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Solar Thermal Technology Development: Estimated Market Size and Energy Cost Savings

Volume I - Executive Summary

W. R. Gates

February 1983

Prepared for
U.S. Department of Energy
and Sandia National Laboratories, Livermore
Through an Agreement with
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ABSTRACT

Estimated future energy cost savings associated with the development of cost-competitive solar thermal technologies (STT) are discussed. Analysis is restricted to STT in electric applications for 16 high-insolation/high-energy-price states. Three fuel price scenarios and three 1990 STT system costs are considered, reflecting uncertainty over future fuel prices and STT cost projections.

STT R&D is found to be unacceptably risky for private industry in the absence of federal support. Energy cost savings were projected to range from $0 to $10 billion (1990 values in 1981 dollars), depending on the system cost and fuel price scenario. Normal R&D investment risks are accentuated because the Organization of Petroleum Exporting Countries (OPEC) cartel can artifically manipulate oil prices and undercut growth of alternative energy sources. Federal participation in STT R&D to help capture the potential benefits of developing cost-competitive STT was found to be in the national interest.

Analysis is also provided regarding two federal incentives currently in use: the Federal Business Energy Tax Credit and direct R&D funding. These mechanisms can be expected to provide the required incentives to establish a viable self-sustaining private STT industry. Discussions of STT impacts on the environment and oil imports are also included.

FOREWORD

The Jet Propulsion Laboratory's (JPL's) Benefits Assessment Task has responsibility for evaluating the benefits and impacts associated with the successful development of cost-competitive solar thermal energy technologies. During 1981, the JPL Benefits Assessment Task focused on developing a methodology to assess the potential economic and social benefits associated with solar thermal electric systems. During 1982, efforts centered on refining the benefit assessment methodology. The computer model was modified to allow reoptimization of the conventional generating capacity with increases in the level of solar penetration, the data base was updated to include revised regional synthetic utilities, and the analytical assumptions were updated to reflect changes in tax laws and other factors.

The results of the FY 1981 analysis were reported in JPL Publication 82-70, "Solar Thermal Technologies Benefits Assessment: Objectives, Methodologies, and Results for 1981". The results contained in the 1981 report were updated in FY 1982 and are superseded by the results presented here.

This report is divided into two separate volumes. Volume I is an Executive Summary and Volume II contains the detailed assumptions, methodology, results, and discussion of the study.

ACKNOWLEDGMENTS

The work described in this report was performed during FY 1982 by the Benefits Assessment Task of the Solar Thermal Planning and Information Project at the Jet Propulsion Laboratory, California Institute of Technology. It was sponsored by the Solar Thermal Technical Program Integrator at Sandia National Laboratories, Livermore (SNLL), for U.S. Department of Energy's Solar Thermal Technology Division through an agreement with the National Aeronautics and Space Administration. (Task RE-152, Amendment 354; Sandia Order 92-9714.)

This analysis involved the collaborative efforts of many individuals at JPL and SNLL. Katsuaki Terasawa established the basis for the methodology and provided insights in interpreting the results. Hamid Habib-agahi assisted in formulating the approach, conducting the analytical work, and interpreting the results. Michael Davisson developed the computer program used in the utility simulations and provided the data required to conduct the simulations. Michael Guth assisted with the utility simulations and examined the impact of solar thermal electric systems on U.S. oil imports. Robert Gershman conducted the regional environmental analysis. E.S. (Ab) Davis, Richard O'Toole, and Julia Sheldon of JPL and Patrick Eicker and Joan Woodard of SNLL provided feedback during the effort which improved the quality and clarity of the results. Susan Elrod typed the many drafts of this report and drew the figures supplementing the text. Catherine Edwards edited and prepared the text for publication. Any remaining errors, omissions, misrepresentations, or misinterpretations are the responsibility of the author.

CONTENTS

EXECUTIVE SUMMARY

A. OVERVIEW

The U.S. Department of Energy's (DOE's) Solar Thermal Technology (STT) Program is developing four concentrating solar thermal technologies (i.e., central receivers, parabolic dishes, parabolic troughs, and hemispherical bowls) and one non-concentrating technology (i.e., solar ponds). The thermal ouput of these systems can be used for generating electricity, providing industrial process heat (IPH), cogeneration, or producing fuels and chemicals. Numerous combinations of technologies and applications resulting in a broad range of potential impacts and benefits are possible if solar thermal technologies can be developed successfully into cost-competitive products. Quantifying the relationship between the developmental risks and potential benefits is essential to determining the future federal role in solar thermal R&D and in formulating an R&D strategy which maximizes the benefits accruing from the DOE Solar Thermal Technology Program.

Previous studies which estimated the potential economic and social benefits of solar thermal technologies have not attempted to quantify the correlation between the success of the R&D program and the expected market size. The methodology employed in this study accounts for both the risks inherent in the R&D program and the uncertainties of the future energy market in calculating the size of the markets for solar thermal technology.

The assessment was restricted to solar thermal electric applications for central receivers and parabolic dishes without storage. The analysis was further limited to the southwest and southcentral regions of the U.S. during the 1990s. The model was designed to quantify two primary variables associated with achieving the STT Program's 1990 cost goals: (1) potential economic market size for STT and (2) energy cost savings. Using the results of these calculations, the implications of STT for various areas (including the environment, fuel price uncertainity, OPEC influence, oil import impacts, public versus private benefits, and the Federal role) were analyzed and discussed.

Although not specifically analyzed in this study, the results of the model could have also been used to examine the impact of STT on issues such as employment opportunities, tax revenue effects, export market potential, and technology base expansion. Figure 1 summarizes the components of the benefits assessment study.

B. METHODOLOGY

A methodology was devised to estimate the expected demand for solar thermal technology (i.e., the economic market potential) and calculate the corresponding net savings in energy costs. The methodology uses a utility simulation model to compute the type and quantity of fuel, conventional generating capacity, and operations and maintenance (O&M) expenses displaced by STT systems of different capacities. Together, these measures determine the total value of solar thermal systems to electric utility owners. Purchase

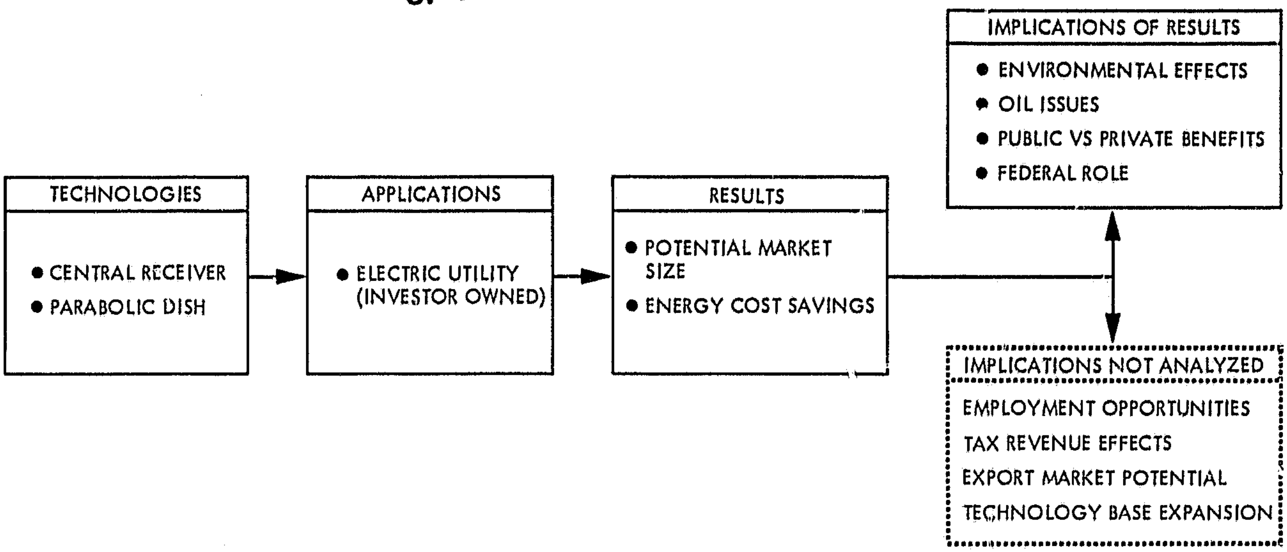

Figure 1. Elements of the Benefits Assessment Study

decisions, however, are based on changes in the total value of STT to utilities as STT capacity increases. Changes in the total value, referred to as incremental values, indicate the economic benefits attributable to expanding STT capacity. As long as the incremental value of STT exceeds its cost, utilities will purchase additional solar thermal capacity.

The incremental value of STT is calculated by determining the change in total value between successive STT capacity levels and normalizing by the change in system capacity. The utility simulation model is used to estimate incremental STT values to the electric utility owners (STT demand side), given: descriptions of the utility's generating capacity and load patterns, scenarios for future energy costs, cost-induced changes in generating capacity and load patterns over time, insolation levels, and the financial parameters related to the utility's investment decision criteria. Using three estimates for STT production costs (representing the STT supply side), the economic market size and corresponding net energy cost savings were estimated for solar thermal electric systems installed in 1990. The methodology described here was applied making the assumptions which are summarized in Table 1.

C. RESULTS

If STT system cost reductions are secured, solar thermal electric systems are expected to begin competing in coal-dominated grid-connected electric utilities in the mid-1990s. The economic market potential will increase as STT system costs (without storage) reach the range of $1750/kWe to $1200/kWe (the 1990 and 2000 cost targets, respectively, in 1981 dollars). The net energy cost savings associated with the various scenarios range from $0 to $10 billion.

Figure 2 illustrates that the size of the market for solar thermal systems strongly depends on achieving the solar thermal cost targets and is

Table 1. Summary of Assumptions Used in Analysis

	Assumption	Comments
(1)	Parabolic dish and central receiver STT systems	--
(2)	No storage	Forces STT to compete with coal.
(3)	Investor-owned utility	Uses less attractive financing than that available to municipal utilities and rural electric cooperatives or third-party owners.
(4)	Aggressive transition to coal	Utilities assumed to be installing coal plants in preference to oil/nuclear plants, except where environmentally constrained. Thus, STT must compete with the lower-priced coal facilities in the future.
(5)	Southwest and southcentral/southeastern regions only	Average characteristics of utilities in these two regions were used.
(6)	1990 installation	Calculation is simplified by assuming all STT plants installed in the early 1990s are installed in a single year, 1990. Overstates actual 1990 installations, but ignores post-1990 increases in demand.
(7)	Electric Power Research Institute (EPRI) utility data	Gives lower conventional generating cost estimates than other sources; captures expected improvements in conventional technology, predominantly early morning and early evening peak demands.
(8)	SOLMET insolation data	Three levels: high (Albuquerque, NM), medium (Fresno, CA), and low (Fort Worth, TX).
(9)	1981 dollars	--
(10)	National Energy Plan (NEP III) fuel prices	Source: Energy Information Administration's 1980 Annual Report to Congress.
(11)	Electricity demand escalation rate	3%/year.
(12)	No intertechnology competition for alternative energy sources	May overstate the potential market share captured by STT.
(13)	Supply side cost = 1990's cost goal ±25% (i.e., 2200, 1750, and 1300 $/kWe)	Provides three STT production cost scenarios based on varying degrees of R&D success by 1990.

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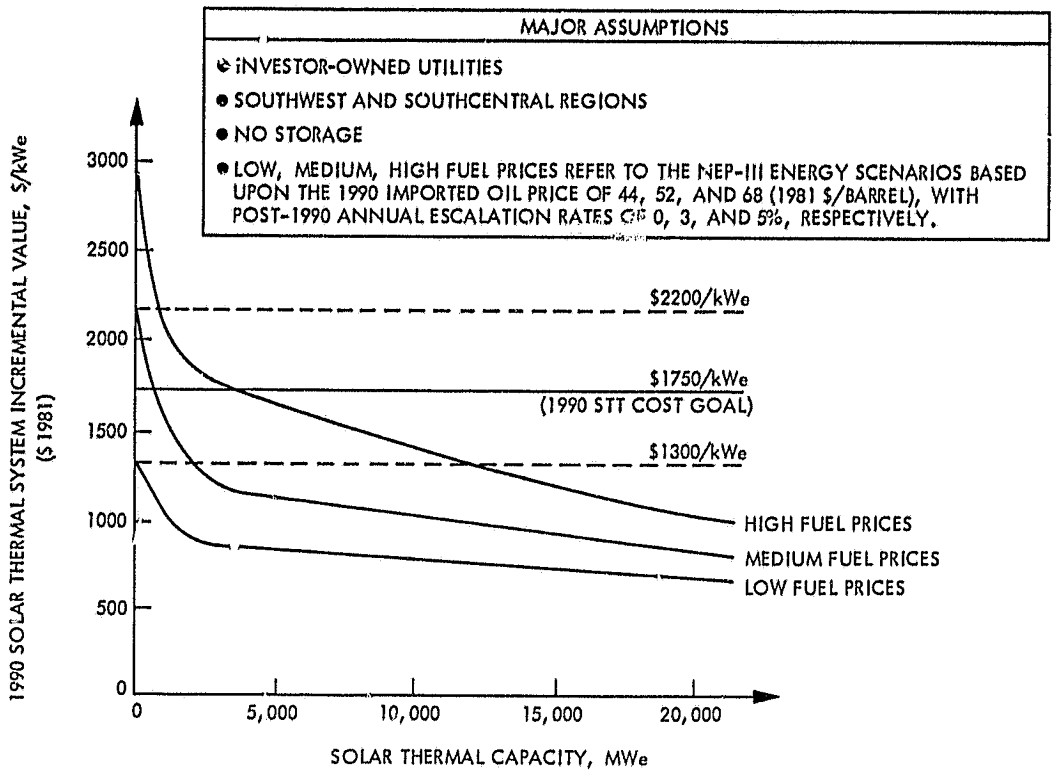

Figure 2. 1990 Market Potential for Cost-Competive Solar Thermal Electric Systems Under Three Fuel Price Scenarios

sensitive to future fuel prices. The incremental value of solar thermal systems to utilities is highest initially because the systems are competing with the highest-priced utility installations (primarily oil- and gas-fired) in the areas of best insolation. Values decrease rapidly as the total amount of solar thermal capacity installed increases because solar thermal energy must displace lower-priced utility installations (primarily coal-fired) in areas with less desirable insolation levels. Thus, the results duplicated in Figure 2 indicate that the 1990s market potential for solar thermal technologies is limited except under optimistic assumptions regarding future fuel prices and system costs.

The high percentage of coal-fired capacity and the poor correspondence between peak insolation and peak electricity demand for the utilities used in the simulation create a situation which is relatively unfavorable for solar thermal electric systems without storage. These assumptions force new solar thermal installations to compete primarily with coal-fired generating capacity once the potential for displacing oil-fired capacity is exhausted by earlier solar thermal installations. This condition is summarized in Figure 3 which shows the amount of coal as a percentage of total fuel displaced by solar thermal energy as solar thermal capacity increases for each fuel price scenario. However, despite the high percentage of coal that solar thermal energy must displace, solar thermal systems can be competitive on a limited basis even without storage in utilities which exhibit these characteristics.

Table 2 summarizes the net energy cost savings for three oil price scenarios and three levels of STT cost. If high fuel prices prevail and a

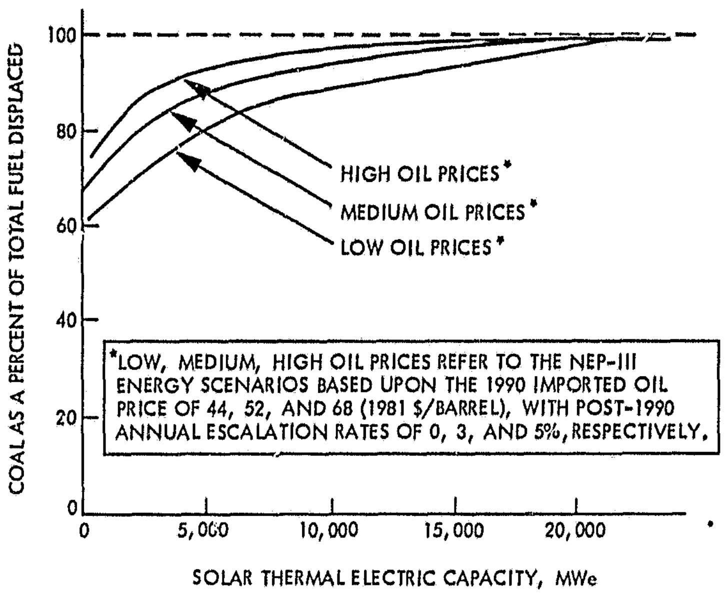

Figure 3. 1990 Solar Thermal Electric Capacity and Life-Cycle Coal Displacement

Table 2. Total Net Energy Cost Savings of Solar Thermal Electric Systems

	3 Scenarios for STT Total Net Energy Cost Savings* (1990 Values in Billions of 1981 Dollars)		
STT System Costs**	Low	Medium	High***
$2200/kWe	0	0	1
$1750/kWe	0	****	3
$1300/kWe	****	2	10

*Low, Medium, High refer to the NEP-III energy scenarios based upon the 1990 imported oil price of 44, 52, and 68 (1981 $/barrel), and post-1990 annual escalation rates of 0, 3, and 5 percent, respectively.

**Low, Medium, High system costs reflect varying production volumes and levels of R&D success.

***Assumes 1990 conventional generating capacity incorporates technology improvements available by 1990. However, unexcepted future technology innovations may occur which displace the higher-priced fuels, potentially reducing the net energy cost savings projected for STT.

****Positive values which become zero after rounding to nearest billion.

system cost of $1300/kWe is achieved, STT has the potential to save $10 billion (1990 values expressed in 1981 dollars). If the 1990 cost goal of $1750/kWe is met, the expected savings will be $3 billion. Even at the high system cost target of $2200/kWe, an estimated $1 billion will be saved. On the other hand, if the low fuel prices prevail, savings will be negligible even if a system cost of $1300/kWe can be achieved. The potential payoff to the private investor or entreprenuer is clearly very uncertain.

The values reported in Table 2 and Figure 2 are 1990 values (in 1981 dollars). If the reader wishes to compare the benefits estimated in this study with the cost of R&D, further analysis is required. First, the 1990 values reported here must be discounted to a base year (use of the Office of Management and Budget's suggested minimum real discount rate of 7% is recommended). Second, the associated annual R&D expenses must also be discounted to the same year.

D. DISCUSSION OF ADDITIONAL IMPACTS

Development of STT would also have an impact on other factors such as the environment and the level of oil imports. Fuel displacement data from the utility simulation can be used to approximate the significance of these inputs.

Environment. Environmentally, STT provides important benefits by reducing the use of fossil fuels in electrical power generation. Reducing the use of fossil-fired fuels will alleviate air pollution emissions (including SO_x, NO_x, CO_2 build-up). Compared to the quantity of fossil fuels consumed nationally in the electric utility, transportation, industrial, commercial, and residential sectors, the potential STT fuel displacement is relatively insignificant. Correspondingly, the impact of STT on the national air pollution problem will also be limited.

Regionally, however, the environmental impact of STT can be significant. Electric power plants account for a substantial percent of the pollutants in many regional air basins. STT penetration in these air basins would reduce the capital expenditures associated with emission control technology, which could increase the value of STT by as much as $150/kWe. At $1750/kWe, this represents almost 10 percent of the initial system cost.

STT would also eliminate power plant emissions that were not controlled by emissions standards. These additional reductions in air pollution provide health benefits and reduce crop damage. Alternately, STT installations may provide salable pollution offsets. Industrial growth is frequently constrained in air basins where pollution exceeds federal standards. The creation of salable offsets through STT installations would provide the opportunity for further industrial growth at the regional level.

Oil Import Impacts. The short-run impact of STT on oil imports will be limited. Fuel displacement data from utility simulation indicates that STT without storage displaces primarily residual oil. In the southwest and southcentral regions where insolation levels are favorable, there is a residual oil glut. On the east coast where insolation levels are less favorable, residual oil consumption exceeds the supply from domestic crude. However, short-run substitution between residual oil and other oil types for electricity generation and refining is limited. Furthermore, using the excess supply of southcentral and southwestern residual oil to satisfy the demand on the east coast would require that the oil be both transported and further refined to lower the sulfur content. High costs make this reallocation economically prohibitive, thus limiting the short-run impact of STT on oil imports.

However, long-run impacts of STT on oil imports can be significant. In the long-run, refinery and utility generating capacity will change in response to the glut of residual oil. Substitution will occur both between types of oil and between oil and other fuels. Alternative uses will be found for residual oil, some of which may reduce the demand for other types of oil. Since imported crude is the highest cost source of oil in the U.S., these changes should reduce oil imports. In this case, STT would reduce oil imports thus increasing national security and improving the U.S. balance of payments.

E. IMPLICATIONS FOR PRIVATE SECTOR INVESTMENT

The pattern of values estimated in Table 2 illustrates that the potential energy savings from STT are very sensitive to future fuel prices and STT system costs. The R&D risks associated with reducing system costs and developing production capabilities for solar thermal technologies are similar to those faced by any new industry. However, the recent fluctuations in energy price projections have introduced significant additional uncertainty into the investment decision.

Fuel Price Uncertainty. Projections of future fuel prices have varied widely over time. Since oil is the marginal energy resource, world oil prices have a large impact on all fuel prices. Since the summer of 1979 to early 1982, oil price projections have changed from low to high and back to low again. These wide fluctuations in oil price forecasts increase the risks associated with investments in STT R&D and production facilities.

OPEC Control. Fuel price uncertainty is accentuated by the influence of the OPEC cartel. The OPEC nations possess a significant percentage of the lowest cost oil resources. As a result, world oil prices are influenced by the price-setting policies of OPEC, and OPEC's influence is expected to continue in the future. If solar thermal technologies (or other alternative energy resources) threaten to displace substantial quantities of imported oil, OPEC has the ability to lower oil prices and undercut the price of developing technologies. In other words, there may be a correlation between oil prices and the success of R&D in alternative energy resources.

F. RECOMMENDATIONS FOR FEDERAL PARTICIPATION

After examing the benefits, impacts and risks of developing cost-competitive solar thermal systems, Federal participation was found to be in the national interest. The rationale for this conclusion and two of the current policy tools for implementing this role are briefly discussed below.

Public versus Private Benefits. Public objectives differ from those of a private, profit-making firm. Public objectives include minimizing the impact of OPEC's control over fuel prices, and limiting the negative environmental consequences of oil, coal, and nuclear facilities. These impacts are indirect impacts when they are not directly reflected in the market price of STT. Since private industry is unable to capture the benefits of these indirect impacts, the private sector will underinvest in STT if the indirect benefits are significant. Further, industry is unlikely to fund the necessary R&D if OPEC's influence over oil prices continues to add additional investment risk.

Federal Roles. Federal participation in the development of solar thermal technologies is required to offset the uncertainty in oil prices introduced by OPEC and to capture the significant indirect as well as direct economic and social benefits associated with solar thermal development. In addition to realizing the energy cost savings presented in Table 2, expenditures on solar thermal R&D would limit the disruptive impact of future increases in the world oil prices, improve the balance of payments and strengthen national security by reducing oil imports, and lessen the environmental deterioration resulting from oil, coal, and nuclear facilities. The Federal government can pursue a variety of policy options to provide incentives to establishing a cost-competitive solar thermal industry. Among the possible alternatives, two Federal incentives currently being used to reduce system costs are (1) tax incentives to encourage STT installations and (2) direct R&D funding. While a variety of other Federal incentives can have similar effects, attention in this discussion has been restricted to the energy tax credits and direct R&D funding.

Tax incentives, including accelerated depreciation, the Federal Business Energy Tax Credit, and other energy tax credits (at both state and federal levels), will encourage third party investors to provide early STT markets. These early markets will provide operating experience which will help refine R&D efforts and stimulate investment in STT production facilities. If the federal and state tax incentives are extended to the end of the 1980s, early solar thermal electric systems in the range of $3000/kWe (1981 dollars) financed by third party investors can penetrate coal-dominated utilities in all but the low oil price scenario.

Complementing the tax incentive, direct R&D funding will assist in establishing solar thermal technologies capable of meeting both the 1990s and 2000 cost goals for solar thermal electric systems without storage ($1750/kWe and $1200 kWe, respectively, in 1981 dollars). Achieving these system costs during the late 1990s would lead to a self-sustaining private STT industry capable of competing in an environment characterized by coal-dominated utilities.