk.

Next we are going to hear from Ms. Lockwood.

STATEMENT OF MS. BARBARA D. LOCKWOOD, MANAGER, RENEWABLE ENERGY, ARIZONA PUBLIC SERVICE COMPANY

Ms. LOCKWOOD. Madam Chairman, Members of the Committee, and staff, thank you for the opportunity to provide APS' perspective on utility-scale solar power.

Arizona is the second fastest growing state in the country, growing at three times the national average. APS serves more than a million customers, who at their peak consume more than 7,000 megawatts of electricity, and electricity demand is growing at a rate of hundreds of megawatts each and every year.

As has been discussed all afternoon this afternoon, in Arizona our most abundant resource is sunshine, and APS is looking for ways to put the sun to work providing electricity. APS is committed to making Arizona the solar capitol of the world.

The focus of my comments today is on CSP or Concentrating Solar Power technology, which we have also heard a lot about from the previous witnesses today.

As Congressman Mitchell mentioned, APS recently announced the Solana Generating Station. Solana is a 280 megawatt solar power plant, to be located just outside of Phoenix, Arizona. APS has signed a long-term contract with Abengoa Solar, the project developer and owner, for all of the electricity generated by Solana. If operating today, Solana would be the largest power plant, solar power plant, in the world.

The plant will use nearly three square miles of parabolic trough mirrors and receiver pipes, and operating at full capacity the plant will produce enough electricity to power 70,000 homes.

Also mentioned frequently today, including Congressman Hall and Chairman Gordon, is the importance of energy storage when it comes to solar, and that is one of the most important aspects of the Solana Generating Station, is its ability to capture and store energy for later use. By using large insulated tanks filled with molten salt, heat captured during the day can be stored and used to produce electricity when the sun is no longer shining. This value cannot be underestimated. Because it can provide energy even after the sun has set, this technology provides maximum value and reliability for APS and its customers.

Solana also provides significant economic benefits for the State of Arizona. The Solana Generating Station will provide 1,500 construction jobs, and 85 permanent operations jobs. The total economic impact is much greater. All totaled, Solana will result in over a billion dollars in economic development for Arizona.

And, Solana is not the end of APS' interest in CSP, as Kate mentioned earlier we believe this is a viable commercial technology that can provide significant energy for our customers in coming years. Depending on many factors, APS alone could envision over 1,000 megawatts of CSP in our system in the next 10 to 15 years.

Today, the single biggest obstacle in the success of Solana is the potential expiration of the 30 percent investment tax credit. I am sure that is something you have heard many times before, and will probably hear many times again. Without this tax credit, Solana is simply not affordable today.

I also need to be clear that a one- or two-year extension of the ITC will not be sufficient. While it may be acceptable for small-scale solar projects, and for wind projects, large-scale solar is different. The approval, permitting and construction of the Solana Generating Station will take three to four years to complete. We cannot begin until we know it will be eligible ITC once it is complete.

As Congressman Mitchell mentioned, if a long-term extension of the ITC is not granted, Solana will not be completed. If the ITC is extended for a sufficient period, there will be many other plants like Solana built in the next five to 10 years. If not, the industry will lose its momentum and no large-scale solar plants will be constructed.

The future of large-scale solar depends on getting those first few plants in operation.

Thank you, Madam Chairman, and Members of the Committee, for the opportunity to share this information with you.

[The prepared statement of Ms. Lockwood follows:]

PREPARED STATEMENT OF BARBARA D. LOCKWOOD

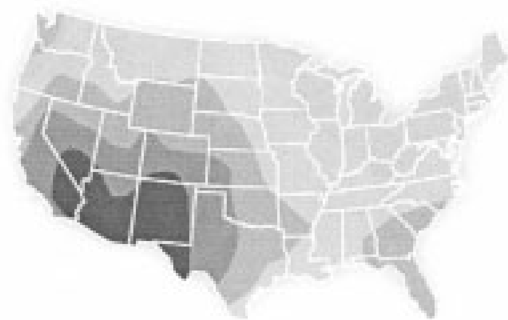
Mr. Chairman and Members of the Subcommittee, thank you for the opportunity to provide Arizona Public Service Company's (APS') perspective on utility-scale solar power. My comments will focus on the opportunity solar provides for clean, reliable electricity, and the challenges associated with realizing that potential.

APS is the largest and longest serving electric power utility in Arizona. Arizona is the second fastest growing state in the country, and APS has more than a million customers who, at their peak energy consumption, use more than 7,000 megawatts of electricity. By 2025, APS will have nearly two million customers demanding over 13,000 megawatts of electricity. To meet this rapid growth in electricity demand, APS is investing $1 billion a year in infrastructure. That number does not include additional generation sources. For APS alone, our peak demand is growing at hundreds of megawatts per year, or the equivalent of one medium-sized natural gas plant each and every year. Meeting the growing needs of our customers is both a challenge and an opportunity.

In Arizona, our most abundant renewable resource is sunshine. The solar resource in Arizona is virtually unlimited, with more than 300 days of sunshine each year. In addition, Arizona has sizable quantities of wide-open, flat landscape that is ideal for the installation of large-scale solar equipment. Among the most important factors in considering a resource for electricity production is the reliability of the fuel. Arizona's solar climate provides a resource that is both dependable and predictable.

APS is committed to making Arizona the solar capital of the world and bringing affordable renewable energy to all its customers. A balanced renewable energy portfolio including solar, wind, geothermal and biomass/biogas resources is fundamental to our operating strategy. For the past two decades, APS has worked with the solar industry and researchers around the U.S. and the world to bring lower cost and reliable solar electricity to our customers. In 1988, the APS Solar Technology And Research (STAR) center was developed to support the advancement of solar resources, including field operation of both photovoltaic and concentrating solar technologies. In addition to STAR, APS currently has over five megawatts of photovoltaic power plants in operation providing reliable solar energy to our customers.

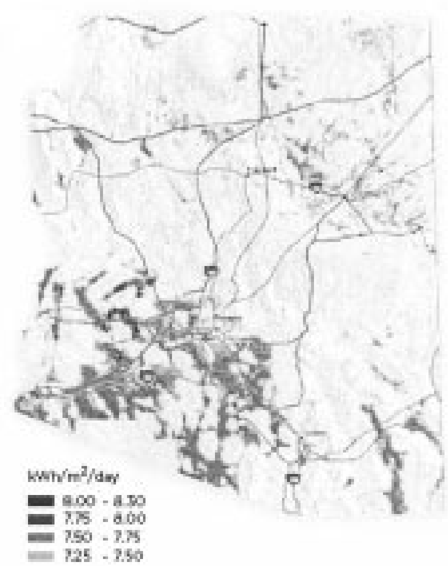
THE SOLAR RESOURCE



US Solar resource - NREL

Near-optimal landscape, weather, proximity to electric transmission and other essential factors make Arizona one of the best solar climates in the nation.

Development of large-scale solar electricity generation plants requires a unique set of conditions. Although solar intensity is high in most of Arizona and some other areas of the south-west, other considerations reduce the area practically available for development of this resource. Optimal areas would include generally flat (≤1% slope) land that is not affected by summer monsoons or heavy blowing dust, proximity to transmission lines and available water for plant operation. In addition, when selecting sites for solar generation, consideration must be given to the desert ecosystem and the sensitive species that inhabit it. As this map shows, Arizona is one of the few places in the United States where the solar resource is world class and the rigorous development requirements are met.



APS has also supported the advancement of concentrating solar power (CSP). These technologies are "thermal electric systems" that use solar heat to drive generators and engines. CSP thermal systems include solar trough concentrator systems and central receiver (power tower) systems that use many mirrors to focus light on a central solar collector. CSP also include solar dish Stirling systems and other advanced solar concepts.

In fact, APS constructed the first commercial CSP plant in the United States in almost 20years. The Saguaro Solar Power Plant, which came on-line in 2006, is a one megawatt parabolic trough facility located just north of Tucson at Red Rock, Arizona. This plant has provided critical learning for APS, the CSP industry, and researchers. While small in size, it has facilitated new interest in CSP around the country and the world.

But that was just the beginning of our entrance into commercial CSP. Also in 2006, APS stepped forward to lead a coalition of southwestern utilities interested in CSP. The Joint Development Group is a consortium of seven entities exploring the possibility of a 250 megawatt CSP project to be located in Arizona or Nevada. Acting as project coordinator, APS issued a request for proposals in December of 2007. If all goes well, the consortium project could be selected this summer.

But our most significant step to date is the announcement on February 21, 2008, of the Solana Generating Station. Solana is a 280 megawatt solar power plant to be located 70 miles southwest of Phoenix near Gila Bend, Arizona. APS has signed a long-term contract with Abengoa Solar, project developer and owner, for 100 percent of the electricity generated by Solana. Solana is the Spanish word for "sunny place."

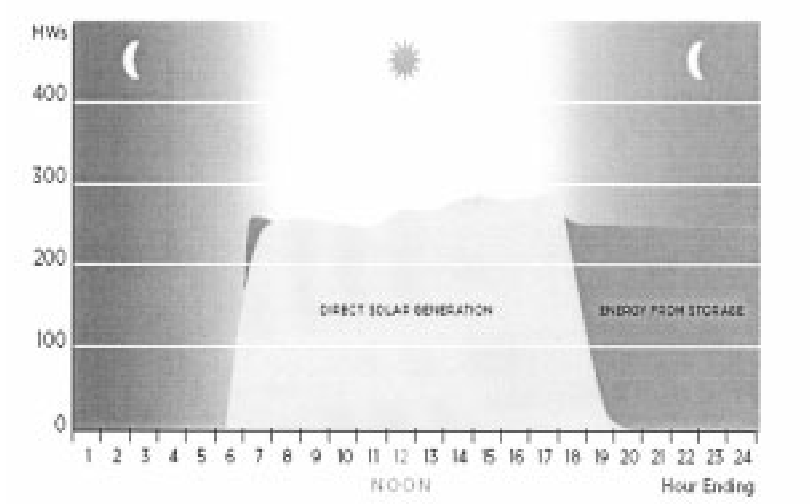
If operating today, Solana would be the largest solar power plant in the world. The plant will use nearly three square miles of parabolic trough mirrors and receiver pipes, coupled with two 140-megawatt steam generators. Operating at full capacity, the plant will produce enough electricity to power 70,000 Arizona homes.

Solana also provides significant economic benefits to the State of Arizona. The Solana Generating Station will provide 1,500 construction jobs between 2008 and 2011 and 85 permanent operations jobs. Solana will also generate between $300 million and $400 million in tax revenue over the 30 year life of the plant. All total, Solana will result in over $1 billion in economic development for the Arizona economy.

Finally, Solana is an emission-free source of electricity, avoiding nearly 500,000 tons of carbon dioxide, 1,065 tons of nitrogen oxides, and 520 tons of sulfur dioxide each year. It is the equivalent of removing 80,000 cars from the road each year. Solana will also use 75 percent less water than the current agricultural usage of the land.

APS selected Abengoa Solar as its partner for Solana because of its track record as a solar developer, its critical operational experience and a reputation for meeting contractual obligations.

One of the most important aspects of Solana is its ability to capture and store solar energy for later use. By incorporating large insulated tanks filled with molten salt, heat captured during the day can be stored and used to produce electricity when the sun is no longer shining. The molten salt and heavily insulated tanks are able to retain heat with very high efficiency, and the stored heat can then be extracted in the evening or even the following day to create electricity.



The stored heat not only increases the total amount of electricity generated, it also adds specific operating benefits for APS. The ability to use stored heat on demand, also referred to as "dispatching," allows APS to respond to customer usage patterns and emergency energy needs more effectively. Most southwest utilities experience their highest customer demand during the summer months. While the power need is substantial in the middle of the day, peak energy demand occurs in the late afternoon and into the early evening hours. Because it can provide energy even after the sun has set, the solar trough with thermal energy storage provides the maximum value for APS and its customers.

Diversification of generation resources is critical to maintaining a reliable electric system and concentrating solar power provides a significant opportunity to diversify energy resources. In addition, the costs to construct and maintain concentrating solar power plants have declined while at the same time equipment and labor costs, rising fuel prices and emissions concerns are increasing the risks of conventional resources.

APS also recognizes that renewable energy strategies will become even more important under the prospects of carbon legislation. With zero carbon emissions, energy from solar power provides one method of addressing concerns around global warming while continuing to provide reliable electricity to our customers.

And Solana is not the end of our interest in CSP. APS is currently engaged in a formal dialogue with our regulators, stakeholders and customers about our future energy sources. We are exploring the availability, cost, regulatory and policy implications associated with many different types of resources including nuclear, natural gas, coal, energy efficiency and renewable energy. One of several scenarios under discussion is one where CSP plays a central role, adding 1,350 megawatts by 2020. Each of these efforts will help us to meet, and possibly exceed, the progressive Renewable Energy Standard established by the Arizona Corporation Commission.

CSP, in particular the solar trough, is proven, reliable technology. There are no technical barriers to deployment of this technology today, and APS is aggressively exploring the near-term potential.

In considering the long-term potential for utility scale solar, one topic of consideration is how to integrate large solar plants into the regional and national electric grid. This topic raises numerous issues including availability of land for large scale installation and the availability of transmission facilities and transmission capacity to deliver the energy to load centers. The lack of transmission capacity and how that is managed will be a significant factor in the long-term success of utility-scale solar. In fact, transmission is generally constrained in much of the west and significant new transmission investment is needed in the coming years for all types of generation be they renewable or conventional generation. New transmission is being planned throughout the west and in California, New Mexico, Nevada, and Texas specifically to access renewable resources including wind and geothermal. Others states and utilities, including APS, are studying their needs for both intra- and interstate transmission to ensure a robust grid to meet the needs of the West's burgeoning population. The studies include the ability to reach those areas of the west with abundant cost-effective renewable resources.

Also, the possibility of locating large scale solar on federal land should be investigated and analyzed. By its nature, solar technologies require significant geographic footprints. A general rule of thumb for a solar installation is five to 10 acres per megawatt. As I previously stated, the Solana Generating Station requires three square miles of contiguous land. Considering that the Federal Government is the largest land owner in the U.S., a study of federal land in high solar resource areas that may be made available for CSP development would also be beneficial and appropriate.

However, the biggest obstacle to the success of utility-scale solar, including Solana, is the potential expiration of the federal Investment Tax Credit (ITC). Solana, and projects like Solana, became possible when the federal ITC for solar systems was increased from 10 percent to 30 percent in 2006. While large-scale solar is still more expensive than conventional resources, the 30 percent investment tax credit decreased the cost sufficient to make these projects a reasonable option. Without these tax credits, large scale solar projects, including Solana, are simply not affordable today. As you know, the 30 percent ITC is scheduled to expire at the end of 2008. The approval, permitting and construction of the Solana Generating Station will take three to four years to complete. The Solana project also requires well over a billion in capital investment. APS, Abengoa Solar, and the financial institutions providing funding for Solana require certainty that Solana will be eligible for the ITC once operational. *If a long-term extension of the ITC is not granted, Solana will not be completed.*

A different federal tax credit, the production tax credit (PTC), has spurred significant development for other renewable energy resources, most notably wind energy. The PTC has been extended five times since its introduction in 1992 and each extension was for one to two years. Although the wind industry has worked toward longer-term extensions, wind energy projects, and smaller scale solar projects, have much shorter time frames for construction, which makes short-term extensions of the PTC acceptable, if not preferable. Although the solar ITC is typically packaged with the PTC in discussions of extensions, large-scale solar has very different needs related to tax credits. *A one- or two-year extension of the solar ITC is simply not sufficient to make large scale solar projects like Solana a reality.* In fact, a one or two year extension of the Solar ITC may effectively cancel the project. Large scale solar has little hope of realizing its potential without a long-term extension of the ITC. APS believes an eight-year extension is optimal. Eight years should be sufficient to get a number of large scale solar facilities completed. It is also long enough to establish the supporting industries like mirror and receiver manufacturing in the United States. Once the industry gains a foothold, prices will decline and incentives will no longer be necessary.

Another critical aspect of the ITC is the fact that it is not available to public utilities. The restriction needlessly narrows application of the credit and is unfair to U.S. citizens because the vast majority purchase power from a public utility, as it is defined by the tax code. This current policy forces a third-party owner to take advantage of the ITC and it creates unnecessary uncertainty and costs to the system. It requires the utility and regional grid to consider the operational and financial risks inherent in any third party relationship thus potentially affecting the utility operating strategies. APS is managing these risks with Solana, but it creates a sub-optimum situation when it is the only strategy available.

I was also requested to address a recently published article. "A Solar Grand Plan," published in the *Scientific American Magazine* in December 2007, describes a world where solar energy provides 69 percent of the U.S.'s electricity by 2050. It includes huge tracts of land covered in solar and a new direct-current transmission system across the U.S. It also includes 16-hour thermal storage for CSP and compressed-air energy storage for photovoltaics, which allow the production of energy from solar resources around the clock.

"A Solar Grand Plan" is certainly grand. It's a big, bold vision for a new energy era. Without analyzing the details of the plan, there appear to be no glaring technical issues with the proposed strategies. CSP and photovoltaics are proven technologies. As described, thermal storage and compressed-air energy storage are likely viable concepts. Finally, direct current transmission is already in operation today.

No, the challenges with this plan are not technical. But there are enormous planning, regulatory, and policy challenges with achieving this vision. Most importantly, energy policy decisions are made largely at the individual utility and State level. Each utility and state has different perspectives, and different regulatory authorities, that control the vast majority of decisions around generation sources and transmission. And although I haven't analyzed the cost presented in the article, the execution of such a plan would clearly depend on gaining great cost efficiencies.

Clearly, the potential for utility scale solar electricity is enormous. If, and only if, the ITC is given a long-term extension, I predict we will see several thousand megawatts of utility scale solar developed in the next five to 10 years. At least seven major projects have been announced since 2006. If the ITC is not extended for a sufficiently long period of time, the industry will lose its precious momentum and no large scale solar plants are likely to be constructed. The future of large scale solar depends heavily extending the ITC and getting those first few plants in operation.

These initial plants are planned to supplement existing fossil fuel resources and help to satisfy our growing energy needs. In the long-term, utility scale solar could be a viable option in replacing base load fossil fuel facilities as those assets are retired. But costs need to decline significantly to make that a viable option. Only then will solar be a viable option for replacing base load assets that are being retired. Assuming success in the near-term, the prospect for the next 20 to 50 years is virtually unlimited.

Thank you, Mr. Chairman and Members of the Subcommittee for the opportunity to share these observations and opinions with you.

BIOGRAPHY FOR BARBARA D. LOCKWOOD

Barbara D. Lockwood is the Manager of Renewable Energy for Arizona Public Service (APS) where she is responsible for APS' renewable energy programs including large-scale generation and customer programs. Ms. Lockwood joined APS in 1999. Ms. Lockwood began her career in the chemical industry at E.I. DuPont de Nemours in various engineering and management roles on the east coast. Subsequent to DuPont, Ms. Lockwood moved into consulting and managed diverse projects for national clients across the United States.

Ms. Lockwood holds a Bachelor of Science in Chemical Engineering from Clemson University and a Master of Science degree in Environmental Engineering from Georgia Institute of Technology. Ms. Lockwood is a registered professional chemical engineer in Arizona and California.

Ms. GIFFORDS. Thank you, Ms. Lockwood.

And finally, Mr. Kastner.

STATEMENT OF MR. JOSEPH KASTNER, VICE PRESIDENT OF IMPLEMENTATION AND OPERATIONS, MMA RENEWABLE VENTURES LLC

Mr. KASTNER. Thank you, Madam Chairman, and the Subcommittee Members, for providing this opportunity.

As many of your questions addressed the Nellis Air Force Base project I would like to begin by recognizing Lieutenant Colonel Karen White, who is in the audience today. Lieutenant Colonel White was instrumental in making the Nellis Air Force Base project a success, and it is great to have her here.

Ms. GIFFORDS. Welcome, Colonel, thank you for being here today. We appreciate it.

Mr. KASTNER. On behalf of MMA Renewable Ventures and the solar industry, I am happy to provide the following comments related to the development and financing of utility-scale solar.

In 2007, MMA completed the project development and third party financing of over 22 megawatts of solar, including the 14 megawatt facility at Nellis Air Force Base, the largest PV installation in North America.

We are actually pursuing domestic opportunities in other renewables and our parent company MMA has built this business largely around sustainable and socially-responsible investment opportunities, including affordable housing, renewable energy, and sustainable land investments.

Ms. GIFFORDS. Mr. Kastner, I don't mean to interrupt, but can you move the microphone a little bit closer?

Mr. KASTNER. Sure.

Ms. GIFFORDS. Okay.

Mr. KASTNER. The Nellis project involves a public/private partnership that is advantageous because the affiliated public entities could not avail themselves of the Federal tax benefits. The project was enabled by the following commercial arrangements:

1. A 20-year site lease with the United States Air Force;
2. A power purchase agreement with Nellis Air Force Base;
3. An agreement to sell Nevada Power the renewable energy credits associated with the project for 20 years;
4. An installation contract with Sun Power Corporation;
5. And finally, financial arrangements that included construction financing from Merrill Lynch, permanent debt financing from John Hancock, and tax equity financing from Citicorp, Allstate and MMA Financial.

The combination of these complex legal and financial arrangements enabled the project. We believe that this type of public/private partnership provides a commercial approach that can be used at a variety of sites of varying size and scale in the U.S.

All fuel-less electric generation technologies are more capital intensive than conventional combustion-based technologies. And thus, they require long-term stability and certainty in financial, legal and regulatory environments, in order to mobilize the long-term investment. The following concepts are key to providing stability and certainty for solar projects.

As has already been mentioned, first and foremost, a long-term extension is needed for the current 30 percent investment tax credit. The ITC is critical to the development and financing of utility-scale solar projects and DG projects, and necessary to ensure continuing domestic project development.

History has shown that the short-term tax credit, subject to the uncertainty of congressional reauthorization, can actually be detrimental to the development of renewable energy. Uncertainty around the extensions of the production tax credit for wind power increases the cost of capital for projects and causes the inflation of equipment costs due to supply constraints. We would expect the same fate for solar without the long-term extension of the tax incentive.

Stability and certainty are also critical for the commercial arrangements which enable the projects. In the case of the Nellis installation, a change in law risk within the standard REC contract had the potential to make the project somewhat less than financeable. If the Public Utility Commission of Nevada had not issued an order that provided assurances regarding this change in law risk the project may not have been financed.

In most states where solar PV projects are being implemented, they are enabled, at least in part, by State renewable portfolio standards. This is certainly true for the Nellis project.

The geographic reach and timing of such programs would be enhanced through a Federal initiative. The National RPS would provide certainty by guaranteeing a minimum degree of market demand for renewable energy. Such an initiative must provide ample flexibility for State programs that surpass federal minimum standards and encourage the dissemination of best regulatory and utility procurement practices, including standardized contracts that provide sufficient long-term certainty for mobilizing capital markets.

Such an initiative should also support diversification through the development of promising technologies in appropriate regions. A specific solar requirement from the Nevada RPS helped to enable the Nellis project, and is why it occurred in Nevada, and not in Arizona or New Mexico.

Lastly, a federal cap and trade system, or emission tax, would help to internalize the environmental and social costs of emissions caused by burning fossil fuels. This would also help to create a level playing field for all generation types.

In conclusion, investors are beginning to respond to the market-driving incentives for solar energy provided by Federal and State government. The Nellis project is a great example of how these types of incentives can be combined to create a viable project opportunity.

These types of opportunities will only reach the volumes required to significantly reduce the costs of solar energy if the incentive programs are structured to ensure the creation of a stable, long-term market for investment. The market for these opportunities could be expanded greatly through various actions at the federal level, including a national RPS and the adoption of a market mechanism or tax for internalizing external costs of emissions from conventional energy sources.

Thank you.

[The prepared statement of Mr. Kastner follows:]

PREPARED STATEMENT OF JOSEPH KASTNER

Good Morning. On behalf of my company, MMA Renewable Ventures, LLC and the solar industry, I am happy to provide the following comments related to the development and financing of utility scale solar projects.

In 2007, MMA Renewable Ventures completed the project development and financing of more solar photovoltaic projects in the United States than any other company in the U.S. as measured by total capacity installed (more than 22 MWp) from over 20 discrete projects. We are especially proud of the development and financing of the 14MWp solar photovoltaic (PV) project on Nellis Air Force Base—the largest such project ever built in North America and one of the largest in the world.

In a significant portion of these projects, the land owner and power purchaser has been a public entity such as a Federal Government department, municipality, or transit district. As you know, such entities cannot avail themselves of the federal investment tax credits (ITCs) and accelerated depreciation benefits offered under the Internal Revenue Code. In all of these transactions, MMA Renewable Ventures served as the third party project developer and financing party which develops the projects, negotiates the power purchase agreements, secures the necessary land rights, negotiates engineering, procurement, and construction contracts, negotiates interconnection agreements with distribution utilities, and obtains construction and permanent financing (debt and tax equity). Consequently, we are intimately knowledgeable and experienced with every aspect of project development and finance of solar PV projects.

In addition to solar PV projects, MMA Renewable Ventures is actively pursuing and developing wind, biomass, biofuel, and energy efficiency opportunities in the U.S. market. We expect to add energy efficiency projects to our portfolio of operational assets in 2008 and wind, biomass, and biofuel projects within the next two calendar years. Similar to solar, many of these opportunities are dependent upon an extension of currently existing tax credit provisions, in this case the production tax credit (PTC) in Section 45 of the tax code.

MuniMae, the parent company of MMA Renewable Ventures, has built a business largely around sustainable and socially responsible investment opportunities. Historically, this has involved affordable housing and more recently renewable energy and sustainable land investments.

Description of the Solar Project at Nellis AFB

The development and financing of the solar project at Nellis Air Force Base (AFB) was based on the following commercial arrangements:

1. Nellis AFB has leased 140 acres of property to a special purpose entity called Solar Star NAFB, LLC, owned and operated by MMA Renewable Ventures, for a period of twenty years beginning January 1 following the start of commercial operation for the project;
2. Solar Star NAFB has in turn agreed to sell the power output of the plant to Nellis AFB for a coincident term;
3. Solar Star NAFB has also agreed to sell the renewable energy credits (RECs)—the tradable credits representing the environmental attributes, benefits and other values of renewable energy—to Nevada Power for the same 20-year term. Nevada Power purchases such credits in order to comply with the Renewable Portfolio Standard required under Nevada's Renewable Energy Law;
4. On behalf of Solar Star NAFB, MMA Renewable Ventures negotiated an engineering, procurement, and construction contract (EPC Contract) with PowerLight Corporation, which is now SunPower Corporation, Systems (SunPower). Under the EPC Contract, SunPower purchased more than 70,000 solar modules and 54 inverters, constructed the tracking systems, assembled racks of modules, transported equipment, arranged labor on the site, and interconnected all the system components;
5. On behalf of Solar Star NAFB, MMA Renewable Ventures arranged for construction financing from Merrill Lynch, debt financing from John Hancock Insurance Company, and equity financing from CitiCorp North America, Allstate Insurance Company, and MMA Financial.

The sum total of these complex legal and financial arrangements enabled the construction of the largest PV plant in North America. While the specifics of each party and arrangement may vary from project to project, we believe that this public-private partnership model provides a commercial approach that can be used at a variety of sites of varying size and scale.

Recommendations for Promoting Utility-Scale Solar Projects

Utility-scale solar projects represent the greatest opportunity for solar electric generation technologies to reach cost parity with conventional gas and coal-fueled electric generation. When equipment, labor, and capital are deployed to build solar projects at a scale counted in tens of megawatts, gains from economies of scale including the spread of transaction costs can deliver lower cost solar power. Additionally, this will spur the cost efficiencies required to make the deployment of distributed generation more competitive with retail electricity rates requiring minimal subsidies.

In order to promote the development of projects of such scale, project developers and financial entities need to have a relatively stable financial, legal, and regulatory environment. All fuel-less electric generation technologies are more capital intensive than conventional combustion-based technologies, requiring long-term stability in the business environment to mobilize capital. The following concepts/initiatives are key to the development and financing of utility-scale solar:

1. Long-Term Federal Tax Incentives

The current 30 percent investment tax credit (ITC) for solar projects expires at the end of 2008. At present, these federal incentives are critical to the development and financing of utility-scale solar projects. Without the federal tax benefits, utility-scale solar projects will not be viable because the cost of energy will simply be too high.

The effectiveness of existing incentives is significantly limited in driving development of utility scale projects with long lead time particularly given the pace of development and consumer adoption of energy technologies. The existing tax credits or incentives are short-term, piecemeal programs subject to the uncertainty of the Congressional reauthorization and/or appropriations processes. For example, the production tax credit for wind and other types of renewable energy, established in 1992, has been subject to three expirations and several short-term extensions (some retroactive). Uncertainty around the ITC extension increases the cost of capital due to the risk of meeting a deadline and leads to a boom and bust cycle which has caused the inflation of equipment costs purely from supply constraints.

Congress should pass a long-term ITC to drive substantial private sector investment in clean energy technologies. Investors need stable, long-term, and predictable incentives. MMA Renewable Ventures supports a minimum seven-year timeframe for clean energy tax credits because this is the minimum period necessary to enable rational investment decisions and deployment of resources in utility scale projects. The federal regulatory environment's support for energy technologies can be significantly improved by establishing consistency and predictability.

At the bottom line, those of us who are actually building and financing utility-scale solar projects need greater certainty of the federal tax benefits. In addition, the ITC could benefit from the amendment of several rules within the IRS code:

- Eliminate the basis adjustment so that one-half of ITC is not "recaptured";
- Make renewable energy investments eligible for Community Reinvestment Act (CRA) consideration. Structured correctly, this could serve to catalyze both distributed and utility-scale solar projects in low and moderate-income communities and/or serving public facilities. It would also serve to attract additional institutional investors into the space and help to create "green-collar" jobs in lower-income communities;
- Create an "economic substance" carve-out for solar tax credits similar to what was done for low-income housing tax credits;
- Raise the production tax credit (PTC) for solar to make it competitive with the ITC and give investors a choice of either one. The PTC structure is a better fit for some investors and will encourage more capital to enter the solar space;
- Match the residual value exemption currently available to the low income housing sector, allowing for no constraints at resale after the tax benefits have been monetized;
- Abolish the possibility for ITC recapture in the event of a catastrophic loss without replacement by the end of a calendar year;
- Allow tax equity to enter project after the system as reached commercial operation under any financing structure.

2. A Stable Legal Framework

One of the important prerequisites for investors in utility-scale solar projects is certainty the commercial arrangements will remain intact for the full term of the financing. Utility purchasers, commissions, and State and federal regulations all need to provide certainty and assurances that the various commercial arrangements will not materially change throughout the life of the project.

For instance, in reviewing the standard contracts proposed for the Nellis AFB project it was determined that certain elements in the site lease and the streams of revenues from the power purchase arrangement with Nellis AFB and the REC Agreement with Nevada Power made the project somewhat less than financeable. The most significant instance involved the change-in-law risk associated with the REC agreement. If the Public Utility Commission of Nevada had not issued an order that approved the contract and an associated stipulation that provided assurances regarding change-in-law risk, the project might not have been financed.

3. A National Renewable Portfolio Standard

Today, renewable energy resources provide a fraction of total U.S. energy, with the potential for significant growth. More than twenty-seven states and the District of Columbia utilize a wide variety of renewable portfolio standard (RPS) mechanisms to drive a greater reliance on renewable energy. A basic RPS requires the electric utilities (investor-owned utilities and publicly-owned utilities) within a state to procure a percentage of their electricity output necessary to meet load from renewable energy sources in a specified timeframe. Current State policies require varying percentages of renewables, typically targeting a goal of one percent to five percent in the first year, increasing each year to achieve a goal of five percent to 20 percent over approximately 10–15 years.

In general, a utility can meet RPS requirements by incorporating renewable energy into its fuel mix in one of four ways: (1) building renewable energy facilities; (2) purchasing power directly from an existing renewable energy source; (3) buying RECs; or (4) by encouraging production of distributed renewable energy, efficiency, or conservation. The specifics of each RPS program vary widely state to state from the goal, to the criteria, to the method of implementation. Many State programs set standards for specific technologies to ensure diversity of electricity supply by supporting the development of promising technologies that may not currently be the most economic.

A national RPS would set the minimum standard for wholesale renewable energy usage throughout the United States. This would serve the important function of guaranteeing a minimum degree of market demand for renewable energy generation. Every state would be required to develop an energy regulatory strategy that includes a base level RPS with performance-based metrics that would drive investment in, and adoption of, viable, cost-effective renewable energy technologies. Specifically, Congress would mandate the establishment of minimum State renewable energy procurement standards with ample flexibility for State programs that surpass the federal minimum standards, encouraging dissemination of best regulatory and utility procurement practices, and providing states with incentives to increase reliance on renewable energy, reward energy efficiency, and to provide for a national REC market. For the reasons stated previously regarding stability, it is important that a national RPS is cognizant of existing State programs to ensure long-term investments already undertaken are not adversely affected. The federal RPS would require sufficient non-compliance measures in order to provide a strong incentive for utility compliance.

A national RPS can be a market driving, demand side solution for addressing the broader goals of energy policy through development of diverse, secure renewable energy sources and energy efficiency, while at the same time encouraging technological advances throughout the energy supply chain. The future of renewable energy production in the United States resides in this synergy of governmental policy and emerging technologies—and without each, the aim of diversified, sustainable, and efficient energy production is simply impossible in the foreseeable future. By setting these aggressive goals for renewable energy production targets, the government will drive innovation and the market will create solutions.

4. Valuing Carbon Emissions and Other Externalities

The current cost of conventional fossil-fuel electricity does not include the environmental and social costs associated with the emission of carbon, mercury, and other pollutants into the atmosphere. Either a cap-and-trade system or emission specific taxes would complement long-term subsidies and the establishment of minimum market demand by internalizing the impact of burning fossil fuels into the price of electricity. This would tend to make solar energy more competitive with fossil fuel-fired electricity and further boost investment.

Market Differences in the Southwest

The southwestern portion of the U.S. including California, Nevada, Arizona, and New Mexico has the strongest solar resource in the country. The State of Nevada has an RPS-driven REC market that provides a large part of the economics for the Nellis solar project. The RPS rules for the state have specific requirements for solar and applies a multiplier to RECs (termed Portfolio Energy Credits under the Nevada RPS) produced by solar facilities. RPS programs in the other three states exist, but are not necessarily structured properly for significant market penetration of utility-scale solar projects.

California

California has catalyzed solar development through the California Solar Initiative (CSI) program which utilizes a short-term production based incentive. This direct subsidy has spurred the development of distributed generation projects (mostly less than one megawatt), but is not applicable for utility-scale projects. It is expected that California will introduce a tradable REC program for the existing state RPS in the near future that will encourage distributed generation projects currently suffering from subsidy levels declining faster than capital costs for key equipment. California utilities have utilized a request for offer (RFO) process fulfilling their RPS requirements. Since there is no solar set-aside, most of these contracts have been awarded to other renewable technologies that are currently more cost effective than solar. Contracts which have been awarded to solar projects under the RFO process have largely gone to earlier stage solar technologies that have yet to be implemented. The California Public Utilities Commission recently announced a feed-in tariff based on the a revised calculation methodology for the "market price referent" that sets the ceiling price for contracts awarded in the RFO process. The new methodology attempts to take into account the time-of-use benefits associated with the solar production curve matching well with the state-wide demand in California. The current consensus is that the announced feed-in tariff does not provide adequate levels of compensation for solar PV projects.

Arizona

There are certain regulatory hurdles that impede the development of solar and other clean technologies in Arizona. Low energy rates and tariff structures that do not adequately incentivize the peak-producing benefit of solar negatively impacts the economics of solar. Net-metering policies are essential to opening up the market to more wide-spread adoption, instead of limiting potential customers only to those who have 365 day operations, and large load centers. Under the current net-metering rules only small systems are rewarded, otherwise solar generation that exceeds on-site usage is not compensated for. Like net-metering, interconnection standards must be standardized across the state and have a minimum of 2MW to sufficiently promote industry adoption. Lastly the available incentives are insufficient. APS has taken the lead in establishing a PBI program, which is an important step, and for the most part well-designed (20 year PBI structure), however the total available funding is only enough to fund a few MW per year—which is not enough to entice the solar PV industry to undertake the cost and risk of entering a new market.

New Mexico

New Mexico has shown true leadership in the aggressive RPS goals and high net metering limits. This includes solar specific requirements that must be fulfilled beginning in 2011. The law also includes a "Reasonable Cost Threshold" which limits the payment of power from solar installations to currently unfinanceable levels.

Conclusion

Investors are beginning to respond to the market driving incentives for solar energy provided by Federal and State governments. The Nellis AFB project is a great example of how these types of incentives can be combined to create a viable project opportunity when a third-party can enter and efficiently monetize the tax benefits. These types of projects will only reach the volumes required to significantly reduce the cost of solar energy if the incentive programs are structured to ensure the creation of a stable, long-term market for project developers, installers, equipment manufacturers, and investors. The geographic market for these opportunities could be expended greatly through several actions at the federal level including a national RPS and the adoption of a market mechanism for internalizing the external costs of emissions from conventional sources of energy.

BIOGRAPHY FOR JOSEPH KASTNER

Joseph Kastner is Vice President of Implementation and Operations for MMA Renewable Ventures LLC. He is responsible for sourcing and developing qualified renewable energy projects that fit the investment profile of the company and oversees the management of assets under construction and operation. Prior to joining MMA Renewable Ventures, he was responsible for project implementation, operation and maintenance as the renewable energy division manager for NUON Renewable Ventures USA LLC, a U.S.-based subsidiary of the Dutch utility NUON bv. Prior to NUON, Mr. Kastner worked as a consultant to commercial and residential building owners and investors in the areas of energy efficiency and the use of photovoltaic and thermal solar energy systems. Mr. Kastner has a Master's Degree in Energy Engineering from Stanford University, a Master's Degree in Environmental Science and Management from the Donald Bren School at the University of California–Santa Barbara, and a Bachelor's Degree in Mechanical Engineering from the University of Minnesota.

DISCUSSION

Ms. GIFFORDS. Thank you, Mr. Kastner.

We appreciate the testimony from all of our witnesses, and now we are going to turn the floor over to the Members of the Committee to have a chance to ask you some questions.

I know that Mr. Hall has to leave shortly after 2:00, so I believe if I can get my questions in first, Mr. Hall, then we will move to you, and I know you have to catch your plane.

In terms of the technology on the table, it is set for a briefer period than the five minutes, so what we will do is, halfway through you will see the light turn on, but when you see it getting orange and then red, if you can please either close up the questions, we'd like to be able to move rapidly through a round of questions.

THE GRAND SOLAR PLAN: JOBS AND ECONOMIC BENEFITS

So, I would actually like to kick off with Mr. Hansen, who talked about the Grand Solar Plan. For those individuals who have not had a chance to read the "Scientific American" article, we can provide that through the office here, and I will make sure that Members of the Committee have access to it as well, although I believe that most Members have had a chance to read it. It is very compelling. But, there we go, that is the front cover. There we go.

I would like to dig a little bit deeper in terms of the economic benefit. You talked a lot about what it would bring in terms of the energy, and the power, and sustainability, but could you speak a little bit in terms of jobs and actual dollars?

Mr. HANSEN. Madam Chairman, I tried to pack about 10 years worth of information into five minutes, so it was difficult.

The Solar Grand Plan, looking from the year 2009 to 2020, is the period when the incentives, the subsidies so to speak, to help move the technology forward, would be needed.

It is our belief that after 2020 that those technologies would be compatible economically with traditional generation methodologies—coal, natural gas, et cetera. So, beyond 2020 the economics would look very similar to how the current economic situation is for development of new electrical generation.

Between now and that point in time, I believe our study indicated there would be about 150,000 jobs that would be generated. And, really, we are looking for the Abengoa type of projects to be part of this Solar Grand Plan. There would be some additional drilling required, some people that would be required to additionally add that capacity for storage in the ground, but that would be, again, existing technology, it would provide more jobs for the natural gas drillers, if you will, to provide that kind of storage in the future.

All of the details have not been shaken out yet, we need more time to be able to put it together. We actually do have another paper coming out. It is out for peer review at the present time, that will have more information of the details of how many jobs and where those jobs would be located. The transmission system, the energy storage systems, they will not be just in the U.S. southwest, they will be throughout the United States. So, it will bring benefits to all of the United States, not just the southwest.

NELLIS AIR FORCE BASE PARTNERSHIP

Ms. GIFFORDS. And, going back to Mr. Kastner, and I want to just make it clear for everyone who understands, that Nellis Air Force Base launched in a public/private partnership not more than a couple of years ago, and I believe it took you about a year to complete this project. But, 40 percent of the energy consumed on Nellis Air Force Base is now powered by solar energy, which is extraordinary when you think about a very short period of time and ability to move so quickly in that.

The Mayor and I will be visiting Nellis Air Force Base in a couple of weeks, and we will be bringing members of the community along with us as well. But, can you talk a little bit about, from a policy standpoint, several of us are from the southwest, from southwestern states, you know, what did it really take in terms of leadership to be able to implement that project, tax credits, and how you can see that expanding in different states as well?

Mr. KASTNER. Yes. I mean, the key driving force for the economics is the renewable energy credit contract with Nevada Power, and that was really catalyzed by the renewable portfolio standard within Nevada that requires a certain amount of solar to be produced within the state.

Nevada Power issued an RFP for qualifying for these contracts before the Nellis project, during the conception of the Nellis project, and that is what, you know, really brought it forward, provided an RFP by the Air Force to do the project, knowing that this contract was available.

INTERNATIONAL COMPETITION IN SOLAR ENERGY

Ms. GIFFORDS. And, a general question I want to address to Ms. Maracas, and to Ms. Rauluk. I see behind you we have some representatives from the Solon AG Company, a German company that has been investing here in southern Arizona, and I want to thank you for that. I know that the United States southwest is now competing, not just with areas like Nevada, or California, or New Jersey, but we are now competing with different countries as well.

Can you please touch on some of that international competition, and how we here, you know, in the United States are going to be able to be a major player 10, 15, 20, 25 years from now?

Ms. MARACAS. Yes. I think that is a very relevant question, and it is worth adding, I think, that one of the reasons that large-scale companies like Abengoa, Bright Source, Solar Millennium and others, are now coming into the U.S. market, is because there have been over recent years a number of very favorable policies in European markets that have really spurred activity.

In Spain, there is a feed-in tariff that is, essentially, a guaranteed something like 21 Euro cents per kilowatt hour that is paid to anybody who generates 50 megawatts, or less than 50 megawatts, and just, essentially, develops a project that goes into the nationalized grid in Spain.

So, of course, with that kind of an incentive, lots and lots of activity has been spurred in the Spanish marketplace. Other countries in Europe have similar measures, and the markets are growing rapidly in those countries.

Well, that has enabled companies to, like I just mentioned, to develop economies of scale, achieve technology advancements, and make the technology more affordable in the U.S. market.

As Mark pointed out earlier, we have the best solar resource on the planet. In all of Spain, Spain's solar resource would not have even shown up on Mark's map. And so, and I am quite serious, this is about 6.25, is that right, is kind of the high number that they strive for in Spain, compared to the 7.5 or eight kilowatt hours per square meter today that we have in this area in our home state.

So, the combination of a really desirable solar resource in the southwestern states, and, particularly, our home state, that and the credible developers who are not coming into the marketplace, I think create a really good recipe for expanded growth here.

Ms. GIFFORDS. Okay, thank you.

And briefly, Ms. Rauluk.

Ms. RAULUK. I think it is important to remember, it is useful to have a feed in tariff or something that provides the extra value for the kilowatt hour that is produced from solar energy. That is a needed link in the marketplace. And, that is why Europe has really gone beyond what we have done in the U.S., because their value attributed to the kilowatt hours is significantly higher than it is in the United States.

But, I think we have to remember that who pays that, because that dollar amount for the extra value that you are paying for has to come from the rate payers, effectively, and there is really a limit to how much you can ask the rate payers to pay.

In Europe, it was a little bit easier. First of all, they have fundamentally higher electricity rates. So, if you are adding a penny to the kilowatt hour it is not a 10 or 20 percent increase, but it is, you know, less than that, and also the electric power industry is structured a little more simply.

So, my greatest concern is, I would love to see that the incentives available in the United States would be in excess of .20, .30 cents a kilowatt hour, you would get massive amounts of solar energy put in place. But, fundamentally, somebody has to pay, and, you know, how do we do that, and that is something we really need to think about.

Thank you.

Ms. GIFFORDS. Thank you.

Mr. Hall.

WHY DOES SOLAR ENERGY NEED SO MUCH ASSISTANCE?

Mr. HALL. I guess to follow up, Ms. Rauluk, why does solar need so much assistance to be a viable source of energy?

Ms. RAULUK. Well, sir, there is a couple of reasons, one of which is that you are paying for all of your fuel up front, so that is the number one thing. But, fundamentally, the solar energy industry is relatively small compared to other energy industries and scale really, really is important.

So, the incentive structure, the way it has always been envisioned, and this is something that we have been doing in the U.S. for the last five to eight years, the incentive structure is to bring the scale of the industry and all of the manufacturing efficiencies, et cetera, et cetera, to bear on the problem and bring the cost down.

And, basically, we are realizing, though, efficiencies in both cost and performance, and this is a relatively medium-term incentive structure that we are talking about, and I would like to point out that there is not an energy system on the planet that has not been heavily incentivized because it is an important matter. We need to have reliable energy sources.

So, to do this for solar is really no different than what we have done for oil and gas, and I could go on into the list.

Mr. HALL. Well, I guess I was listening for you to say the reward would be great if we really could conquer this solar thrust, but you know the cost of solar energy can, if I was listening to the testimony right, can only come down and become competitive if the Federal Government, through carbon regulation, forces fossil fuels higher.

Is that what I am hearing? Is that your recommendation?

Ms. RAULUK. Actually, I think in some markets solar energy is competitive right now. If you have a market where peak power prices are in excess of .14–.15 cents a kilowatt hour, which they are in some markets, there are ways that you can put the installation together where it actually is fairly cost effective.

Mr. HALL. I think the rewards would really be great if and when we can conquer the problems with solar energy. It is unlimited, the reward would be unlimited. But, I see across this country a major war against fossil fuels at this time. I am from a fossil fuel state. Texas is one of ten states that produces energy for the other states. I see a thrust toward knocking out fossil fuels. If we knocked out fossil fuels, even in the next five years, these lights go out on us.

We get 60 percent of our energy from countries that don't like us. Our goal ought to be toward trying to lessen that percentage so we are not dependent on people that hate us and fly our airplanes into our buildings to kill our people. We need to really be addressing that, and solar can really help to do that, if we could find the money to put in there. But, I do not think we can find it by knocking down fossil fuels, when it is all we have now, and all we get from Saudi Arabia, 40 percent of our energy comes from them, is solely, totally, completely fossil fuels.

I think if we are going to declare war on something, we need to declare war through technology, finding cleaner fossil fuels and finding a way to do better while we seek solar. I am very fond of solar, and I think it has unlimited possibilities.

Mr. Mehos, in your testimony you indicate that without the continuation of the investment tax credit new capacity is going to be delayed by about 10 to 15 years. How quickly do you think the capacity could be developed if the tax credits were extended? I know you cannot say it is going to be six years, 10 days, and 45 hours, but just give me a good estimate of it.

Mr. MEHOS. I think the best answer to that is to look at what Arizona Public Service and Abengoa are doing with the 280 megawatt project. That plant probably has a construction period of, oh, let us say around two years, not knowing that specifically. But, with the investment tax credit, if that begins to roll along, what we will see are those sizes of plants being built yearly, and probably multiples of those plants.

So, if I had to guess, I would say 500 megawatts to a gigawatt per year, even in the near-term, and let us say the near-term is in that five to 10, once we get past this four-year threshold, then every year after that 500 megawatts to a gigawatt or more per year.

Mr. HALL. In your testimony you also indicate that without the tax credit, solar would not be very competitive with conventional energy plants for quite a while.

Should the tax credit not be available, what do you envision the cost to consumers would be compared to conventional sources of energy that we have right now?

Mr. MEHOS. Without the investment tax credit, using concentrating solar power as a proxy for solar, and it is probably the least cost technology of those at this point, the conventional cost from our concentrating solar power plant is probably on the order of .17 or.18 cents, let us say, a kilowatt hour, without the investment tax credit.

If we compare that to conventional technology in the intermediate load markets, that is about a 50 percent capacity factor.

For a combined cycle plant, you are probably looking at .10 or .11 cents per kilowatt hour. So, we are looking at, roughly, 50 or 70 percent higher.

ENVIRONMENTAL EFFECTS OF USING SOLAR POWER

Mr. HALL. Ms. Lockwood, I think my time is about up. In your testimony, you indicate that since the Federal Government is the largest landowner in the United States we should study the use of available land resources for CSP development.

Now, what are the effects to the environment from the use of solar power?

Ms. LOCKWOOD. Congressman Hall, the effects to the environment depend on the particular location that you are in. The most obvious and clear impact is the amount of land that is consumed.

We are fortunate here in the desert southwest that we have large tracts of unused land that is very well suited for solar power. We certainly have to consider homes of exotic species and other types of environmental impacts when you are looking at siting solar, but we have large tracts of land that are very well suited for this technology today.

Mr. HALL. The use of all of these aides to the pursuit of solar power, you mentioned that, and I would ask you, would you support the use of closed military bases, you know, BRAC closes a lot of bases around the country, I think every 10 years, and this is just a suggestion to you to be thinking about, because you seem to be championing that. Do you support the use of closed military bases for development of large-scale solar projects?

Ms. LOCKWOOD. Congressman Hall, I believe that is a perfectly valid opportunity for putting that land to use.

Mr. HALL. I know BRAC has a provision for refineries being built where you lose a BRAC. I don't know what your State law is, what BRAC closed down for the State of New Mexico, but we lost several in Texas, and they were cut down all over the United States.

Ms. GIFFORDS. Mr. Hall, we do not allow them to close in southern Arizona either, and you realize that.

Mr. HALL. Yes, I know you would not allow that. You get the pitch forks out.

But, we put a provision in there. EPA is the major problem to getting permits to do things, and we had a provision in there at one time that if we made a request to EPA and they did not deny it in 30 days it was granted. And, I know you would like that, wouldn't you? We liked that. I don't think it made it through the Senate—very little gets through the Senate nowadays. But that is a good way to get refineries. Refineries are the reason gas is going higher; there are no refineries. Companies like Exxon and others do not want to put money into it, it takes 29 or 30 years to get their money back.

EPA would do nothing and we cannot appeal from nothing. So, we would rather have them turn us down in 30 days, and then we can appeal it, or grant it in 30 days and you go on with it. That is something that you might think about as you support the use of closed military bases, because I agree with you on that.

I think my time is up. I wish I had more.

Ms. GIFFORDS. Thank you, Mr. Hall.

Vice Chairman Lipinski.

INCREASING THE EFFICIENCY OF SOLAR CELLS

Mr. LIPINSKI. Thank you, Chairwoman.

First of all, I want to note that it is good to see, we have almost as many engineers on this panel as we have in the House of Representatives. I am one of the few engineers in the House. I also notice we have two Stanford alums here—I have an engineering degree from Stanford—and one from Berkeley unfortunately.

But, I want to start out in a little different direction in terms of the technology involved right now, and where we are going with that. I co-hosted a nanotechnology showcase a couple weeks ago in Washington to see some of the new products that are coming out using nano technology. And, I know at the University of Illinois they have done some work and found that by placing silicon nano particles onto silicon solar cells they can increase the power by about 60 percent and increase the life of the cell.

Where is this work right now, in terms of improving PV cells, and how much of a difference is that going to make in the near future, near to short-term, to mid-range future, in terms of how efficient solar energy is? Whoever wants to tackle that one.

Mr. Hansen.

Mr. HANSEN. I will try to take that one, thank you.

TEP did invest in a manufacturing company, Global Solar, and I was involved in the technology looking for that, so I have some background in photovoltaics. In fact, I have a preference for photovoltaics as opposed to concentrating solar power.

You know, back in 1957, when silicon and gallium arsenide were used to develop photovoltaics, they were the predominant metals, if you will, for the use at that time. Since then, we now have those and efficiencies have improved from the less than one percent in 1957 to the 15 to 22 percent for silicon-based. Gallium arsenide-based are now almost at 40 percent, and we do have some materials over 40 percent efficiency. The—are more for silicon and sigs of copper—desalinate have all improved their efficiencies over the last decade. All the work with global solar weighs efficiency for long-scale production runs from two percent to over 11 percent. So, all of these technologies are improving.

I think we need to be careful not to focus on the efficiency when we talk about utility-scale, but to focus on cost per installed kilowatt. We have a lot of land in Arizona. I do not live in Tucson, I live in Apache County in the northeastern part of Arizona, when I travel from my home to our coal-fired power plant, and our solar plant, we have about 4.5 megawatts of solar photovoltaics there, I pass by approximately 150 square miles of land that has about, as I like to say, eight bushes and one house on it, and there is a lot of room, it is fairly flat land. We have space in Arizona.

Efficiency deals with space. Cost is going to be the driver. We need to be improving efficiency, but we need to keep our eye and our focus on reducing the costs. The nano technologies that are now being developed, and some of the organic dye technologies as well, and some of the more advanced thin films, do show promise to be able to reduce the cost of the photovoltaics to dramatically lower numbers, talking in numbers that are less than a dollar per watt, whereas, conventional technologies today are typically at the module level in the neighborhood of $4 to $5 a watt, some as low as $3.50. This is what will drive the cost, and that is really the issue on photovoltaics, is the cost. We need to bring the cost down.

Ms. RAULUK. I would like to mention a couple of things. First of all, and I am not an expert in all of the technology improvements and innovations that are in the pipeline right now, but just from my discussions and work with my colleagues at the University of Arizona and Raytheon Missile Systems, these folks have viable technologies that are, I would call it, in the final stages of R&D. So, there are some very exciting and interesting things in the PV, the concentrating PV, or CPV, and the highly-concentrated PV area that are coming out of the laboratory.

Now, there are incremental changes, incremental improvements that are happening with PV, and when people look at, well, what is the efficiency and the cost, and how is this all working out, no one is thinking about, well, what is coming out of the labs, because the commercialization process is a difficult process with some uncertainties attached to it.

But, let me just point out that, you know, a lot of people say, well, let us not do anything until the technology is really great, and then we will just go and one of the things that supports the technology in the labs right now is the recognition of a marketplace existing and viable. So, when these technologies are coming out of the lab, which I expect they will within the next three years, they will need to get financed by venture capital and then second-stage financing, et cetera, et cetera, and people are going to look at that and say, well, where is the market? So, even if we have a good technology, it is important that we do not wait until we get these things coming out of the labs, but that we have a systematic and reliable investment plan for the future.

Mr. LIPINSKI. Thank you. I see a red light, and I will yield back. If we have a second round, I will have another question.

Ms. GIFFORDS. Okay, thank you.

Mr. LIPINSKI. Thank you.

Ms. GIFFORDS. Mr. Matheson.

ACCELERATED TECHNOLOGY INNOVATION

Mr. MATHESON. Well, thank you.

I am not an engineer. I am, my background is in finance, but I used to be an independent power developer, and developed co-generation facilities. And, now I sit in Congress, where we try to come up with public policy ideas to help foster these new technologies.

And, it seems to me that we need to be looking at this on a couple of different paths at the same time. I have heard all the witnesses talk about the need for, lack of a better term, federal subsidies to help create large-scale commercial applications of technology.

What I am curious about is another path that we also ought to be talking about, I think, and that is the notion of how do we get these technologies to be more efficient so that they are commercially viable, perhaps, with less subsidies, or, perhaps, with no subsidies.

And, Mr. Mehos, your last slide, at the end of your presentation, the kick-starting utility-scale solar slide, you mentioned that there is an exercise for DOE that is estimated at $50 million a year to achieve the accelerated goals. And, that was what I was wondering about, is that program. It sounds to me, you can confirm this for me, but DOE has identified a path to help accelerate this technological innovation, and I think as Members of the Science Committee that is, obviously, something we have great interest in as well.

So, can you share with us a little bit about what that accelerated effort entails?

Mr. MEHOS. Sure. The accelerated effort, as I briefly mentioned, in along two paths. It is continued technology development on the specific technologies, trying to achieve higher temperatures, and I will describe that in a second.

The two technologies in the concentrating solar power program that achieve these higher temperatures are the line focused parabolic trough technologies and the more point-focused central receiver technologies, as well as the point-focused disturling technologies. But, of those first two, the parabolic trough and the central receiver technologies, going to higher temperatures achieves a couple of things. One, it allows you to operate your cycle at higher efficiencies, that does decrease the levelized cost of energy. As importantly, or maybe even more important, as you go to the higher temperatures we are dealing with high amounts of thermal storage materials having a higher delta T difference between your hot temperature and your cold temperature to work with, significantly decreases the amount of thermal storage that you are working with, and that, in itself, also decreases the cost of thermal storage, or of the levelized cost of energy.

So, those are two of the higher pathways, higher temperature pathways, that lower your cost.

We are working on a number of other avenues. We are looking at higher temperature materials, higher reflectivity materials, better absorbing, less emitting materials. We had a study some time ago now, I think back around 2002 with Sergeant Inlundy, basically, identified three mechanisms for reducing the cost of solar power, none of which were power peaked. The first one is the research I described. That results in about a 30 percent reduction in the cost of electricity. The second one is just increasing the size of your plant, the type of work that APS and Abengoa are working on, going from smaller to 280 megawatts. And, the last one is learning, it is deployment, and the more you deploy these technologies, actually, this does get into policy, then the lower the cost of the technology over time.

FINANCING TECHNOLOGY DEVELOPMENT

Mr. MATHESON. And, is it fair to say that, I mean, obviously, one of the variables that helps this process go is if Congress appropriates the funds so that this effort can happen. Dollars, you know, money is part of making this technology develop.

Mr. MEHOS. Yes.

Mr. MATHESON. Are there other policy options that also need to be considered or adjusted that Congress hasn't done that could help facilitate the development of these technologies?

Mr. MEHOS. Yes, I believe so. I think in project finance one of the key issues is risk. When we start talking about $1 to $2 billion projects, I mean, the risk associated with that is relatively high. The parabolic trough technology is actually fairly low risk, but still project finance can be an issue.

And, as you look toward some of these higher temperature technologies, like the central receiver, or the disturling technology as an example, the policy of loan guarantees, or federal loan guarantees, comes to play there.

Mr. MATHESON. Okay, that is helpful.

One other slide that I wanted to ask you about. You showed the difference of whether the 30 percent ITC is extended or not, and the roll out of solar technology. It is probably impossible for you to estimate, because we do not have a policy in place yet in this country, but did you consider if the cap on trade program is put in, and there is a price associated with the carbon, how that would affect the curve when you are developing those drafts?

Mr. MEHOS. No, that's a good question, and we have considered it, we do not have the ability to model that yet.

Mr. MATHESON. Yes.

Mr. MEHOS. That is one of our outcomes this year, we will be able to model those types of systems.

Mr. MATHESON. Mr. Hansen, this is a little off target, but you mentioned smart grid when you were talking, and, you know, the Congress just passed smart grid legislation in the energy bill that passed last year. Do you feel like the legislation that Congress passed was helpful for smart grid? Are there other things we should be doing beyond what was in that legislation, or do you have any thoughts on that?

Mr. HANSEN. Good question. What you passed is very helpful. It is a good start. What we need now is additional, kind of what Valerie just alluded to, we need scale. That is up to the utilities.

Over time, over working with our individual State regulatory entities, we will be able to get recovery for those additional costs.

Mr. MATHESON. Right.

Mr. HANSEN. I think the Federal Government has stepped up to the plate and given us the tools that we need from the federal level. I think we now need State level to step up to the plate.

So, I appreciate the efforts you had last year. Thank you.

Mr. MATHESON. Great. Thanks.

Madam Chair, I see my time is expired.

Ms. GIFFORDS. Thank you, Mr. Matheson.

Mr. Mitchell.

LAND USAGE FOR SOLAR POWER

Mr. MITCHELL. Thank you.

One of the things that was mentioned earlier was that to be successful large-scale solar facilities need land, and the Solana project is three square miles. Is there any possibility that we can be able to, with technology, lessen the need of land? You know, also mentioned was that the reason that there was a market in the southwest for solar was because we had the land, and that we had high renewable portfolio standards.

One of the fights we had over this last energy bill was over the national portfolio standards, and it was knocked out mainly because there were states that said they really didn't have the land, or they didn't have the sunshine, and as a result the portfolio standards are really out here in the southwest.

Is there anything we can do maybe to help establish a higher portfolio standard nationwide at the same time maybe not use as much land as we are going to be able to use here?

Anybody.

Mr. HANSEN. If I may, again, going back to the question asked earlier about efficiency, improving the efficiency, raising the efficiency of photovoltaics, raising the temperature of the collection on concentrating solar, will reduce the amount of land that is required.

Every state has the ability to produce some level of solar. There was a study done a few years back by Black and Beech on the State of Pennsylvania. I went to school in the State of Pennsylvania, I grew up in New Jersey. I don't remember seeing the sun a whole lot of the time, but, quite frankly, the result of that study indicated that the only renewable resource that could meet all of the energy needs of Pennsylvania was solar. So, every state does have the ability to put in solar.

The roof tops are available, without having to use any land. There is a wide range of solar technologies available. TEP's experience is with about 12 of those at this present time, and what we have found is that different technologies have advantages in different climatic zones, as I said in my written testimony. All of the technologies need to be developed, so that we, as a United States, have a portfolio of opportunities. We, as utilities, can pick and choose among these different technologies as to what is most appropriate for our state.

I am not going to weigh in on the issue of a national renewable energy standard. I think the State of Arizona has stepped up to the plate and done an excellent job leadership-wise in developing one that is appropriate for Arizona. But, I do think that over time, with the federal level support, with the national labs, and with universities, the funding can be provided to improve the efficiency, to improve the overall storage capability, for energy in the future that is going to drive things like the solar, Grand Solar Plan and these other technologies to economic fruition, so that they will, in fact, become economically compatible with coal and natural gas.

Ms. RAULUK. One of the reasons why distributed generation has value is that you don't need really large contiguous pieces of land. And, in fact, you can, Mr. Hansen already mentioned, you can put photovoltaics on roof tops, but you can also put photovoltaics in smaller pieces of land and every community has pieces of land that may be old industrial sites, next door to an old industrial site, maybe it is a buffer for an airport, whatever, that are not, you know, several square miles, but are maybe a half a square mile, or even less than that, and you can use that land for a distributed application, because it can scale down to that.

So, I think that the amount of contiguous land doesn't really constrain us when we are talking about a distributed format, and there are plenty of opportunities to do that.

PRICE OF "GREEN" POWER

Mr. MITCHELL. One last question, maybe this is Ms. Lockwood. You know, some people pay an extra little premium to encourage green production of power. Is there any way that anybody is going to take advantage of that once Solana comes on line, or is it all just going to the grid and everybody still pays the same price?

Ms. LOCKWOOD. Congressman Mitchell, we very much believe in the power of our customers to drive the policy and our resource choices. So, absolutely. Solana is several years away, but we do envision a way that our customers can choose to pay a small premium and have all or part of their energy served by Solana.

Ms. GIFFORDS. We only have a few more minutes left, and since I am going to afterwards ask our witnesses to come up, I am going to defer my questions, maybe just one additional question from each of the Members before you have to leave.

UTILITY-SCALE VERSUS DISTRIBUTED GENERATION

Mr. LIPINSKI. Yes, I will lead off here. I just want to know, we are in heaviest discussion here about utility-scale mostly, but also distributed generation. Is there any conflict or tension between the two, in terms of one obviating the need for the other? I just want to throw that out there and see some smiles on faces about this. It must be something that you deal with regularly.

Mr. HANSEN. If I may, they can be compatible with each other. TEP's studies have indicated that for us to produce 10 percent of our annual energy from solar we need about 610, 620 megawatts of solar installed.

If every home in Tucson were to have about a three kw system, which is realistic in size, that would give us about that 600 megawatts of solar.

It is at about that point when the energy storage becomes a critical component, if we are going to move solar beyond that 10 percent of our annual energy. That is why TEP has always been trying to develop a balance of distributed generation as well as utility-scale.

Even if every home in Tucson were to install nine kilowatts of photovoltaics, that is 30 percent of our energy. The other 70 has to come from someplace, and we are proposing, at least I am proposing in the long-term, that that comes from the utility-scale solar, such as the 280 megawatt system that Abengoa is planning to put in. But, it could also be from photovoltaics.

In the long-term, the two systems have to mesh, and the glue that makes them mesh is the storage. Even distributed generation without utility-scale solar is going to require some level of storage to even out the day to night intermittencies.

The other part of the puzzle that is hard to understand for some people who have not lived in the southwest is that most of the solar energy is actually produced in the springtime in Arizona, away from our monsoon storms. But, of course, most of the consumption is in the summertime, so we have to shift about three months worth of solar energy into the summertime. It actually works out to be approximately 10 percent.

One other factor I think that needs to be considered for the future, is plug-in hybrid electric vehicles. Our calculations indicate that with an additional 10 percent of energy per year we could provide all of the energy that is needed for all of the passenger vehicles in the City of Tucson. So, that does not include heavy trucks, and airplanes, and locomotives, but your normal passenger vehicles. That, again, could be derived from solar, and could provide an additional opportunity for storage if we go back to that smart grid development and how to integrate them as part of this storage philosophy.

Mr. LIPINSKI. Ms. Rauluk.

Ms. RAULUK. I have alluded to this in my spoken comments, and I have a more detailed explanation of it in my written comments, but there is a fundamental conflict right now in the way in which we contractually do these things between distributed generation and the utilities revenues, because the distributed generation is on the customer's site, and they are effectively purchasing less energy from the utility by generating their own energy.

And then the question arises, well, how do you assure the preservation of utility revenues and the assets that they support, because this is not about getting rid of the utilities or getting rid of the fossil fuel generation by any means.

So, there are things we need to do contractually and from a regulatory point of view, and the industry is well into the phase of doing that and creating the mechanisms that, basically, do not conflict, do not have the utility having a natural and inherent animosity towards distributed generation, but that it is a part of the whole system and is valuable for the whole system.

Mr. LIPINSKI. Ms. Lockwood.

Ms. LOCKWOOD. Congressman Lipinski, I do not know that I disagree with anything Mr. Hansen or Ms. Rauluk said, but for us in Arizona, in particular, for APS, it is about growth, and we are growing so fast, our energy consumption is also growing so fast, that we need all resources to meet our energy needs into the future.

We believe that both are required to get where we need to go, and do not believe there is a fundamental conflict. Now, there is some theory that there is only so much subsidy or incentive to go around, and I think that is where a lot of the debate comes in. Does it go to large scale, or does it go to distributed? And, that is a healthy debate. That is something that we need to be talking about. There are different economics when you look at those different sides of the issue.

For utility scale, we very much look at it in comparison to the other resources that we have. Even without carbon today, large scale is getting—large-scale CSP, solar thermal—is pretty competitive. Our Solana plant is about a 20 percent premium over our conventional resources, what we would have expected to pay for fossil fuel resources into the future for that project.

On the distributed side, you look at it not what you pay for other large-scale generation, but you look at what the customer is paying and the offsets for that customer, and how that works within your rate structure also.

So, from our perspective we need them all, and we need to make sure that we are looking at policies that facilitate them all in the appropriate way and the appropriate manner, also considering the economics and how the impact to the rate payer.

Mr. LIPINSKI. Thank you. I thank all the witnesses for their testimony. It was extremely helpful today, and thanks to Congresswoman Giffords for bringing this together.

Ms. GIFFORDS. Thank you.

Mr. Matheson.

COMPRESSED AIR STORAGE AND GREENHOUSE GAS EMISSIONS

Mr. MATHESON. Why, I'm nervous about going over the deadlines that Madam Chair set. Let me ask one real quick question. I have got to chance this.

I was reading about the Grand Plan, and, you know, one of the great benefits of solar in a world where we are concerned about climate change and global warming is that we move away from fossil fuels.

But, I did note that in the energy storage component of the Grand Plan, we are going to use compressed air, there would be some degree of natural gas used. Do you have a sense of what that means in terms of greenhouse gas emission?

Mr. HANSEN. The use of the natural gas for the reheat on the turbine, and this is, before I say that, this is a technology that can be changed. You can make turbines that do not have to have this natural gas input.

Mr. MATHESON. Oh, okay.

Mr. HANSEN. Alternatively, you could be using biomass or some other type of fuel, bio-diesel, et cetera, to do it, but it is approximately one-sixth of the input that otherwise would be required from natural gas or coal under a normal conventional technology.

Mr. MATHESON. Okay, thank you.

That is it.

Ms. GIFFORDS. Thank you.

Mr. MITCHELL. I don't have a question. I would just like to thank everyone, because it was very informative, and not only the written material but your testimony.

So, thank you all very much.

Ms. GIFFORDS. Well, before we bring this hearing to a close, I want to again thank our witnesses for the generous time and for really a very, very interesting discussion.

The Science Committee is, I believe, the bipartisan Committee in Congress, and we have been able to do many things just in the last a little over a year, that I think this country would be very proud to know, if they had a chance to hear about it.

Unfortunately, usually when we have committees the bells ring frequently, so we will have wonderful testimony, and then we will have to jump up, run over and vote and come back. So, what a luxury to actually have a chance to really focus on the information that you have presented before us today.

The record is going to remain open for additional statements from the Members and answers to any follow-up questions the Committee may ask of our witnesses.

I would also like to thank the bipartisan Science and Technology Committee staff for being here, for coming out from Washington to help conduct this hearing. Also, members from my staff, Tamarack Little, Wyatt King, Jacqueline Jackson, are just a couple that have worked so hard to bring this committee here to southern Arizona as well.

I want to thank the solar experts, and there are many in the room today, and, hopefully, we will have a chance to hear from you in a couple of minutes, because we are going to ask our witnesses to come forward and to answer questions from the general public as well.

But, to the public, thank you for caring so much about the future of the southwest, the future of our country, and the future of how we can take this tremendous potential, harness it, and turn it into some real energy.

So, with that, the witnesses are excused and the hearing is adjourned. Thank you.

[Whereupon, at 2:37 p.m., the Subcommittee was adjourned.]

Appendix 1:

ANSWERS TO POST-HEARING QUESTIONS

ANSWERS TO POST-HEARING QUESTIONS

Responses by Thomas N. Hansen, Vice President, Environmental Services, Conservation and Renewable Energy, Tucson Electric Power

Questions submitted by Representative Adrian Smith

Q1. You spoke about the need for transmission and storage for solar energy. When built, do you envision this infrastructure would be available to other renewable energy technologies, such as wind, an important Nebraska resource?

A1. Most definitely. I envision a large number of storage facilities distributed around the country. The storage should ideally be located locally with respect to where the electric consumers are located, effectively on a regional basis, with one storage facility serving at most five million people. Locating underground energy storage locally provides the optimum solution for energy security for the residents in that area. The nationwide electrical transmission system would allow for the movement of wind energy produced in Nebraska to be stored in Nebraska or California or Maine. Just as our Interstate Highway System enables goods produced in one area to be efficiently delivered in another region, the interstate transmission system would efficiently enable solar, hydro, wind, geothermal, tidal, current and biomass energy to be moved around the Nation in a controlled manner to maximize efficiency of production and delivery. The combination of properly sized local storage with national transmission would allow management of the overall system to minimize congestion.

Q2. As a Member of the House Science and Technology Committee, I have a keen interest in NASA and the space program. Could solar energy collected in space be a viable source of energy for the U.S.? What are the benefits and challenges of this technology?

A2. This concept has been discussed for decades and is, in my opinion, technically viable although some components of the technology need to be improved in terms of reliability and efficiency. One big advantage includes better solar intensity above the atmosphere and 24/7 solar production potentially without day/night cycles or clouds to block the sun. This results in much higher specific energy production per unit area of solar collector reducing the size of the solar collector by 80 percent or more. Building a multi square-mile solar collector in space will be challenging in terms of providing sufficient resources of material and people to a synchronous orbit. Wireless transmission of energy from space to Earth would require very accurate targeting systems and dedication of a few square miles of receivers and buffer zone on the ground to convert the beamed energy back into grid power at high efficiency. However, a large single energy receiver at the Earth end of a space solar energy collection system could be at risk from an act of terrorism, while multiple receiver zones would present more risk of component failure and resulting repair, in addition to an increase in initial cost. It also may be challenging to convince people that it is safe to live near a receiver zone. A space bound energy collector would be at greater risk of damage from collision with meteorites without protection from the atmosphere. Maintaining optimal orbital geometry to enable a space bound solar collector to keep sight of the sun at all times while also keeping its energy beam to Earth on target will be technically challenging, but not impossible. Interestingly, given that the space located solar collector would produce energy at a constant rate, energy storage would still be required to balance the constant energy input with a variable energy demand. The national transmission system would be required to allow for delivery of the space produced energy from a single, or small number of multiple, Earth side satellite energy receivers to all U.S. energy consumers. Some larger questions that still need to be answered are economic: What is the total cost of such a space located solar energy production system? What is the energy balance—will it take more energy to place the energy system in orbit and maintain it than the system will produce over its lifetime? Will more valuable jobs be created for Americans with a space bound energy collection system or a terrestrial located energy collection system? Both the space bound and terrestrial solar energy collection concepts deserve further consideration, although terrestrial solar energy collection technologies are fully developed and available commercially today.

ANSWERS TO POST-HEARING QUESTIONS

Responses by Valerie Rauluk, Founder and CEO, Venture Catalyst Inc.

Questions submitted by Representative Adrian Smith

Q1a. You spoke about distributed generation systems, in which smaller generation systems (rooftop units and 10–50 acre land units) spread electricity generation over "unused real estate" and reduce risk of large scale power outages. Would the Federal Investment Tax Credit provide incentive for individuals to install smaller generation systems (e.g., rooftop units) and to become a part of a distributed generation network? If not, how could the Federal Government encourage this type of development?

A1a. Yes, the FTC does provide incentives for individuals interested in a distributed generation application and participating in a network.

Q1b.

How would you envision the development of distributed generation systems? Who will pay to connect these smaller generation systems into a cohesive network?

A1b. In addition to extending the FTC set to expire at the end of this year, the Federal Government could further encourage such installations by setting distributed generation requirements for utilities nation-wide and to encourage incentives and research and development (especially commercialization R&D) for distributed systems and the intelligent controls and storage options that increase a DG network's value and resiliency.

Q2a. As a Member of the House Science and Technology Committee, I have a keen interest in NASA and the space program. Could solar energy collected in space be a viable source of energy for the U.S.?

A2a. Theoretically, it could be subject to resolving certain technological challenges. However, in the near-term, there are many cost-effective opportunities for harvesting solar energy on the surface of the planet.

Q2b. What are the benefits and challenges of this technology?

A2b. The chief challenge is delivering the collected solar energy to where people can use it, in electric power parlance, the "load." The cost of delivering to the load from remote locations on Earth is one of the fundamental challenges and costs and is why solar energy in a distributed format is more beneficial than central station applications. Energy generation from space would create even greater costs and challenges. However, there may be some benefits to doing so. I have not reviewed the literature concerning this option and cannot offer any insights into the benefits.

ANSWERS TO POST-HEARING QUESTIONS

Responses by Joseph Kastner, Vice President of Implementation and Operations, MMA Renewable Ventures LLC

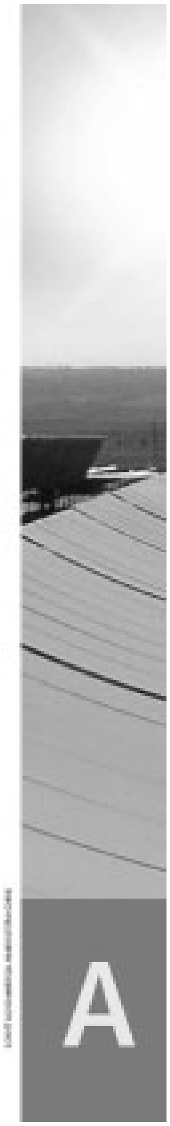
Questions submitted by Representative Adrian Smith

Q1. As a Member of the House Science and Technology Committee, I have a keen interest in NASA and the space program. Could solar energy collected in space be a viable source of energy for the U.S.? What are the benefits and challenges of this technology?

A1. It is my understanding that the DOE studied the collection of solar energy with photovoltaic panels is space several decades ago. Some of the large hurdles for this idea include providing a safe, efficient means for transmitting the electricity to a terrestrial collection point (the DOE contemplated using microwaves) and the mobilization of a large-scale construction project in space (to make it worthwhile the array would be many times larger than the International Space Station). Such a large array would also be quite susceptible to space debris.

Appendix 2:

Additional Material for the Record



By 2050 solar power could end U.S. dependence on foreign oil and slash greenhouse gas emissions

By Ken Zweibel, James Mason and Vasilis Fthenakis

High prices for gasoline and home heating oil are here to stay. The U.S. is at war in the Middle East at least in part to protect its foreign oil interests. And as China, India and other nations rapidly increase their demand for fossil fuels, future fighting over energy looms large. In the meantime, power plants that burn coal, oil and natural gas, as well as vehicles everywhere, continue to pour millions of tons of pollutants and greenhouse gases into the atmosphere annually, threatening the planet.

Well-meaning scientists, engineers, economists and politicians have proposed various steps that could slightly reduce fossil-fuel use and emissions. These steps are not enough. The U.S. needs a bold plan to free itself from fossil fuels. Our analysis convinces us that a massive switch to solar power is the logical answer.

Solar energy's potential is off the chart. The energy in sunlight striking the earth for 40 minutes is equivalent to global energy consumption for a year. The U.S. is lucky to be endowed with a vast resource; at least 250,000 square miles of land in the Southwest alone are suitable for constructing solar power plants, and that land receives more than 4,500 quadrillion British thermal units (Btu) of solar radiation a year. Converting only 2.5 percent of that radiation into electricity would match the nation's total energy consumption in 2006.

To convert the country to solar power, huge tracts of land would have to be covered with photovoltaic panels and solar heating troughs. A direct-current (DC) transmission backbone would also have to be erected to send that energy efficiently across the nation.

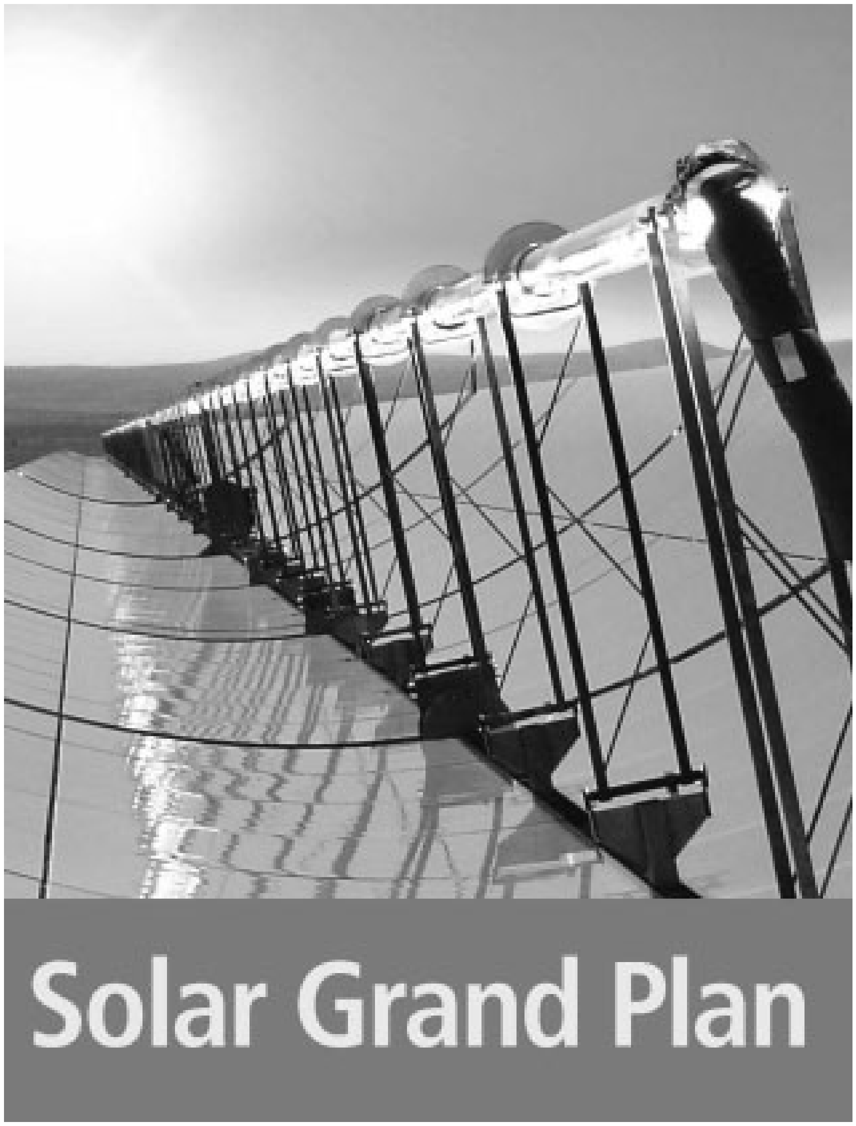
The technology is ready. On the following pages we present a grand plan that could provide 69 percent of the U.S.'s electricity and 35 percent of its total energy (which includes transportation) with solar power by 2050. We project that this energy could be sold to consumers at rates equivalent to today's rates for conventional power sources, about five cents per kilowatt-hour (kWh). If wind, biomass and geothermal sources were also developed, renewable energy could provide 100 percent of the nation's electricity and 90 percent of its energy by 2100.

The federal government would have to invest more than $400 billion over the next 40 years to complete the 2050 plan. That investment is substantial, but the payoff is greater. Solar plants consume little or no fuel, saving billions of dollars year after year. The infrastructure would displace 300 large coal-fired power plants and 300 more large natural gas plants and all the fuels they consume. The plan would effectively eliminate all imported oil, fundamentally cutting U.S. trade deficits and easing political tension in the Middle East

KEY CONCEPTS

- A massive switch from coal, oil, natural gas and nuclear power plants to solar power plants could supply 69 percent of the U.S.'s electricity and 35 percent of its total energy by 2050.
- A vast area of photovoltaic cells would have to be erected in the Southwest. Excess daytime energy would be stored as compressed air in underground caverns to be tapped during nighttime hours.
- Large solar concentrator power plants would be built as well.
- A new direct-current power transmission backbone would deliver solar electricity across the country.
- But $420 billion in subsidies from 2011 to 2050 would be required to fund the infrastructure and make it cost-competitive.

—*The Editors*


Solar Grand Plan

and elsewhere. Because solar technologies are almost pollution-free, the plan would also reduce greenhouse gas emissions from power plants by 1.7 billion tons a year, and another 1.9 billion tons from gasoline vehicles would be displaced by plug-in hybrids refueled by the solar power grid. In 2050 U.S. carbon dioxide emissions would be 62 percent below 2005 levels, putting a major brake on global warming.

Photovoltaic Farms

In the past few years the cost to produce photovoltaic cells and modules has dropped significantly, opening the way for large-scale deployment. Various cell types exist, but the least expensive modules today are thin films made of cadmium telluride. To provide electricity at six cents per kWh by 2020, cadmium telluride modules would have to convert electricity with 14 percent efficiency, and systems would have to be installed at $1.20 per watt of capacity. Current modules have 10 percent efficiency and an installed system cost of about $4 per watt. Progress is clearly needed, but the technology is advancing quickly; commercial efficiencies have risen from 9 to 10 percent in the past 12 months. It is worth noting, too, that as modules improve, rooftop photovoltaics will become more cost-competitive for homeowners, reducing daytime electricity demand.

In our plan, by 2050 photovoltaic technology would provide almost 3,000 gigawatts (GW), or billions of watts, of power. Some 30,000 square miles of photovoltaic arrays would have to be erected. Although this area may sound enormous, installations already in place indicate that the land required for each gigawatt-hour of solar energy produced in the Southwest is less than that needed for a coal-powered plant when factoring in land for coal mining. Studies by the National Renewable Energy Laboratory in Golden, Colo., show that more than enough land in the Southwest is available without requiring use of environmentally sensitive areas, population centers or difficult terrain. Jack Lavelle, a spokesperson for Arizona's Department of Water Conservation, has noted that more than 80 percent of his state's land is not privately owned and that Arizona is very interested in developing its solar potential. The benign nature of photovoltaic plants (including no water consumption) should keep environmental concerns to a minimum.

The main progress required, then, is to raise module efficiency to 14 percent. Although the

CRITICAL FACTOR	2007	2050	ADVANCES NEEDED
Land area	10 sq miles	30,000 sq miles	Policies to develop large public land areas
Thin-film module efficiency	10%	14%	More transparent materials to improve light transmission; more densely doped layers to increase voltage; larger modules to reduce inactive area
Installed cost	$4/W	$1.20/W	Improvements in module efficiency; gains from volume production
Electricity price	16¢/kWh	5¢/kWh	Follows from lower installed cost
Total capacity	0.5 GW	2,940 GW	National energy plan built around solar power
Volume	0	535 billion cu ft	Coordination of site development with natural-gas industry
Installed cost	$5.80/W	$3.90/W	Economies of scale; decreasing photovoltaic electricity prices
Electricity price	20¢/kWh	9¢/kWh	Follows from lower installed cost
Total capacity	0.1 GW	558 GW	National energy plan
Land area	10 sq miles	16,000 sq miles	Policies to develop large public land areas
Solar-to-electric efficiency	13%	17%	Fluids that transfer heat more effectively
Installed cost	$5.30/W	$3.70/W	Single-tank thermal storage systems; economies of scale
Electricity price	18¢/kWh	9¢/kWh	Follows from lower installed cost
Total capacity	0.5 GW	558 GW	National energy plan
Length	500 miles	100,000–500,000 miles	New high-voltage DC grid from Southwest to rest of country

By 2100 renewable energy could generate 100 percent of the U.S.'s electricity and more than 90 percent of its energy.

efficiencies of commercial modules will never reach those of solar cells in the laboratory, cadmium telluride cells at the National Renewable Energy Laboratory are now up to 16.5 percent and rising. At least one manufacturer, First Solar in Perrysburg, Ohio, increased module efficiency from 6 to 10 percent from 2005 to 2007 and is reaching for 11.5 percent by 2010.

Pressurized Caverns

The great limiting factor of solar power, of course, is that it generates little electricity when skies are cloudy and none at night. Excess power must therefore be produced during sunny hours and stored for use during dark hours. Most energy storage systems such as batteries are expensive or inefficient.

Compressed-air energy storage has emerged as a successful alternative. Electricity from photovoltaic plants compresses air and pumps it into vacant underground caverns, abandoned mines, aquifers and depleted natural gas wells. The pressurized air is released on demand to turn a turbine that generates electricity, aided by burning small amounts of natural gas. Compressed-air energy storage plants have been operating reliably in Huntorf, Germany, since 1978 and in McIntosh, Ala., since 1991. The turbines burn only 40 percent of the natural gas they would if they were fueled by natural gas alone, and better heat recovery technology would lower that figure to 30 percent.

Studies by the Electric Power Research Institute in Palo Alto, Calif., indicate that the cost of compressed-air energy storage today is about half that of lead-acid batteries. The research indicates that these facilities would add three or four cents per kWh to photovoltaic generation, bringing the total 2020 cost to eight or nine cents per kWh.

Electricity from photovoltaic farms in the Southwest would be sent over high-voltage DC transmission lines to compressed-air storage facilities throughout the country, where turbines would generate electricity year-round. The key is to find adequate sites. Mapping by the natural gas industry and the Electric Power Research Institute shows that suitable geologic formations exist in 75 percent of the country, often close to metropolitan areas. Indeed, a compressed-air energy storage system would look similar to the U.S. natural gas storage system. The industry stores eight trillion cubic feet of gas in 400 underground reservoirs. By 2050 our plan would require 535 billion cubic feet of storage, with air pressurized at 1,100 pounds per square inch. Although development will be a challenge, plenty of reservoirs are available,

Photovoltaics

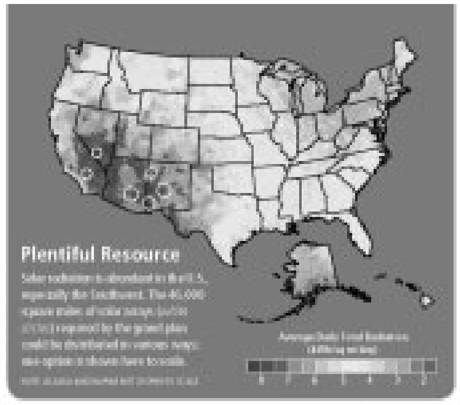
In the 2050 plan vast photovoltaic farms would cover 30,000 square miles of otherwise barren land in the Southwest. They would resemble Tucson Electric Power Company's 4.6-megawatt plant in Springerville, Ariz., which began in 2000 (left). In such farms, many photovoltaic cells are interconnected on one module, and modules are wired together to form an array (right). The direct current from each array flows to a transformer that sends it along high-voltage lines to the power grid. In a thin-film cell (inset), the energy of incoming photons knocks loose electrons in the cadmium telluride layer; they cross a junction, flow to the top conductive layer and then flow around to the back conductive layer, creating current.

and it would be reasonable for the natural gas industry to invest in such a network.

Hot Salt

Another technology that would supply perhaps one fifth of the solar energy in our vision is known as concentrated solar power. In this design, long, metallic mirrors focus sunlight onto a pipe filled with fluid, heating the fluid like a huge magnifying glass might. The hot fluid runs through a heat exchanger, producing steam that turns a turbine.

For energy storage, the pipes run into a large, insulated tank filled with molten salt, which retains heat efficiently. Heat is extracted at night, creating steam. The molten salt does slowly cool, however, so the energy stored must be tapped within a day.



Plentiful Resource

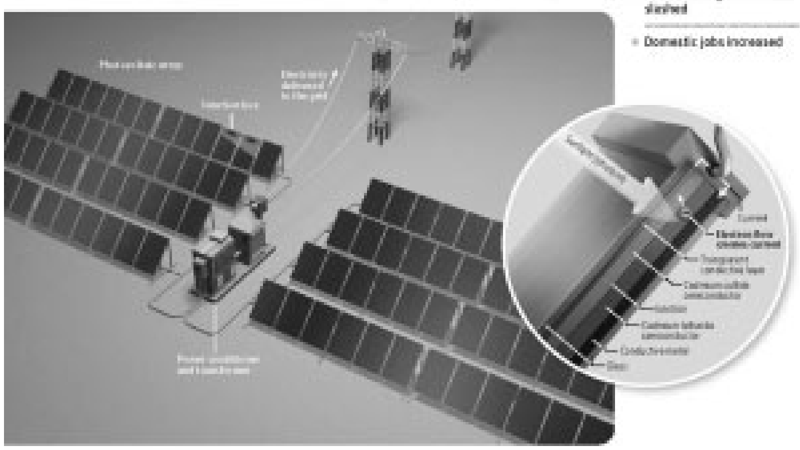
Solar radiation is abundant in the U.S., especially the Southwest. The 46,000 square miles of solar arrays (white circles) required by the grand plan could be distributed in various ways; one option is shown here to scale.

Nine concentrated solar power plants with a total capacity of 354 megawatts (MW) have been generating electricity reliably for years in the U.S. A new 64-MW plant in Nevada came online in March 2007. These plants, however, do not have heat storage. The first commercial installation to incorporate it—a 50-MW plant with seven hours of molten salt storage—is being constructed in Spain, and others are being designed around the world. For our plan, 16 hours of storage would be needed so that electricity could be generated 24 hours a day.

Existing plants prove that concentrated solar power is practical, but costs must decrease. Economies of scale and continued research would help. In 2006 a report by the Solar Task Force of the Western Governors' Association concluded that concentrated solar power could provide electricity at 10 cents per kWh or less by 2015 if 4 GW of plants were constructed. Finding ways to boost the temperature of heat exchanger fluids would raise operating efficiency,

PAYOFFS

- Foreign oil dependence cut from 60 to 0 percent
- Global tensions eased and military costs lowered
- Massive trade deficit reduced significantly
- Greenhouse gas emissions slashed
- Domestic jobs increased



too. Engineers are also investigating how to use molten salt itself as the heat-transfer fluid, reducing heat losses as well as capital costs. Salt is corrosive, however, so more resilient piping systems are needed.

Concentrated solar power and photovoltaics represent two different technology paths. Neither is fully developed, so our plan brings them both to large-scale deployment by 2020, giving them time to mature. Various combinations of solar technologies might also evolve to meet demand economically. As installations expand, engineers and accountants can evaluate the pros and cons, and investors may decide to support one technology more than another.

Direct Current, Too

The geography of solar power is obviously different from the nation's current supply scheme. Today coal, oil, natural gas and nuclear power plants dot the landscape, built relatively close to where power is needed. Most of the country's solar generation would stand in the Southwest. The existing system of alternating-current (AC) power lines is not robust enough to carry power from these centers to consumers everywhere and would lose too much energy over long hauls. A new high-voltage, direct-current (HVDC) power transmission backbone would have to be built.

Studies by Oak Ridge National Laboratory indicate that long-distance HVDC lines lose far less energy than AC lines do over equivalent spans. The backbone would radiate from the Southwest toward the nation's borders. The lines would terminate at converter stations where the power would be switched to AC and sent along existing regional transmission lines that supply customers.

The AC system is also simply out of capacity, leading to noted shortages in California and other regions; DC lines are cheaper to build and require less land area than equivalent AC lines. About 500 miles of HVDC lines operate in the U.S. today and have proved reliable and efficient. No major technical advances seem to be needed, but more experience would help refine operations. The Southwest Power Pool of Texas is designing an integrated system of DC and AC transmission to enable development of 10 GW of wind power in western Texas. And TransCanada, Inc., is proposing 2,200 miles of HVDC lines to carry wind energy from Montana and Wyoming south to Las Vegas and beyond.

PINCH POINTS

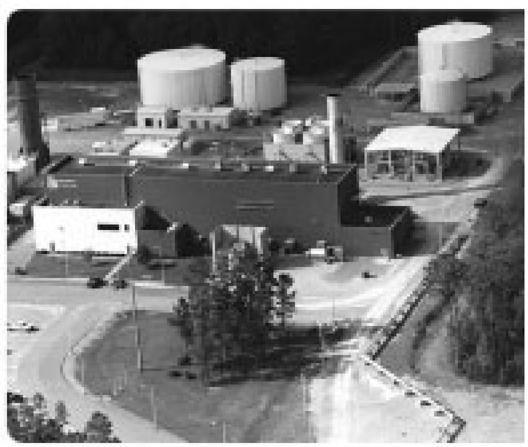
- Subsidies totaling $420 billion through 2050
- Political leadership needed to raise the subsidy, possibly with a carbon tax
- New high-voltage, direct-current electric transmission system built profitably by private carriers

Stage One: Present to 2020

We have given considerable thought to how the solar grand plan can be deployed. We foresee two distinct stages. The first, from now until 2020, must make solar competitive at the mass-production level. This stage will require the government to guarantee 30-year loans, agree to purchase power and provide price-support subsidies. The annual aid package would rise steadily from 2011 to 2020. At that time, the solar technologies would compete on their own merits. The cumulative subsidy would total $420 billion (we will explain later how to pay this bill).

About 84 GW of photovoltaics and concentrated solar power plants would be built by 2020. In parallel, the DC transmission system would be laid. It would expand via existing rights-of-way along interstate highway corridors, minimizing land-acquisition and regulatory hurdles. This backbone would reach major markets in Phoenix, Las Vegas, Los Angeles and San Diego to the west and San Antonio, Dallas, Houston, New Orleans, Birmingham, Ala., Tampa, Fla., and Atlanta to the east.

Building 1.5 GW of photovoltaics and 1.5 GW of concentrated solar power annually in the first five years would stimulate many manufacturers to scale up. In the next five years, annual



construction would rise to 5 GW apiece, helping firms optimize production lines. As a result, solar electricity would fall toward six cents per kWh. This implementation schedule is realistic; more than 5 GW of nuclear power plants were built in the U.S. each year from 1972 to 1987. What is more, solar systems can be manufactured and installed at much faster rates than conventional power plants because of their straightforward design and relative lack of environmental and safety complications.

Stage Two: 2020 to 2050

It is paramount that major market incentives remain in effect through 2020, to set the stage for self-sustained growth thereafter. In extending our model to 2050, we have been conservative. We do not include any technological or cost improvements beyond 2020. We also assume that energy demand will grow nationally by 1 percent a year. In this scenario, by 2050 solar power plants will supply 69 percent of U.S. electricity and 35 percent of total U.S. energy. This quantity includes enough to supply all the electricity consumed by 344 million plug-in hybrid vehicles, which would displace their gasoline counterparts, key to reducing dependence on foreign oil and to mitigating greenhouse gas emissions. Some three million new domestic jobs—notably in manufacturing solar components—would be created, which is several times the number of U.S. jobs that would be lost in the then dwindling fossil-fuel industries.

The huge reduction in imported oil would lower trade balance payments by $300 billion a year, assuming a crude-oil price of $60 a barrel (average prices were higher in 2007). Once solar power plants are installed, they must be maintained and repaired, but the price of sunlight is forever free, duplicating those fuel savings year after year. Moreover, the solar investment would enhance national energy security, reduce financial burdens on the military, and greatly decrease the societal costs of pollution and global warming, from human health problems to the ruining of coastlines and farmlands.

Ironically, the solar grand plan would lower energy consumption. Even with 1 percent annual growth in demand, the 100 quadrillion Btu consumed in 2006 would fall to 93 quadrillion Btu by 2050. This unusual effect arises because a good deal of energy is consumed to extract and process fossil fuels, and more is wasted in burning them and controlling their emissions.

To meet the 2050 projection, 46,000 square miles of land would be needed for photovoltaic and concentrated solar power installations. That area is large, and yet it covers just 19 percent of

[THE AUTHORS]

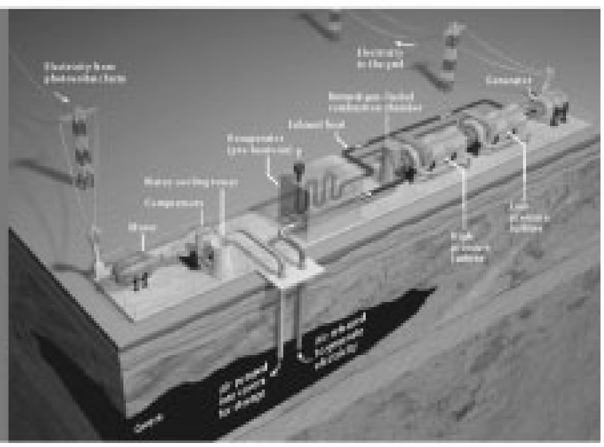
Ken Zweibel, James Mason and Vasilis Fthenakis met a decade ago while working on life-cycle studies of photovoltaics. Zweibel is president of PrimeStar Solar in Golden, Colo., and for 15 years was manager of the National Renewable Energy Laboratory's Thin-Film PV Partnership. Mason is director of the Solar Energy Campaign and the Hydrogen Research Institute in Farmingdale, N.Y. Fthenakis is head of the Photovoltaic Environmental Research Center at Brookhaven National Laboratory and is a professor in and director of Columbia University's Center for Life Cycle Analysis.

Brilliant? Far-fetched?

For a discussion with the authors about the solar grand plan, please visit our Community page at **http://science-community.SciAm.com**; click on Discussions, then Technology.

Underground Storage

Excess electricity produced during the day by photovoltaic farms would be sent over power lines to compressed-air energy storage sites close to cities. At night the sites would generate power for consumers. Such technology is already available; the PowerSouth Energy Cooperative's plant in McIntosh, Ala. (left), has operated since 1991 (the white pipe sends air underground). In these designs, incoming electricity runs motors and compressors that pressurize air and send it into vacant caverns, mines or aquifers (right). When the air is released, it is heated by burning small amounts of natural gas; the hot, expanding gases turn turbines that generate electricity.



Although $420 billion is substantial, it is less than the U.S. Farm Price Support program.

the suitable Southwest land. Most of that land is barren; there is no competing use value. And the land will not be polluted. We have assumed that only 10 percent of the solar capacity in 2050 will come from distributed photovoltaic installations—those on rooftops or commercial lots throughout the country. But as prices drop, these applications could play a bigger role.

2050 and Beyond

Although it is not possible to project with any exactitude 50 or more years into the future, as an exercise to demonstrate the full potential of solar energy we constructed a scenario for 2100. By that time, based on our plan, total energy demand (including transportation) is projected to be 140 quadrillion Btu, with seven times today's electric generating capacity.

To be conservative, again, we estimated how much solar plant capacity would be needed under the historical worst-case solar radiation conditions for the Southwest, which occurred during the winter of 1982–1983 and in 1992 and 1993 following the Mount Pinatubo eruption, according to National Solar Radiation Data Base records from 1961 to 2005. And again, we did not assume any further technological and cost improvements beyond 2020, even though it is nearly certain that in 80 years ongoing research would improve solar efficiency, cost and storage.

Under these assumptions, U.S. energy demand could be fulfilled with the following capacities: 2.9 terawatts (TW) of photovoltaic power going directly to the grid and another 7.5 TW dedicated to compressed-air storage; 2.3 TW of concentrated solar power plants; and 1.3 TW of distributed photovoltaic installations. Supply would be rounded out with 1 TW of wind farms, 0.2 TW of geothermal power plants and 0.25 TW of biomass-based production for fuels. The model includes 0.5 TW of geothermal heat pumps for direct building heating and cooling. The solar systems would require 165,000 square miles of land, still less than the suitable available area in the Southwest.

In 2100 this renewable portfolio could generate 100 percent of all U.S. electricity and more than 90 percent of total U.S. energy. In the spring and summer, the solar infrastructure would produce enough hydrogen to meet more than 90 percent of all transportation fuel demand and would replace the small natural gas supply used to aid compressed-air turbines. Adding 48 billion gallons of biofuel would cover the rest of transportation energy. Energy-related carbon dioxide emissions would be reduced 92 percent below 2005 levels.

Concentrated Solar

Large concentrated solar power plants would complement photovoltaic farms in the Southwest. The Kramer Junction plant in California's Mojave Desert (left), using technology from Solel in Beit Shemesh, Israel, has been operating since 1989. Metallic parabolic mirrors focus sunlight on a pipe, heating fluid such as ethylene glycol inside (right). The mirrors rotate to track the sun. The hot pipes run alongside a second loop inside a heat exchanger that contains water, turning it to steam that drives a turbine. Future plants could also send the hot fluid through a holding tank, heating molten salt; that reservoir would retain heat that could be tapped at night for the heat exchanger.

Who Pays?

Our model is not an austerity plan, because it includes a 1 percent annual increase in demand, which would sustain lifestyles similar to those today with expected efficiency improvements in energy generation and use. Perhaps the biggest question is how to pay for a $420-billion overhaul of the nation's energy infrastructure. One of the most common ideas is a carbon tax. The International Energy Agency suggests that a carbon tax of $40 to $90 per ton of coal will be required to induce electricity generators to adopt carbon capture and storage systems to reduce carbon dioxide emissions. This tax is equivalent to raising the price of electricity by one to two cents per kWh. But our plan is less expensive. The $420 billion could be generated with a carbon tax of 0.5 cent per kWh. Given that electricity today generally sells for six to 10 cents per kWh, adding 0.5 cent per kWh seems reasonable.

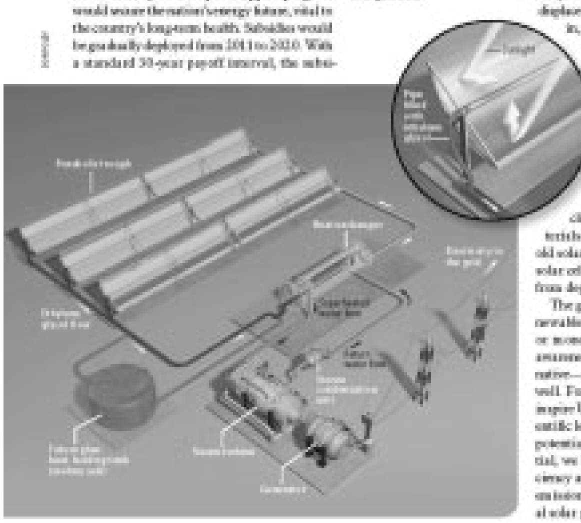
Congress could establish the financial incentives by adopting a national renewable energy plan. Consider the U.S. Farm Price Support program, which has been justified in terms of national security. A solar price support program would secure the nation's energy future, vital to the country's long-term health. Subsidies would be gradually deployed from 2011 to 2020. With a standard 30-year payoff interval, the subsidies would end from 2041 to 2050. The HVDC transmission companies would not have to be subsidized, because they would finance construction of lines and converter stations just as they now finance AC lines, earning revenues by delivering electricity.

Although $420 billion is substantial, the annual expense would be less than the current U.S. Farm Price Support program. It is also less than the tax subsidies that have been levied to build the country's high-speed telecommunications infrastructure over the past 35 years. And it frees the U.S. from policy and budget issues driven by international energy conflicts.

Without subsidies, the solar grand plan is impossible. Other countries have reached similar conclusions: Japan is already building a large, subsidized solar infrastructure, and Germany has embarked on a nationwide program. Although the investment is high, it is important to remember that the energy source, sunlight, is free. There are no annual fuel or pollution-control costs like those for coal, oil or nuclear power, and only a slight cost for natural gas in compressed-air systems, although hydrogen or biofuels could displace that, too. When fuel savings are factored in, the cost of solar would be a bargain in coming decades. But we cannot wait until then to begin scaling up.

Critics have raised other concerns, such as whether material constraints could stifle large-scale installation. With rapid deployment, temporary shortages are possible. But several types of cells exist that use different material combinations. Better processing and recycling are also reducing the amount of materials that cells require. And in the long term, old solar cells can largely be recycled into new solar cells, changing our energy supply picture from depletable fuels to recyclable materials.

The greatest obstacle to implementing a renewable U.S. energy system is not technology or money, however. It is the lack of public awareness that solar power is a practical alternative—and one that can fuel transportation as well. Forward-looking thinkers should try to inspire U.S. citizens, and their political and scientific leaders, about solar power's incredible potential. Once Americans realize that potential, we believe the desire for energy self-sufficiency and the need to reduce carbon dioxide emissions will prompt them to adopt a national solar plan. ■



MORE TO EXPLORE

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