Report to Congress on

Feasibility of 1,000 Megawatts of Solar Power in the Southwest by 2006

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Energy Efficiency and Renewable Energy
U.S. Department of Energy

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EXECUTIVE SUMMARY

In the Conference Report for the Energy and Water Development Appropriations Act, FY 2002, Congress requested the Department of Energy (DOE) to "develop and scope out an initiative to fulfill the goal of having 1,000 megawatts (MW) of new parabolic trough, power tower, and dish engine solar capacity supplying the Southwestern United States by the year 2006." The Report further requested that DOE prepare and submit to Congress a report on this initiative. To fulfill that request, the following report focuses principally on three issues: 1) the solar power industry's capabilities to execute the initiative, 2) costs required to achieve the initiative, and 3) assessment of possible benefits from the initiative.

Although industry has demonstrated the technical feasibility of the three concentrating solar power (CSP) technologies – parabolic troughs, power towers, and dish/engines – each currently produces more expensive electricity than is delivered from fossil fuels. Only with substantial incentives can the 1,000-MW initiative succeed. In recognition of this, the CSP industry has developed an incentive package that it believes would enable it to compete in energy markets and fulfill the 1,000-MW goal. The incentive package is estimated to cost the government (Federal or State) between $1.5 and $2.0 billion over fourteen years. Industry investment in the initiative is estimated at approximately $1.8 billion. Industry believes the initiative could be accomplished within five years from the implementation of its proposed incentive package. DOE believes that bringing on the full 1,000 MW would more likely require six to eight years, even with the incentives industry has suggested. In either case, the initiative could not be accomplished by 2006. Moreover, industry's proposed incentive package would require significant legislative action, which it is not clear would be supported by a majority in Congress or the Administration.

The CSP industry informed DOE that the 1,000-MW initiative would establish manufacturing capability, provide "learning curve" cost reductions, and result in a permanent presence of CSP technologies in U.S. and world energy markets. Industry estimates that the cost of electricity from these technologies could be as low as 6 cents per kilowatt-hour by the end of the initiative. At that cost, solar powered electricity could compete in peaking and green energy markets.

The 2.6 billion kilowatt hours per year of electricity that would be produced by 1,000 MW of new CSP power plants would avoid 1380 million pounds of carbon. This translates to about $106 per metric tonne of carbon avoided. It would also avoid 4.3 million pounds of SO_2 and 4.0 million pounds of NO_x each year. Clearly, the initiative and subsequent Southwestern solar plants could help the Nation achieve the President's goal of an 18 percent reduction by 2012 in greenhouse gas emission intensity. The Southwest has a rapidly increasing population, sufficient uncommitted land areas, and excellent solar resources. Its desire for electric power that maintains the clarity of its air and diversifies its use of domestic energy resources makes the Southwest the ideal location for a 1,000-MW initiative. The initiative also supports the National Energy Policy (NEP) goal of increasing the supply of environmentally friendly, domestic energy resources.

The NEP indicates that all of its goals must be achieved at reasonable cost. Policy officials must ultimately determine whether the environmental and energy security benefits stated above are worth the $1.5 to $2.0 billion cost to taxpayers. Before acting on the initiative, DOE strongly suggests that Congress confer further with all stakeholders to more fully explore the costs and benefits of a 1000 MW initiative.

1. INTRODUCTION

1.1 Purpose

The U.S. Department of Energy (DOE) submits this report in response to Conference Report language accompanying the Fiscal Year 2002 Energy and Water Development Appropriation Act (House Report No. 107-258, at 113). Specifically, the request stated:

> ... the conferees direct the Department to develop and scope out an initiative to fulfill the goal of having 1,000 MW of new parabolic trough, power tower, and dish engine solar capacity supplying the Southwestern United States by the year 2006. A report on this initiative is due to the House and Senate Committees on Appropriations by March 1, 2002.

The major purpose of a large solar installation initiative would be to accelerate the transition of solar power generation technologies from "pre-commercial" status to a point where they could establish sustainable markets. Today, the cost of energy from CSP systems (parabolic troughs, power towers, dish/engines) varies from about 12 cents per kilowatt-hour (kWh) for troughs to 30 cents per kWh for dishes. CSP systems, which generate power during periods of peak electricity demand (particularly in areas with cooling-driven peak loads), command market premiums for peak and "green" power and may need only to meet power costs[*] in the 4 to 6 cents per kWh range.[1,2] Modular dish/engine technologies, which can likely address distributed generation and remote power applications, may be able to target retail markets where prices range between 9 and 22 cents per kWh.[3] In either case, however, the cost of energy from CSP power plants is presently too expensive to compete with low-cost natural gas-fired or coal-fired power plants, which have had many decades of research and development and large-scale deployment experience. In order for a 1,000-MW initiative to be successful, the CSP industry would need Federal or State government resources (e.g., tax incentives and direct subsidies) to bridge the gap.

> ***"A primary goal of the National Energy Policy is to add supply from diverse sources ….it means making greater use of non-hydro renewable sources now available."***
> -National Energy Policy, May 2001

1.2 Methodology

DOE solicited input from industry members regarding their capabilities, intended actions, and assistance that would be required to achieve the goal of having 1,000 MW of new solar energy generation supplying the Southwestern United States. DOE also had A.D. Little, the National Renewable Energy Laboratory, and Sandia National Laboratory perform supporting analyses and develop estimates of the cost of the industry-recommended incentives package.

Due to the critical role of the States in a 1,000-MW initiative, meetings were held with the Western Governors' Association (WGA) in Washington, DC, in December 2001, and Las Vegas, Nevada, in January 2002, to discuss their energy needs and issues. Substantial authority in electricity production and the construction of electric generating capacity is in State control and much of the encouragement of alternative energy production has been the result of State

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[*] Cost refers to the expense required to generate power, whereas price is the amount that a buyer has to pay for the power (and includes the profit required by the entity that generates the power).

legislation. Any actions by the Federal government would need to be coordinated with State activities.

2. INDUSTRY CAPABILITIES AND TECHNOLOGY READINESS

2.1 Industry Capabilities

The CSP industry consists of large companies (e.g., The Boeing Company, Nexant Inc., Florida Power and Light, and SAIC) that have focused a portion of their resources on CSP and small companies (e.g., Stirling Energy Systems, KJC Operating Company, and WGAssociates) that are focused almost entirely on CSP. Although installation of 1,000 MW of new solar capacity would be a major effort, there is a consensus among the industry that they could make this initiative a success.

Industry estimates that the benefits from increased production, manufacturing improvements, and enhanced reliability resulting from this initiative will lower CSP energy costs to between 6 cents per kWh and 9 cents per kWh depending on the technology, location, financing, and solar radiation.[4] At these cost levels, industry expects to be able to establish sustainable markets. Industry participants also expect that R&D advancements will further lower their cost. Depending on R&D investment levels, CSP manufacturers expect their technology to produce electricity at costs of less than 5 cents per kWh in the next ten to fifteen years. DOE's assessment is that CSP costs would be reduced as a result of the initiative. However, there was not time to conduct an in-depth study to verify industry's estimates.

DOE estimates that the cost of CSP might be expected to decrease by 15 to 30 percent through implementation of the 1,000-MW initiative based on historical trends, but acknowledges that this methodology is speculative. Parabolic trough technology has demonstrated a reduction in the cost of electricity of 15 percent with every doubling of cumulative installed capacity. An aggressive program focused on elements yielding a high rate of return on R&D investment (e.g., advanced thermal storage and receiver development) could result in additional cost reductions. The 1,000-MW initiative is expected to result in one to two doublings in installed capacity. Similar cost reductions have been demonstrated for other conventional and renewable power technologies[5]. Wind power, for example, has demonstrated an 18 percent reduction in the cost of electricity with every doubling of cumulative installed capacity and photovoltaics has demonstrated a 20 percent reduction with every doubling. The cost of conventional power technologies also exhibit capital cost reduction behavior, but because fuel cost has a larger influence on the cost of energy for these technologies, reduction in the overall cost of power is not as significant as for CSP. The EIA accounts for these types of cost reductions in their Annual Energy Outlook [6].

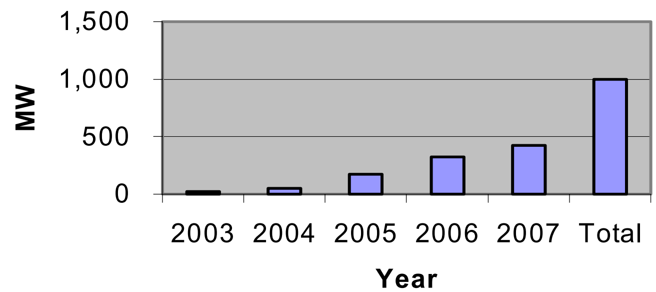
In preparing this report, the principal CSP system developers asserted their intention to pursue the steps necessary to achieve commercial market entry. This would include acquiring the additional investment needed to put in place the required manufacturing capability, engineering and administrative staff, and marketing teams. They indicate the 1,000 MW of CSP projects would also allow them to develop a manufacturing "run rate" that would become the basis for aggressive product pricing and continuing sales.

DOE notes that CSP projects must be sold in a national electricity market that is undergoing change and in which strong competitive pricing pressures are being placed on all potential new power providers. This situation could impact the degree of success of new entrants in the field.

2.2 Power Project Development

The speed at which new solar plants would be installed depends on how fast industry is able to sign long-term power purchase agreements, raise the financing, establish manufacturing capability, and obtain the necessary permits. It is likely, however, that most of the megawatts of capacity would come online late in the five-year period. Figure 1 illustrates one possible scenario as to how the 1,000 MW could be installed*. This reflects the Luz International, Ltd., experience in California between 1984 and 1990, but is proportionately scaled to provide 1,000 MW in the five-year time frame. Luz, a new business in 1984, built a 14-MW trough plant its first year, constructed 80 MW of troughs in each of its final two years, and had in place the capacity to build 200 MW per year by 1990.[7] Current industry participants expect to be able to expand at similar rates.

Figure 1 Projected Plant Installations*



There have been no significant (one megawatt or greater) privately financed CSP projects in the United States since Luz completed 354 MW in 1990. The lack of projects is due in part to the high cost of solar energy relative to natural gas and coal and to the risks associated with new technology. The risk factor is particularly relevant to CSP projects because of the large size (multi-megawatt) of most contemplated CSP power plants. In addition, a factor that inhibited the construction of any new power projects during the 1990s was the uncertainty within the electric power industry of the impact of electric industry restructuring. In industry's view, this initiative would position CSP industry participants to become players in Western U.S. and world power markets.

2.3 Technology Readiness

In contrast to industry's current predictions of reducing costs of CSP technology to 6 to 9 cents per kWh in the five year initiative period and to less than 5 cents per kWh in the longer term, an earlier National Research Council (NRC) report[8] predicted "the likelihood of major breakthroughs that will affect cost and performance (of power towers and troughs) is small." This report followed a 1999 review of the DOE CSP program and led to a conclusion that "the commercial prospects for CSP technologies are not very promising." The solar industry has criticized the NRC's conclusion, indicating that the NRC report provided no analysis nor a

* This assumes all government financial assistance (up to $2 billion) and private investment (up to $1.8 billion) is obtained as identified by the CSP industry.

description of the various advanced technology options, their costs, or their associated technical risks that the NRC considered in arriving at this conclusion.

In 2001, DOE initiated an external review of the CSP program to examine the NRC's recommendations, CSP program performance, and advances in the technology during the past several years. This review, chaired by the Massachusetts Institute of Technology[9], concluded "the CSP Program can play an important role in catalyzing further CSP technology advances, which will further improve CSP economics and market penetration." This review had the benefit of several technological advances not analyzed by the earlier NRC review.

DOE does not dispute that additional research will lead to more technological advances. However, DOE's assessment of the long-term benefits and costs of pursuing CSP, based on the NRC report, led the Department to propose a phase-out the CSP program, as indicated in the President's FY 2003 Budget Request.

Below is a brief description of the CSP technologies.

2.3.1 Parabolic Troughs

The trough plants built by Luz continue to operate, delivering 354 MW, enough power for 100,000 homes. These units constitute the largest solar installations in the world and are among the world's longest continuously operating solar energy projects. They operate daily and demonstrate that CSP power systems can achieve reliability levels equal to those of fossil-fueled plants. The trough plants were designed as solar/fossil hybrids to provide an assurance of output during cloudy periods. Newer plant designs would likely include integral thermal storage, which would enable the plants to provide electricity twenty-four hours a day or tailor their electricity

Figure 2. Trough System

generation to periods when they can obtain the highest price. This ability to deliver energy when needed increases the value of the output. Troughs (Figure 2) operate at about 750ºF. The current cost of electricity production using parabolic troughs is about 12 cents per kWh with industry expectations of cost reductions to between 5 and 6 cents per kWh. This compares with typical fossil fuel generation cost of 4 to 6 cents per kWh in the intermediate and peak energy markets in which troughs might compete.

2.3.2 Power Tower

Power towers (Figure 3) operate at about 1,050ºF. The concept was shown to be viable through fabrication and testing of a 10-MW pilot plant called Solar One.[10] Subsequently, tower technology using molten salt was demonstrated during 1994 to 1999 under an industry/DOE program to evaluate pumps and other salt handling components.[11] As a result, the molten salt working fluid concept was verified and salt storage capability was demonstrated. A continuous 24-hour electrical output was delivered to the California grid for a full week, 100 percent derived from the sun. With these tests, the potential for solar energy, without fossil backup, to supply electricity to large regions of the U.S. and other parts of the world was confirmed. However, no commercial power tower plants have been built. Plants of 100 MW or larger would likely be proposed for the 1,000-MW initiative, raising issues of scale-up, reliability, and maintenance that would need to be evaluated. The cost of electricity production using power towers is estimated to be about 15 to 20 cents per kWh in a first of a kind commercial plant, with industry expectations of cost reductions to between 4 and 5 cents per kWh. This again compares with fossil fuel generation cost of 4 to 6 cents per kWh identified above.

Figure 3. Solar Power Tower Systems

2.3.3 Dish/engine

Dish/engine systems are very modular, require essentially no water, and can operate in hybrid mode. They can feed electricity into the grid, be part of a distributed network, or provide energy to remote locations. Operating at temperatures of about 1,500ºF, dishes are the most efficient of the CSP technologies. They are also the CSP technology most in need of further technology development. The current cost of electricity production using dish/engine systems is about 30 cents per kWh with industry expectations of cost reductions to between 4 and 5 cents per kWh. This compares with fossil fuel generation cost of 9 to 15 cents per kWh in selected distributed applications and 20 to 25 cents per kWh for remote applications.

Figure 4. 25 kW Dish/Engine Systems

Figure 4 shows two different 25-kW dish/Stirling engine designs undergoing tests at the University of Nevada – Las Vegas.[12] These two dishes are being used in tests to provide data necessary to improve the reliability of the dish/engine system. Reliability, particularly of the Stirling engine, has been a problem and the focus of much recent dish R&D. It is DOE's position that dish/engine technology will not be ready for large-scale deployment until the reliability issues have been resolved.

3. PROGRAM REQUIREMENTS: CONDITIONS AND COSTS

3.1 Project Risk and Private Financing

In order to achieve 1,000 MW of new CSP capacity over a five-year period, power project developers must enter into long-term power purchase agreements (PPA) with entities that will buy the electricity generated. CSP power projects must be competitive on a levelized cost-of-electricity (LCOE) basis in order to interest potential customers in a PPA.* After a PPA has been secured, project developers must secure the investment capital required to finance projects, typically in the form of debt (borrowing) and/or equity (ownership share). Attracting investment capital is a significant hurdle faced by project developers of new energy technologies with a high level of perceived risk.

Assistance mechanisms will be needed to bring costs for delivered energy from CSP power projects down to a level that is economically competitive and that will enable developers to secure PPAs.

3.2 Assistance Mechanisms

There are many mechanisms that the government (Federal or State) can use to increase the supply of inexpensive electricity. The Federal government, for example, has built power plants and sold the power (e.g., TVA), as well as sponsored research, development and demonstrations for new technology (e.g., nuclear power). The cost of this initiative would be the same order of magnitude as the President's Clean Coal Initiative, which is projected to cost $2 billion over a 10-year period. Table 1 lists a number of assistance mechanisms available to the government.

* LCOE is the average price of electricity throughout the life of a power plant, taking the time value of money into account. To calculate an LCOE, a power project's expected revenue stream is discounted using a standard discount rate to yield the present value (PV) of the revenue stream. A utility's nominal weighted average cost of capital (WACC) of 10 percent instead of the developer's actual or potential cost of capital is used in this report as the discount rate in both the PV and uniform capital recovery factor (UCRF) calculations so that projects proposed by different developers can be compared on an even basis. The PV is then converted to an annual stream of equal payments using a UCRF. The annualized payment is then divided by the project's annual energy output to obtain the LCOE. LCOE can be a constant dollar value (which excludes inflation) or a current dollar value (which includes inflation), depending on whether the discount rate used to calculate the UCRF is real or nominal.

3.2.1 Industry Preferences

CSP industry members indicated their determination to achieve a sustaining commercial presence as a result of the 1,000-MW opportunity. Consequently, in defining required assistance mechanisms, they focused their attention on incentives they hope would "jump start" a market for their technology.

They chose incentives that would lower capital costs, thus reducing buyer and lender risk and stimulating product flow. These incentives would also promote product acceptance, help develop supplier/customer relationships, and enable achievement of product production rates sufficient for further cost reductions.

Table1: Potential Market Incentives and CSP Industry Preferences

Incentive	Effect	CSP Industry Selection
Land grant	Reduces plant investment	
Income tax reduction	Increases cash available for projects	
Investment tax credit	Encourages 3rd party investment	Trough, tower, dish
Direct Purchases	Creates markets	
Production tax credit	Rewards project performance	Trough, tower, dish
Portfolio standards	Creates markets	
Enterprise zones	Rewards local employment	
Public/private partnership	Reduces risk to investors by the addition of public funding	Tower, dish
Low cost bonds	Reduces borrowing cost	
Loan institutions (e.g., patterned after Fannie Mae)	Creates favorable loan source	
Loan guarantees	Reduces lender risk	Trough, tower, dish

Table 1 lists numerous types of market incentives and identifies those sought by each of the three major CSP technologies. According to industry, the incentive programs were carefully selected. Among the three CSP technologies, the incentive selections closely match but are not identical. In DOE's view, the differences relate to maturity status. The trough technologies benefit from 354 MW of currently operating installed capacity (albeit from technology that is ten or more years old). Trough re-entry into the marketplace is characterized by a lower cost manufacturing "re-start" and overall lower investment risk than power towers or dishes. Consequently, trough assistance requirements are less than the other CSP technologies.

3.2.2 Incentive Specifics

The CSP industry has requested a package of five policy mechanisms for the 1,000-MW initiative to reduce project LCOEs to economically competitive levels and to assist CSP project developers in securing private investment capital. These are:

- A public/private partnership program that provides public-sector (Federal or State) capital investment for CSP projects involving technologies without prior multi-year commercial experience. Power tower and dish/engine projects would be eligible to receive these partnership funds in the amount necessary to reduce the cost of installation to $1.00 per watt – except that public investment per project would be limited in accordance with Table 2.

Table 2. Partnership Contribution

Year *(of Financial closure)*	*Maximum Investment* *($/watt, daylight equivalent capacity)*
2003	4.00
2004	2.40
2005	1.80
2006	1.60
2007	1.40

If, for example, a 5-MW project costing $25M ($5 per watt) were to reach financial closure in the first year of the initiative, it would be eligible for $20M ($4 per watt) of public sector funding. The same project in the second year would be eligible for $12M ($2.40 per watt). Furthermore, the total multi-year cost of the public/private partnership would be limited to $640 million.* DOE notes that this amount could possibly be reduced if the funds in this category were awarded on a competitive basis. These funds would have to be accumulated by the public sector through appropriations or mechanisms such as system benefit charges.

- A 30 percent investment tax credit (ITC). Presently, the solar industry is eligible for a 10 percent ITC.
- Inclusion of CSP as a qualifying technology for a 1.7 cent per kWh production tax credit (PTC). Presently, renewable energy technologies such as wind and closed-loop biomass are eligible for this PTC, but solar is not.
- A solar energy loan guarantee program for CSP loans negotiated during the five-year project period; and
- Transferability of PTC and ITC to tax eligible entities. The PTC and ITC should include relief from the Alternative Minimum Tax (AMT) and make the credit transferable from the developer to the lender (debt) on the project. These provisions are typically included to ensure the effectiveness of the incentives in reducing electricity cost.

To achieve 1,000 MW of CSP deployment, industry believes these incentives are required for the duration of the five-year initiative. Industry also believes the PTC should be in effect for ten years. Costs for this element of the package would thus continue for nine years after the end of the five-year program (i.e., CSP projects put into service in year five of the program would be able to use the PTC for ten years, thus extending the PTC for nine years after the five-year program ended). A company would be eligible for multiple incentives.

It should be noted that the Energy Policy Act of 1992 moved away from the ITC because of a variety of problems associated with it. Experience shows that incentives do not always produce the desired effect. Industry recognized this and, as mentioned above, discussed a number of other incentive options before proposing this package. DOE notes that most of the incentives require significant legislation and the likely commitment of future appropriations.

Although a company would be eligible for multiple incentives, the initiative would have to be structured so that a company could receive only those incentives required for a reasonable rate of return. Establishing the exact incentive package necessary to enable the success of a 1,000-MW initiative at minimum cost is beyond the scope of this report and should be done by tax experts. There is a fine line in developing such a package. An insufficient incentive package will attract too few projects. Too generous an incentive package, on the other hand, will attract unqualified companies with poorly designed systems. Incentives for solar and wind technologies in the 1970s and 1980s, for example, were in some cases too generous and resulted in unsuccessful projects that ultimately damaged the industry they were trying to assist.

If policy officials decide to support the 1,000-MW initiative, to assure that the incentives are not abused, DOE suggests that an oversight body be established that defines the process by which

* This incentive is requested only for dish/engines and power towers because, given the operational history of parabolic troughs, it is likely that parabolic trough project developers will be able to attract debt lenders and equity investors if trough power costs can be reduced to competitive levels through other incentives.

incentives would be distributed, reviews the capabilities and standards of each company applying for a project within the initiative, reviews and approves projects, and keeps track of project progress and the cost of the initiative. The incentives could be allocated on a competitive basis, possibly in phases such that each succeeding phase becomes more competitive. No incentives would be granted for projects that exceeded the 1,000-MW total.

3.3 Cost of Financial Incentive Package

If the incentive package presented in Section 3.2 were adopted, the CSP industry believes that 1,000 MW of new CSP capacity could be installed over a five-year period beginning with the enactment of the complete package. DOE agrees that a large amount of power (perhaps 500-700 MW) could be brought on line within five years, but recognizes that it could take from six to eight years for the full 1,000 MW to be installed. The additional time could result from industry difficulties in securing long-term power purchase agreements, obtaining private sector financing, establishing manufacturing capability in the Southwest, or obtaining necessary permits.

The estimated cost breakdown by incentive and by technology is detailed in Table 3. The costs have been estimated by DOE and reflect installation of 1,000 MW of CSP capacity, based on installation data supplied by industry. Table 4 shows the corresponding CSP industry investment.

Table 3. 14 Year Government Costs of Proposed Financial Incentive Package*

One Scenario ($ Million)

Policy	*Troughs*	*Power Towers*	*Dish/engines*	**Total**
Partnership	-	125	513	638
ITC	384	60	90	534
PTC**	294	306	167	766
Loan Guarantee***	32	3	9	44
Technical Support^				75
Total	710	494	778	2,057
Total ($/watt)	1.42	2.47	2.59	

* Although resources could be provided from either the Federal government or State governments, it is assumed most funding would be borne by the Federal government. There are no additional costs associated with the transferability of PTC and ITC to tax eligible entities.
** The PTC is assumed to start at 1.7 cents per kWh in 2003 and escalate annually at 2.8 percent.
*** The cost of the loan guarantee program is a function of the assumed project failure rate. In this analysis the project failure rate is assumed to be 10 percent. This is a value spread across all technologies, not a scenario of which projects will fail.
^ The CSP industry expects that DOE would provide technical support on an as-needed basis, costing up to $15 million per year over five years.

Table 4: 5 Year CSP Industry Cost of 1,000 MW over Five Years - One Scenario ($ Million)*

Source of Funds	*Troughs*	*Towers*	*Dish/Engines*	Total
Equity	640	100	150	890
Debt	640	100	150	890
Total	1,280	200	300	1,780

*Assumes a 50:50 debt-to-equity capital structure.

As indicated in Table 3, the non-discounted cost of the CSP incentive package is estimated to be approximately $2.0 billion over the life of the initiative. The majority of initiative costs would occur in the first five years. The annual cost would range from $454 million per year at the beginning of the initiative to $45 million per year in year fourteen. The calculations in Table 3 are based on an assumed mix of technologies that would comprise the 1,000-MW goal. In this instance, 500 MW are assumed to come from trough plants. The actual distribution, however, would be determined by the ability of individual members of the CSP industry to obtain long-term PPAs in the Western power market. If, for example, troughs were to comprise the bulk of the 1,000 MW, the total cost would be closer to $1.5 billion.

DOE hired A.D. Little, Inc., to conduct an analysis of industry's estimate of the cost to the government as presented in Table 3. The A.D. Little analyst indicated that the supporting data provided by the CSP industry were reasonable, but that rates of system cost reductions in some cases appeared conservative, resulting in higher costs than expected. The analyst's opinion was that industry, "as a practical matter, decided to err on the high side to better ensure that what is asked for will in fact lead to acceptably low risks to the industry participants if actually implemented."[13]

As Table 4 indicates, successful completion of the initiative would require a CSP industry investment of approximately $1.8 billion over five years, nearly equal to the costs of the incentives shown in Table 3. This estimate is based on the same mix of technologies used for Table 3 and, as before, the values shown could vary by several hundred million dollars depending on the actual mix of CSP systems installed. Raising this level of capital could be a difficult undertaking for project developers employing a new technology.

3.4 Technical Support Requirements

Industry indicated it would need technical support if a 1,000-MW initiative were implemented. This would include access to the unique analysis and test facilities available at the Sandia National and National Renewable Energy Laboratories, the independent review of design changes, and assistance in solving technical problems. This may cost $15 million per year for the five-year duration of the initiative.

3.5 Policy

The National Energy Policy (NEP) indicates that all of its goals must be achieved at reasonable cost. Policy officials must determine whether the environmental and energy security benefits stated below are worth the $2.0 billion cost to taxpayers.

4. RETURN ON THE INVESTMENT

4.1 Potential Initiative Benefits

The 2.6 billion kilowatt hours per year of electricity that would be produced by 1,000 MW of new CSP power plants[14] would avoid 2,180 million pounds of carbon dioxide (CO_2) emissions annually (or 595 million pounds of carbon) compared to a natural gas-fired power plant, and would contribute to improved air quality in the Southwest. At a government cost of $2 billion and an expected lifetime of 30 years, this would translate into a cost of 11.2 cents per pound of carbon avoided (or $246 per tonne C). If used to offset coal-fired power, the CSP power plants would, each year, avoid 5,070 million pounds of CO_2 (or 1380 million pounds of carbon) as well as 4.3 million pounds of SO_2 and 4.0 million pounds of NO_x. This would translate to a cost of 4.8 cents per pound of carbon avoided (or $106 per tonne C). Clearly, the initiative could help the Nation achieve the President's goal of an 18 percent reduction in greenhouse gas emission intensity by 2012 (metric tons carbon equivalent per million dollars gross domestic product). During the next two decades the Energy Information Agency estimates the country will need 76 quads more energy than the 99 quads it now uses. It is hoped that 48 quads of this can be offset through conservation.[15] The remaining 28 quads, however, must be new energy supply. CSP can provide a portion of that energy from domestic resources while not contributing to greenhouse gas emissions. If successful, this initiative could launch a new industry in the Southwest that would build and operate many additional solar power plants that provide electricity to the West.

The benefits listed above support the NEP goal of increasing the supply of domestic energy resources by the increased use of environmentally friendly non-hydro renewable resources, such as solar energy. Diversifying the portfolio of electricity generators also supports the NEP goal "to add supply from diverse sources." DOE notes that all benefits cited depend on successfully completing the installation of 1,000 MW of capacity.

4.2 Regional Impacts

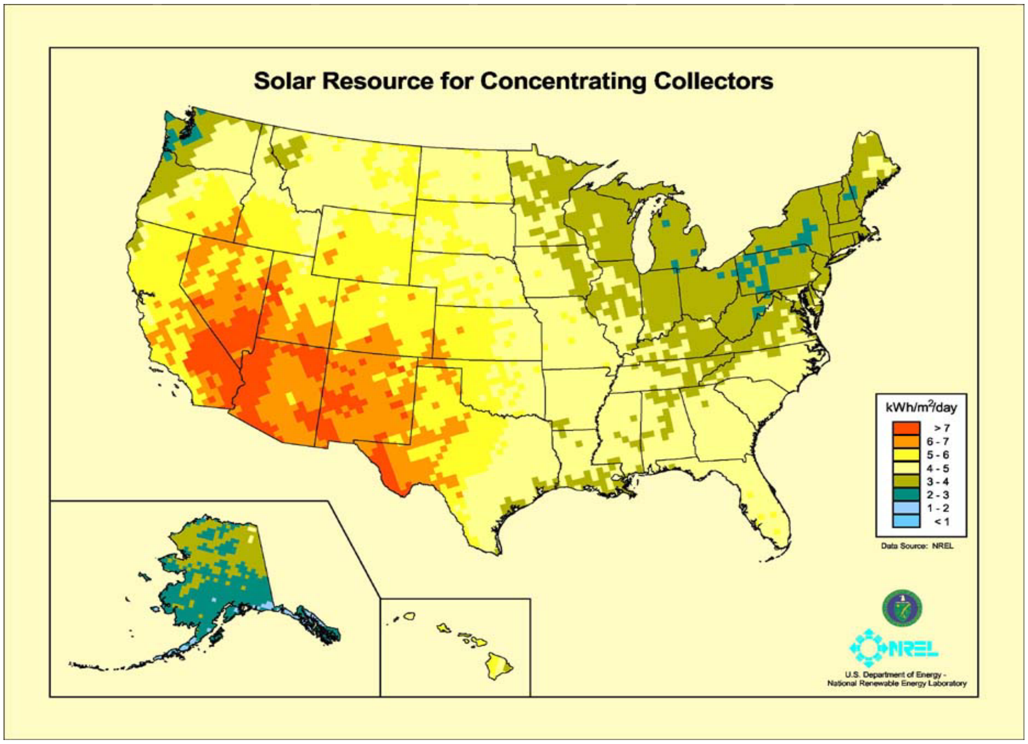
As mandated by Congress, the 1,000-MW initiative would be targeted toward the Southwestern States. Several reasons can be cited for this selection. These relate to the regional solar resource, the region's growth potential, and regional energy markets.

4.2.1 Solar Resource

Solar energy arrives at the surface of the earth as direct light (undisturbed light from the sun) and diffuse light (light scattered by clouds and atmospheric particles). Concentrating solar technologies, by virtue of their optical characteristics, concentrate the direct component of sunlight to convert it to thermal energy and then to electricity.

Figure 5 shows that much of the country west of the Mississippi has high-quality solar resources and that a significant concentration of resources is located in the Southwest. The geographic latitude of the region, the low humidity, and the high altitude of the Colorado River plateau make solar resources in the Southwestern U.S. among the best available in any industrialized nation. In the arid regions of Arizona, California, New Mexico, Nevada, and west Texas lie significant untapped domestic solar energy reserves.

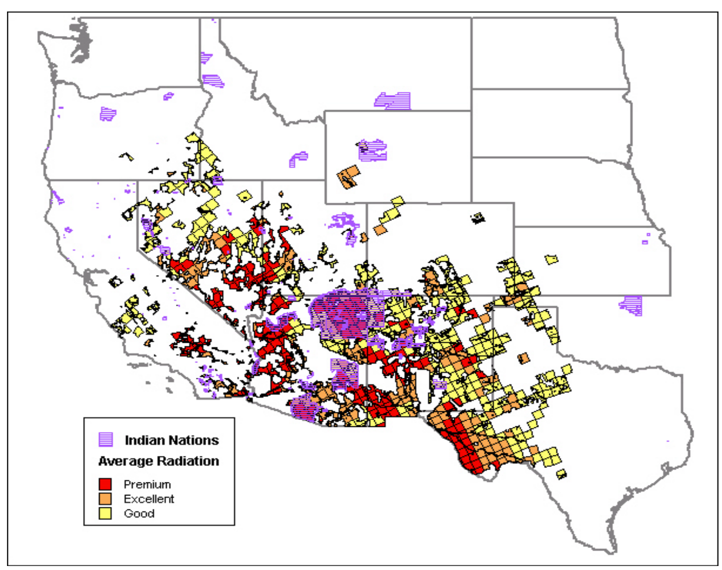
Figure 5



4.2.2 Southwest Solar Generating Potential

Since a typical CSP power plant requires approximately five acres for each megawatt of electrical generation capacity, land availability is a key consideration in project planning. Figure 6 shows available land in the Southwest region with "premium," "excellent," and "good" solar resources that can be utilized by CSP. This representation is different from the map in Figure 5 in that the regions shown in color exclude areas of lesser solar intensity and areas unsuitable for solar power plants (e.g., urban areas, rugged terrain, cropland, national park and national forest service lands, associated buffer areas, and similar non-candidate sites).[16]

Figure 6. SW Solar Potential, Unsuitable Land Excluded



Premium = >7.0 kWh/m^2/day
Excellent = 6.5 – 7.0 kWh/m^2/day
Good = 6.0 – 6.5 kWh/m^2/day

Despite these exclusions, large energy-producing potential remains. CSP plants on about three percent of the available land located within regions of *premium* solar resources could produce over 1,050 billion kWh of electric energy annually, almost equaling the Western States' consumption (1999 annual consumption: 1,100 billion kWh). Given the amount of unused land in the West, especially in desert and semi-desert areas, land availability is not a limiting factor for solar energy development. The map in Figure 6 indicates that portions of the premium resources in the Western

States are located close to major load centers. In addition, the Department of Interior, which manages a significant percentage of the Western lands, is exploring ways of making public land more available for renewable energy projects.

4.2.3 Energy Needs of the Southwest

According to the 2000 Census, the Southwest was the fastest-growing region in the United States during the 1990s. The region's electricity demand reflects this growth and, absent other sources, will largely be satisfied by natural gas and coal. However, according to the Western Governors' Association (WGA), continuation of "business-as-usual" energy practices will have undesirable impacts.[17] Emissions of nitrous oxides and sulfur dioxide have reached problem levels in urban areas, localized districts are threatened by acid rain, and the pristine atmosphere of several national parks has been periodically affected by smog or haze. Some regions have suffered through major wholesale electricity price swings due in part to temporary natural gas shortages. These and other factors (some stemming from transportation applications) motivated the WGA to adopt recommendations to improve air quality and diversify electric generation fuels through expanded use of renewable energy resources.

The Western States have placed increased attention on regional energy resources and have recognized the contributions potentially available from the high levels of Western sunshine. In consideration of these influences, the WGA reacted favorably to exploring further the benefits and costs that might accrue from a major solar initiative.

5. SUMMARY

In its discussions with DOE, the CSP industry has given strong support to a 1,000-MW initiative to assist and accelerate the commercialization of CSP technologies. Industry has indicated confidence in its current products, a commitment to undertake the necessary commercialization actions, a determination to raise the required capital, and a belief that the outcome will be successful. However, DOE observes that achievement of the full 1,000 MW of new installed solar generating capacity within five years depends on many factors, some of which are beyond the control of the CSP industry. Among these factors are implementation of incentives which will require acts of Congress and tax incentives beyond those proposed in the President's FY 2003 Budget, willingness of financial institutions to invest in new energy technologies, availability and price of competing fossil fuels, and speed in obtaining required permits.

Industry proposed a financial incentive package consisting of investment tax credits, production tax credits, investment partnerships, loan guarantees, and tax credit transferability that it believes is necessary for the success of a 1,000-MW initiative. DOE estimates these incentives would cost between $1.5 and $2.0 billion over fourteen years. Industry would be required to raise an additional $1.8 billion to finance the initiative. DOE did not examine scenarios in which the CSP industry is unable to raise the private capital necessary for the initiative.

Industry members maintain that completion of the initiative will position U.S. firms to sell power at competitive prices in peaking and distributed generation markets, both in the U.S. and internationally. DOE's assessment is that CSP costs would be reduced as a result of the initiative. However, there was not time to conduct an in-depth study to verify industry's estimates.

The Southwestern U.S. has a rapidly increasing population, sufficient uncommitted land areas, and excellent solar resources. Its desire for electric power that maintains the clarity of its air and diversifies its use of domestic energy resources, make the Southwest the ideal location for a 1,000-MW initiative. The initiative also supports the National Energy Policy of increasing the supply of environmentally friendly, domestic energy resources.

The NEP also indicates that all of its goals must be achieved at reasonable cost. Policy officials must determine whether the environmental and energy security benefits stated above are worth the $1.5 to $2.0 billion cost to taxpayers. In the preparation of this report, it has not been possible to examine in detail, analyze, and verify all factors bearing on a successful outcome of a 1,000-MW solar initiative. Before Congress acts on the initiative, DOE strongly suggests that Congress confer further with all interested stakeholders to more fully explore the costs and benefits of a 1,000-MW solar initiative.

ENDNOTE

1 Blair Swezey and Lori Bird (2000), *Green Power Marketing in the United States: A Status Report*, Fifth Edition, NREL/TP-620-28738, National Renewable Energy Laboratory, Golden, CO, August 2000.

2 National Renewable Energy Laboratory & Platts-RDI Consulting, *Market Assessment of Large-Scale Concentrating Solar Power Technologies*, July 2002. DRAFT

3 A. D. Little (1999), *Distributed Generation: Understanding the Economics: An Arthur D. Little White Paper*, Boston, MA, 1999.

4 Gilbert Cohen, Duke Solar; Robert Liden, Stirling Energy Systems; Bill Gould, Nexant, Inc., Personal communications, January 2002.

5 International Energy Agency, 2000, "Experience Curves for Energy Technology Policy," OECD/IEA, Paris, France, http://www.iea.org/pubs/studies/files/curve/.

6 Energy Information Administration, 2002, "Annual Energy Outlook 2002." http://www.eia.doe.gov/oiaf/aeo/index.html

7 M. Lotker, *Barriers to Commercialization of Large Scale Solar Electricity: Lessons Learned from the Luz Experience,* SAND91-7014, November 1991.

8 H. Hubbard, et al, *Renewable Power Pathways; A Review of the U.S. Department of Energy's Renewable Energy Programs*, National Research Council, National Academy Press, 2000.

9 J. Tester et al, *CSP Peer Review*, December 7, 2001, http://www.energylan.sandia.gov/sunlab/csppeerreview.htm

10 L. Radosevich, *Final Report on the Power Production Phase of the 10-MWe Solar Thermal Central Receiver Pilot Plant*, SAND87-8022, March 1988.

11 G. J. Kolb and H. E. Reilly, *An Evaluation of Molten-Salt Power Towers Including Results of the Solar Two Project*, SAND2001-3674, November 2001.

12 T. R. Mancini, *UNLV Solar Dish-Engine Demonstration*, SAND2001-2487P, August 2001.

13 P. Teagan, A.D. Little, Personal communication, February 2002.

14 M. Mehos, National Renewable Energy Laboratory, Personal communication. Calculations were done by NREL, February 2002.

15 Secretary Spencer Abraham, speech at National Press Club, Washington, D.C., June 12, 2002.

16 A. Leitner, *Fuel From the Sky: Solar Power's Potential for Western Energy Supply*, prepared for Stirling Energy Systems and the National Renewable Energy Laboratory by Resources Data International, Boulder, CO, November 2001.

17 Western Governors' Association, *WGA Policy Resolution 01-01: Western States' Energy Policy Roadmap*, 8, 2001.