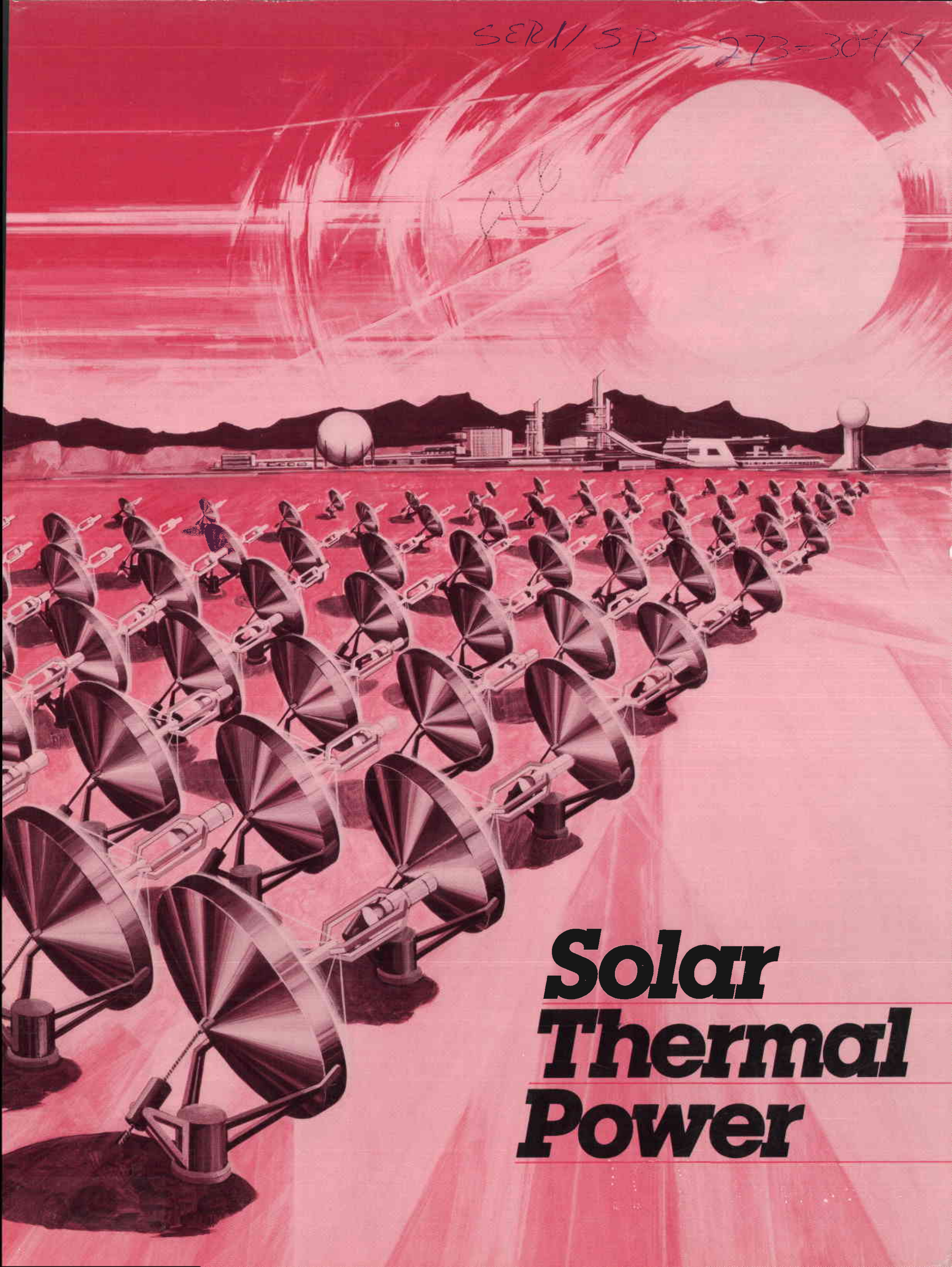

Solar Thermal Power

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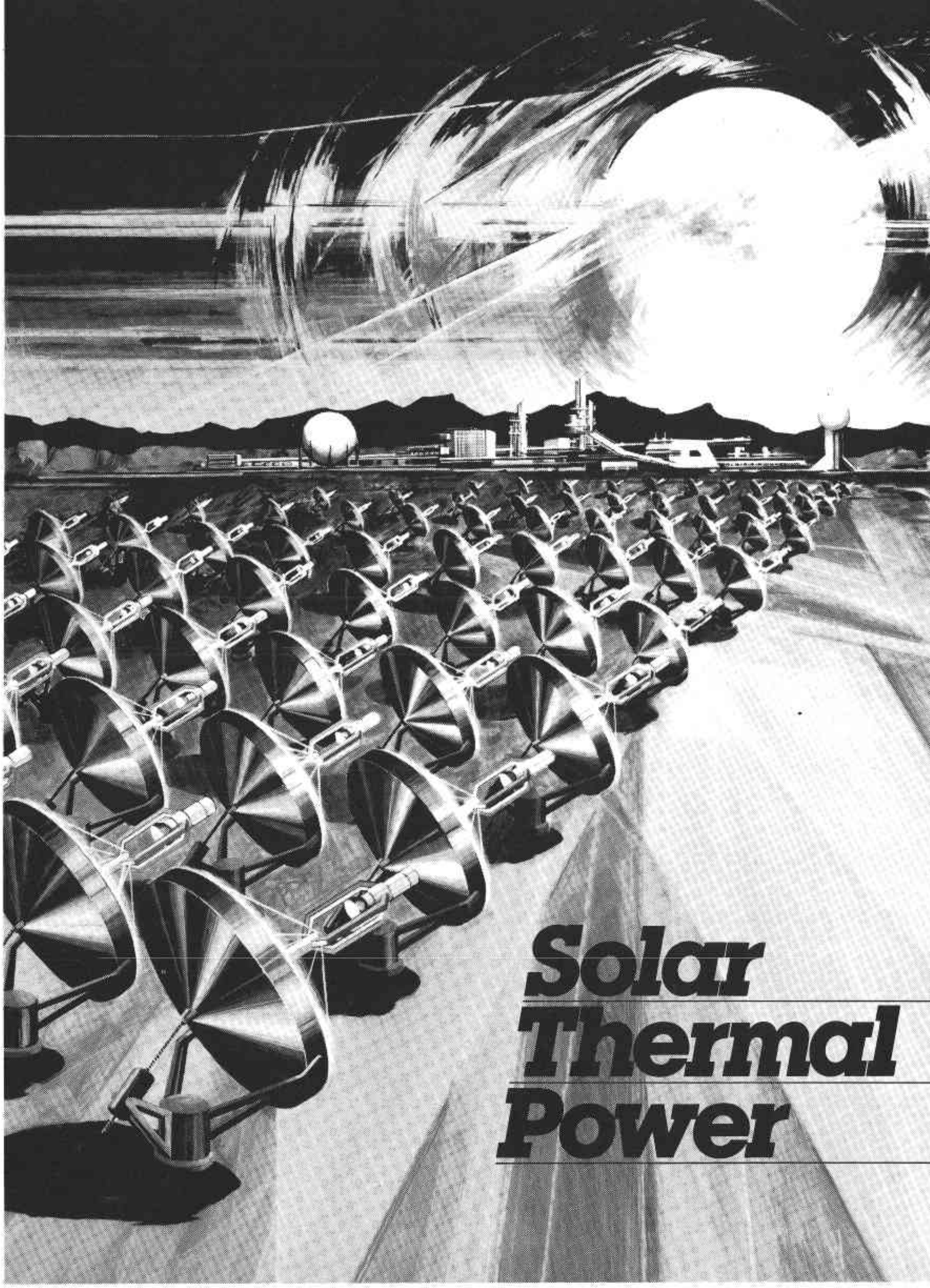

Solar Thermal Power

A Product of the
Solar Technical Information Program

Solar Energy Research Institute
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Preface

The research and development (R&D) described in this document was conducted within the U.S. Department of Energy's (DOE) Solar Thermal Technology Program. The goal of the Solar Thermal Technology Program is to advance the engineering and scientific understanding of solar thermal technology and to establish the technology base from which private industry can develop solar thermal power production options for introduction into the competitive energy market.

Solar thermal technology uses tracking mirrors or lenses to concentrate solar flux onto a receiver where the solar energy is absorbed as heat and converted into electricity or incorporated into products as process heat. The two primary solar thermal technologies, central receivers and distributed receivers, employ various point- and line-focus optics to concentrate sunlight. Current central receiver systems use fields of heliostats (two-axis tracking mirrors) to focus the sun's radiant energy onto a single tower-mounted receiver. Parabolic dishes track the sun on two axes and use mirrors or Fresnel lenses to focus radiant energy onto a receiver. Troughs and bowls are line-focus tracking reflectors that concentrate sunlight onto receiver tubes along their focal lines. Concentrating collector modules can be used alone or in a multi-module system. The concentrated radiant energy absorbed by the solar thermal receiver is transported to the conversion process by a circulating working fluid. Receiver temperatures range from 212°F in low-temperature troughs to over 2700°F in dish and central receiver systems.

The Solar Thermal Technology Program is directing efforts to advance and improve each system concept through the research and development of solar thermal materials, components, and subsystems, and the testing and performance evaluations of subsystems and systems. These efforts are carried out through the technical direction of DOE and its network of national laboratories who work with private industry. Together they have established a comprehensive, goal-directed program to improve performance and provide technically proven options for eventual incorporation into the nation's energy supply.

To be successful in contributing to an adequate national energy supply at reasonable cost, solar thermal energy must eventually be economically competitive with a variety of other energy sources. Components and system-level performance targets have been developed as quantitative program goals. The performance targets are used in planning research and development activities, measuring progress, assessing alternative technology options, and making optimal component developments. These targets will be pursued vigorously to ensure a successful program.

This document discusses experimental solar thermal systems and their effectiveness in generating electricity and producing heat for industrial applications. In addition, this publication describes the progress made in developing solar thermal power plants and suggests the potential of renewable alternatives to conventional technology.

Acknowledgements

This document was prepared under the guidance of the Solar Thermal Technology Division, Office of Heat Technology, U.S. Department of Energy, and was coordinated and published by the Solar Energy Research Institute for the U.S. Department of Energy. SERI wishes to express appreciation to Dan Halacy for his assistance in writing this document and to the Solar Energy Industries Association for their review and helpful suggestions.

Contents

Introduction

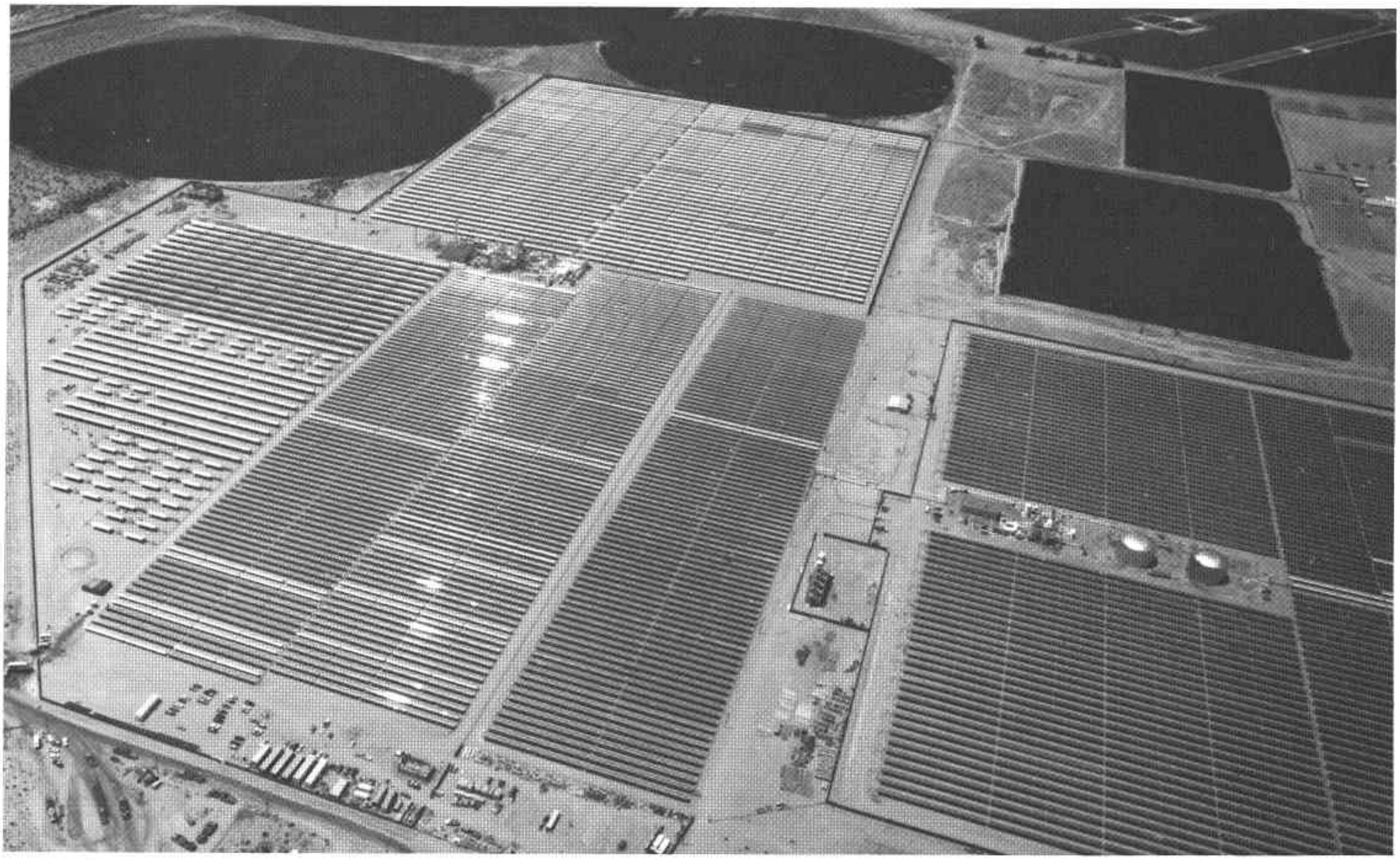
The world runs on energy, and most recently that energy has been in the form of oil, coal, and natural gas. These conventional resources are finite, of course, and cannot be counted on forever. Long-term energy sufficiency for the United States — and the world as well — requires the development of a renewable energy resource to supplement dwindling fossil fuels. Renewable energy from the sun — an almost limitless supply — can be counted on as far into the future as needed. Because it can extend the useful life of our scarce resources, a world that once hailed the discovery of oil as revolutionary is beginning to recognize the great importance of solar energy.

Many people traveling through Southern California, or flying over it, are impressed to see huge solar thermal power plants covering acres of desert with gleaming collectors and the generating equipment that feeds electricity into utility grids. Such plants near the town of Barstow now produce more than 55 megawatts of electric power. Farther south, at Warner Springs, California, a smaller solar plant generates about 4 megawatts of electric power. And while most of us

Solar One — A 10 MW_e Central Receiver Plant Near Barstow, California are just becoming aware of them, these solar electric power plants are already serving the everyday needs of thousands of people.

Experimental and commercial solar thermal systems are now demonstrating their effectiveness in important applications ranging from the generation of electric power to the production of heat used in industry for many purposes. This report describes the remarkable progress already made with these solar thermal plants, and suggests the potential of the solar thermal renewable-energy alternative.

SOLARPLANT 1 at Warner Springs, California



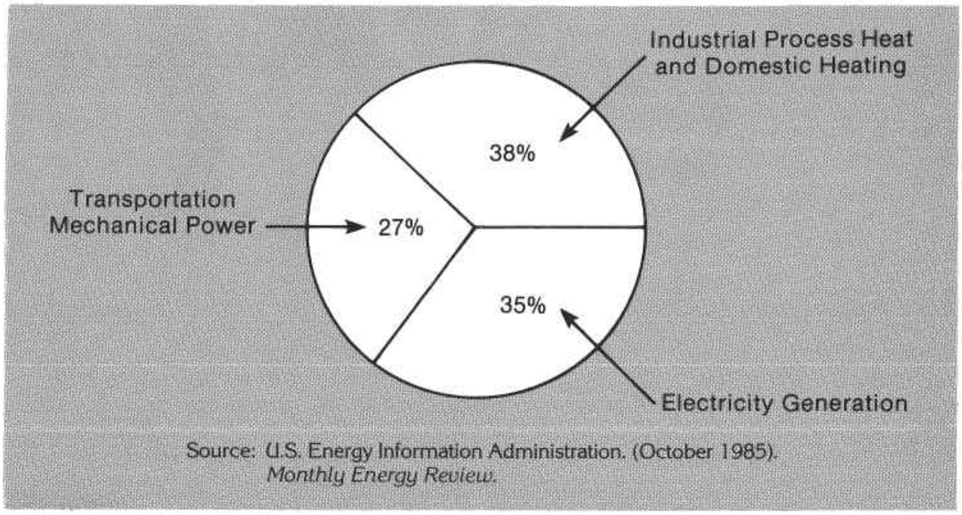
Parabolic Troughs Operating in Southern California Edison's SEGS 1 Near Barstow, California

Our Need for Solar Energy

Energy has become a key ingredient in American life: It powers the farm machinery, runs the mills, keeps our transportation system moving, and keeps our homes warm in the winter and cool in the summer. Not surprisingly, studies by social scientists at the Electric Power Research Institute and Midwest Research Institute show a strong correlation between energy consumption and the quality of life.*

The last century has seen a tremendous increase in energy consumption. Instead of the 40 million Americans a century ago, we now number about 240 million. And instead of the daily 6 kilowatt-hours of energy equivalent that each of our forefathers used, we each use about 250 kilowatt-hours per day. As a result, our national energy use is hundreds of times what it once was.

With only 6% of the world's population, the United States uses about 30% of the world's purchased energy. To bring everyone to the United States' standard of living would require about six times as much energy as the world uses now. Solar energy offers an abundant nonpolluting energy source that can help people raise their standard of living.



How We Use Energy in the United States

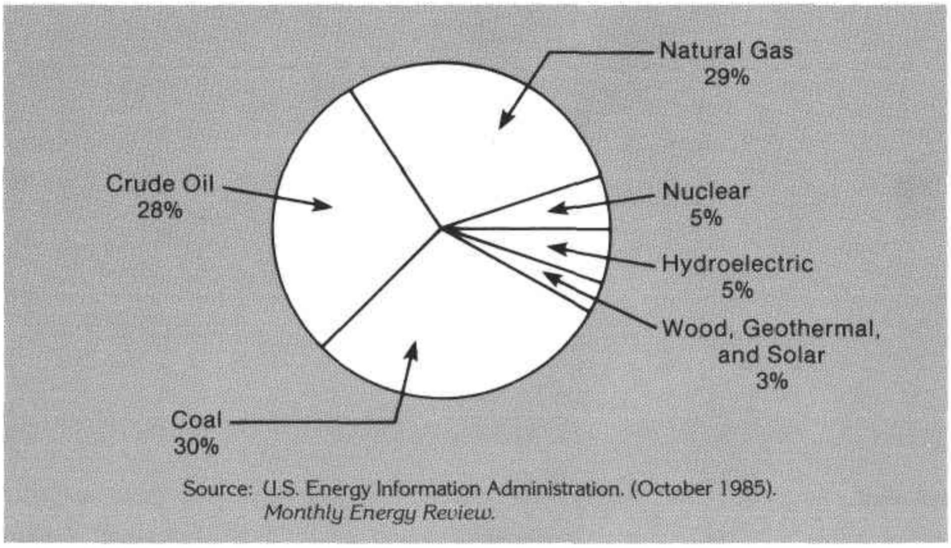
How Much Energy We Use

Burn one kitchen match and you produce about one British thermal unit (Btu) of heat energy. One quadrillion (10^{15}) Btu, conveniently called a "quad," is equivalent to 170 million barrels of oil, 45 million tons of coal, or 1 trillion cubic feet of natural gas. In 1984, the United States used a total of about 74 quads of energy. This was a 4.5% increase over 1983, an indication that our energy consumption is rising again after the brief decline in response to oil shortages during the 1970s.

And How We Use It

In the United States, industry uses about 28 quads of the 74-quad total. Residential and commercial use — including heating and cooling, lighting, entertainment, and communications — is a close second at about 26 quads. The remaining 20 quads powers our air and surface transportation systems. In other words, about 35% of our energy is used to produce electricity, 38% provides industrial process heat and domestic heating, and the remaining 27% furnishes transportation and the mechanical power for stationary engines.

* Electric Power Research Institute, (April 1980). "Quality of Life: An International Comparison." *EPRI Journal,* Vol. 5, No. 3, pp. 26-31.



U.S. Energy Sources (1984)

How Long Will Conventional Energy Sources Last?

In rough numbers, coal now provides 30% of our domestic energy production; natural gas 29%; oil 28%; nuclear power and hydropower 5% each; and wood, geothermal energy, and solar energy a total of 3%. In 1984 we had to import an additional 13 quads of energy, mostly oil, to take care of our needs.

Estimates of the proven world oil reserves by the U.S. Geological Survey* and Chevron Corporation† indicate that these reserves will last for about 35 to 60 years. However, the U.S. oil production to proven reserve ratio indicates that, if all foreign oil were cut off, our domestic reserves would last us only about 8 to 10 years‡ — unless supplemented with other energy-producing resources. Proven reserves of natural gas in the free world amount to about a 55-year supply.† We have enough coal in the United States for several centuries at present rates of consumption, but environmental problems including CO_2 and acid rain restrict its use and make it more costly. Furthermore, coal is utilized to make a number of needed products, including chemicals and pharmaceuticals.

Solar energy falling on the 48 continental United States each year is 44,000 quads — more than 500 times as much energy as we use. Our planet is warmed to a comfortable global temperature of 59°F by the sun. It provides all fresh water and food and fiber, and lights the world during the day.

The Renewable Energy Options

About 8% of our energy comes from indirect solar energy in the form of hydropower, wood, and other natural fuels. Besides solar thermal heat and electric power, other renewable options being researched include geothermal energy, biomass, windmills, and photovoltaics. Solar thermal technology, the subject of this report, is a versatile form of renewable energy. It can be stored conveniently and released during peak usage periods. In addition to heat for the production of electricity, residential use, and industrial processes, solar thermal energy has the potential to provide high value transportable fuels and chemicals including hydrogen and fertilizers.

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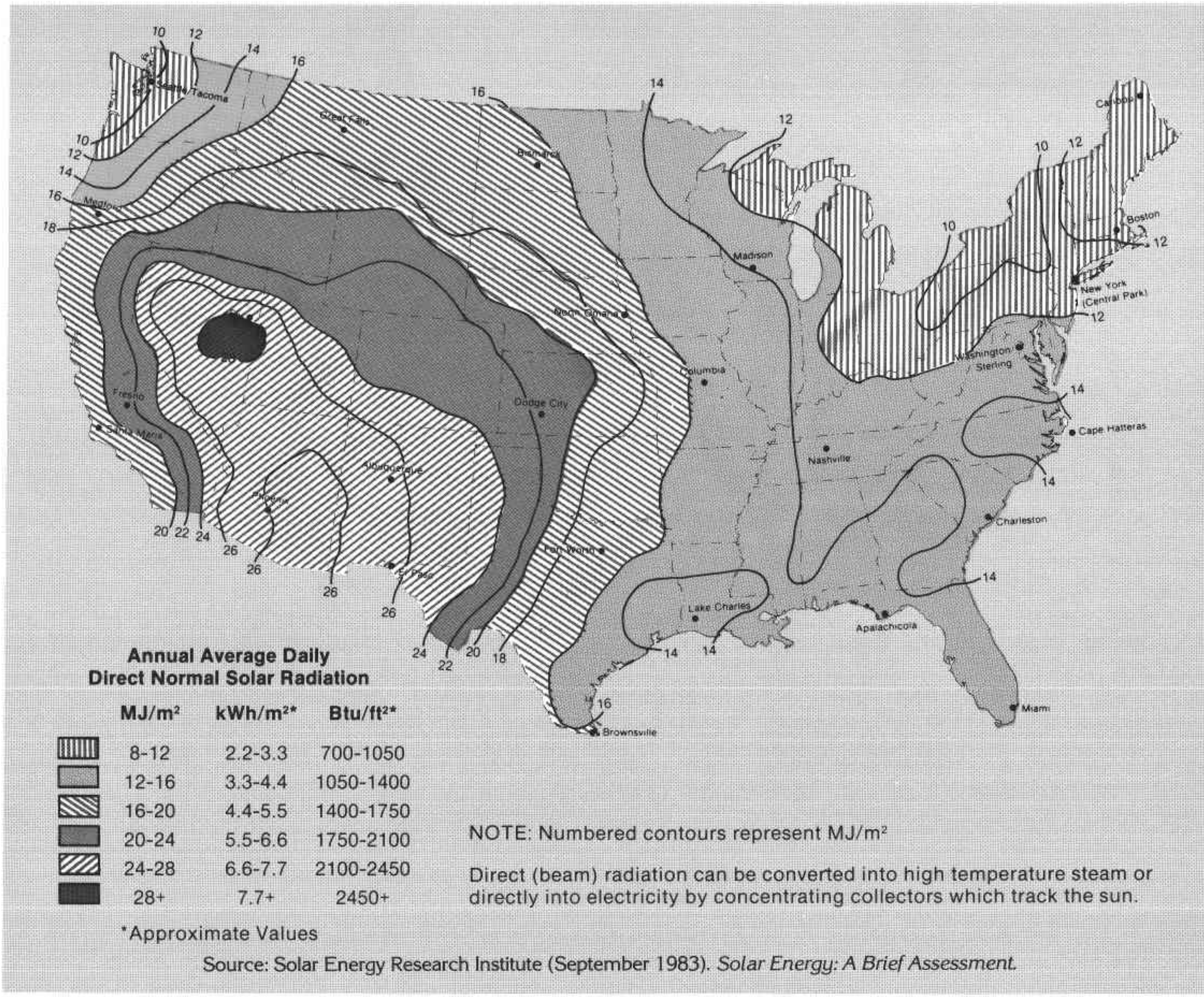
* U.S. Geological Survey. (1985). *World Petroleum Resource — A Prospective, Open File Report 85-248.*

† Chevron Corporation. (June 1985). *World Energy Outlook.*

‡ Energy Information Administration. (1984). *U.S. Crude Oil, Natural Gas, and Natural Gas Liquids Reserves, 1984 Annual Report,* DOE/EIA-0216.



Where the Sun Shines

The Basics of Solar Thermal Power

The sun is actually a colossal nuclear fusion power plant 93 million miles from Earth. In less than 40 minutes, the United States receives more energy in the form of sunlight than from all the fossil fuels that we burn in a year. This is the largest energy resource we have. Non-concentrated solar energy has been used effectively for millions of years to produce light and heat, and grow our food. Now we are exploring the use of concentrated sunlight for other applications, such as producing electricity and industrial process heat.

Solar Basics

One acre of land in direct sunlight intercepts the equivalent of about 3,500 kilowatts of energy. This is enough energy to supply the electrical need of over 1,000 homes. Not all regions of the United States are equal with respect to solar energy received due to a variety of factors such as cloud cover and air pollution. The direct and diffuse rays of the sun are suitable for solar collectors to heat a home or supply its hot water needs, but are not nearly strong enough for efficient power generation, which requires concentrating a large amount of solar energy into a small area. Since solar thermal plants use this concentrating approach, only the direct component of the sunlight is used, and hence, the plants must be sited in areas of high direct insolation or solar radiation. The objective of a solar thermal plant is to collect as much solar energy as possible and deliver it to where it can be used. The map shows the regions of the United States that receive most solar direct radiation, and suggests why the first large solar thermal electric power plants were built in the Southwest.

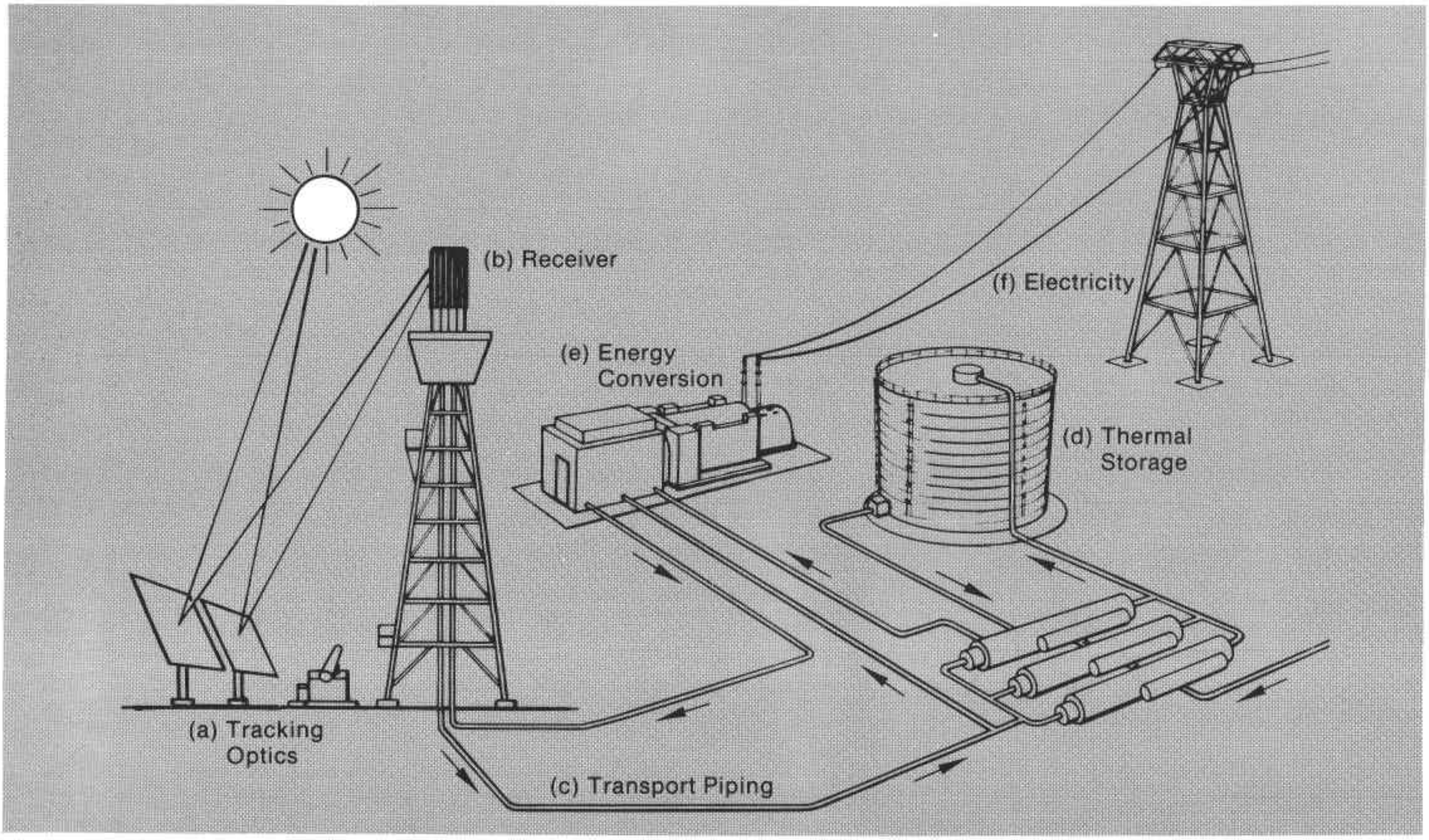
The reflecting mirror and burning glass (magnifying lens) principles of focusing the sun's rays make it possible to achieve temperatures approaching that of the sun's surface. In ancient Greece, Archimedes is said to have used a large number of soldiers' shields as reflectors to ignite the sails of attacking Roman ships. About two centuries ago, French scientist Antoine Lavoisier came close to melting platinum in a two-lens solar furnace. Lenses work because of the refraction, or bending of light rays. Today's advanced solar concentrator technology similarly bends or reflects light rays to produce very high temperatures in a very small target area.

Solar Thermal Systems

A solar thermal plant converts solar energy to useful energy with four basic subsystems:

- Concentrator
- Receiver
- Transport/Storage
- Conversion/Delivery

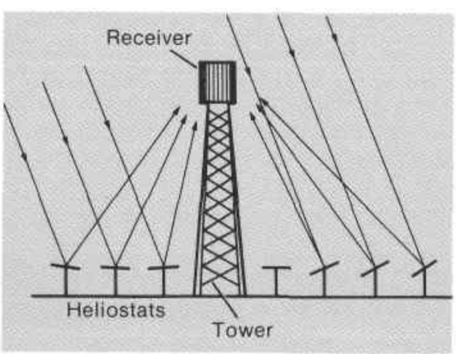
As shown in the drawing, the solar concentrators focus large amounts of solar energy onto the receiver, which heats a fluid used to provide heat for industrial applications or to generate electric power. This fluid sometimes must be transported through a piping system, or even stored for later use. At the point of use, heat is converted to electric power and delivered to the grid — or used to produce steam, hot water, or hot gases for industrial applications. Different types of solar thermal energy systems organize the basic subsystems differently to serve their respective requirements.



Solar Thermal System. Solar thermal systems convert the sun's radiation to useful products (such as electricity, fuels, or direct heat) via a thermal process. The basic elements of any solar thermal design are (a) the tracking optics used to concentrate the sun's energy, (b) the receiver, which transfers the sun's energy to a fluid, (c) piping to transfer the hot fluid to (d) storage for later use or directly to (e) the conversion device, which converts the heat in the fluid to a usable form such as (f) electricity or process heat.

Central receiver systems are sun-tracking mirrors called heliostats to reflect solar energy to a receiver *atop* a tower and heat a fluid circulating through the receiver. The principal advantage of central receiver systems is their ability to efficiently deliver energy at very high temperatures. A heat-transfer fluid, which could be steam, molten salt or sodium at temperatures of from 1000°F to 2700°F, can be used to drive a turbine to produce electric power.

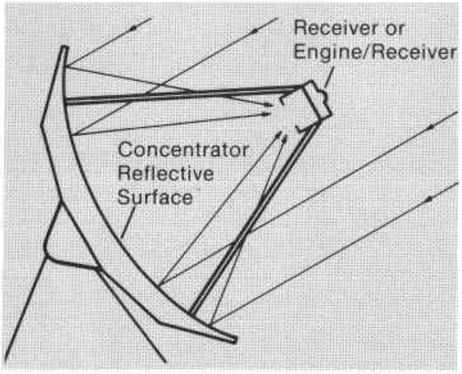
If thermal storage is incorporated in the solar thermal power system, solar energy can be stored for producing electric power when the sun is not shining. Semi-automatic operation of the central receiver system under varying requirements and conditions is accomplished by a master control system. A central receiver system typically produces power in the range of tens of megawatts or higher.



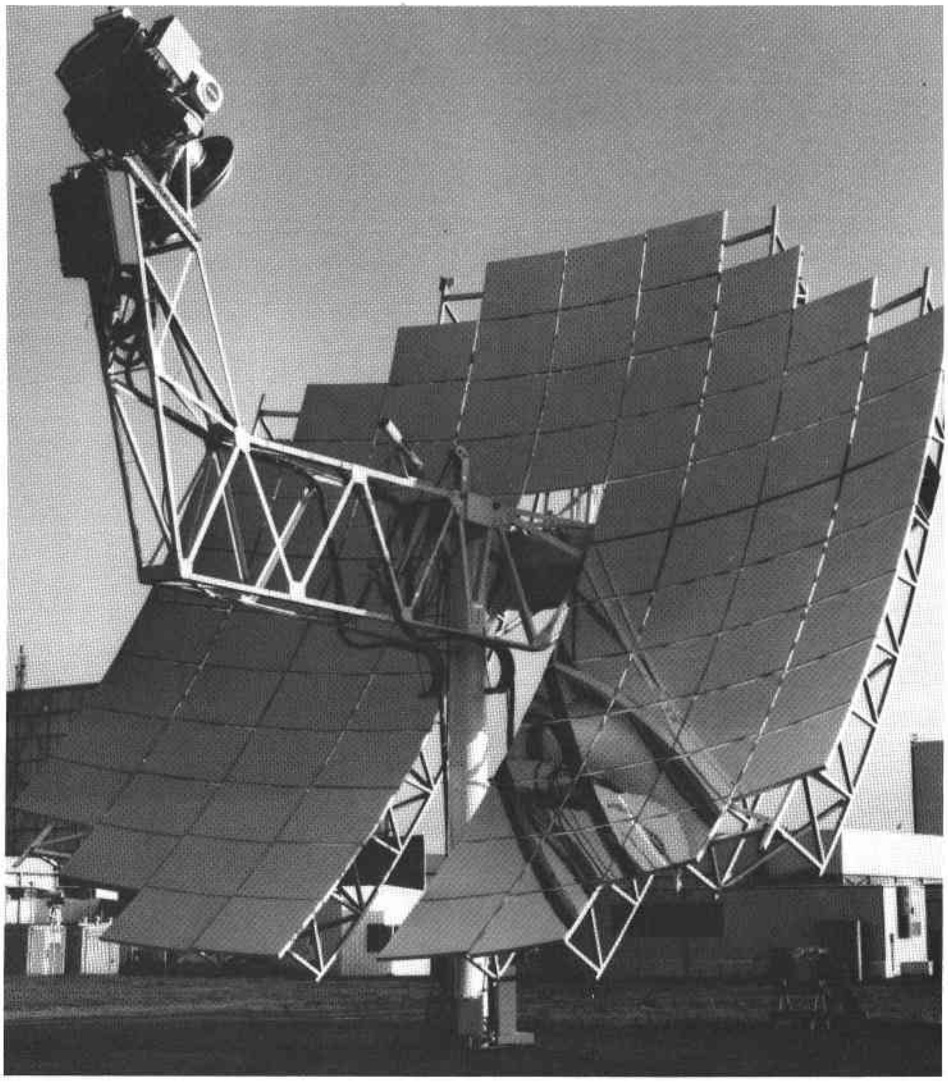
Central Receiver

Solar One Central Receiver System

Dish systems use a parabolic two-axis tracking concentrator to accurately focus the sun's rays onto a receiver mounted above the dish at its focal point. Solar energy heats fluid circulating through the receiver and this hot fluid is pumped elsewhere for a variety of uses, or electric power can be generated by a small engine mounted at the focal point of the dish. Each dish is a unit that can function independently or as part of a group of dishes. A single parabolic dish, 15 meters in diameter, can achieve temperatures in excess of 2700°F and efficiently produce up to 50 kilowatts of electricity. A group of parabolic dishes can produce many megawatts of electricity.



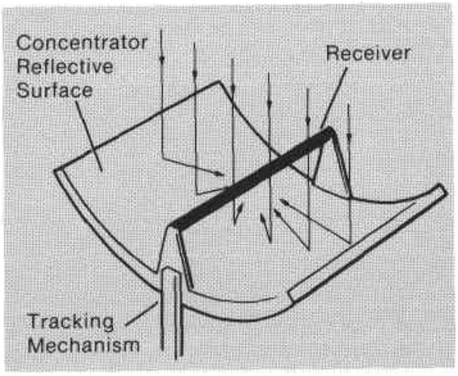
Parabolic Dish



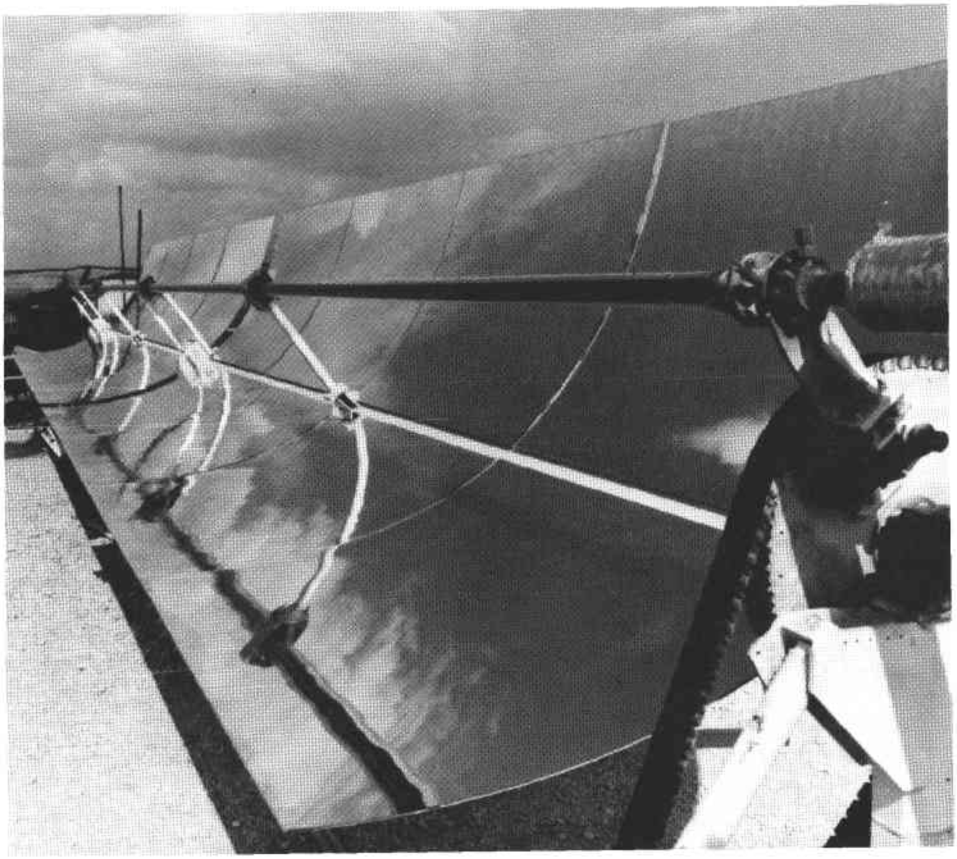
McDonnell Douglas Parabolic Dish

Trough systems concentrate solar energy onto a receiver tube positioned along the line focus of the trough. Fluid in the receiver is heated and then transported through an insulated piping network to the point of use. Trough systems usually track the sun in only one axis and operate in a temperature range of 212°F to 660°F.

As with dish concentrators, modularity is a key advantage of parabolic trough systems. The basic module is a row of reflectors actuated by a drive motor to track the sun. A control system operates as many modules as required to heat the fluid in the pipes to the temperature to provide process heat. This energy can be increased in temperature using fossil energy, if needed, for applications such as driving a generator for electric power production. These hybrid solar and fossil fuel systems can provide energy around the clock if necessary.



Parabolic Trough



A Solar Thermal Trough Concentrator

The Benefits of Solar Thermal Energy

Summing up, solar thermal energy is a viable supplement to conventional resources. The solar fuel is free and practically limitless. It is a secure source of energy and offers increased self-sufficiency. Solar energy is a versatile resource, with a broad range of temperatures for industrial processes in addition to the production of electric power.

Solar power plants can be built in sizes from tens of kilowatts to hundreds of megawatts. These plants may be stand-alone, added to conventional power plants, or hybrid (solar and fossil) designs. They are excellent for following utility peak loads, lend themselves easily to energy storage, and can provide base-load power with such storage. Furthermore, they may be built in modular units, and construction times have proved to be much shorter than that of conventional plants. Finally, the environmental impact of solar thermal energy systems is minimal.

Solar Thermal Power Experiments

The use of solar thermal power is not as recent as it may seem. More than a century before the Department of Energy's Solar One at Barstow, California began producing electric power, French scientists used solar thermal engines to pump water, print a newspaper, distill water, and even make ice!

These French scientists, who demonstrated their innovations at the Paris Exposition of 1878, were not alone in harnessing the sun. At about the same time, Swedish-American John Ericsson operated a 2½-horsepower solar engine. By 1901, English engineer Aubrey Eneas pumped water for an ostrich farm in Pasadena, California (not far from Barstow) with a 4½-horsepower solar engine. In 1908, Willsie and Boyles operated a 15-horsepower solar engine in the sunny desert at Needles, California. This demonstrated the advantage of sunny skies for such projects.

By 1912, American engineer Frank Shuman had designed and built a solar engine that dwarfed all those that preceded it. Using a system of trough concentrators, this large solar plant produced 70-horsepower for an irrigation project near Cairo, Egypt.

Remarkable as these early solar engines were, they were doomed by cheap and transportable coal, gas, and liquid fuels. Although solar radiation itself was free, the equipment needed to collect and convert it to useful power cost more than conventional heat engines. Today's new generation of solar power plants must address this same problem, but with several advantages.

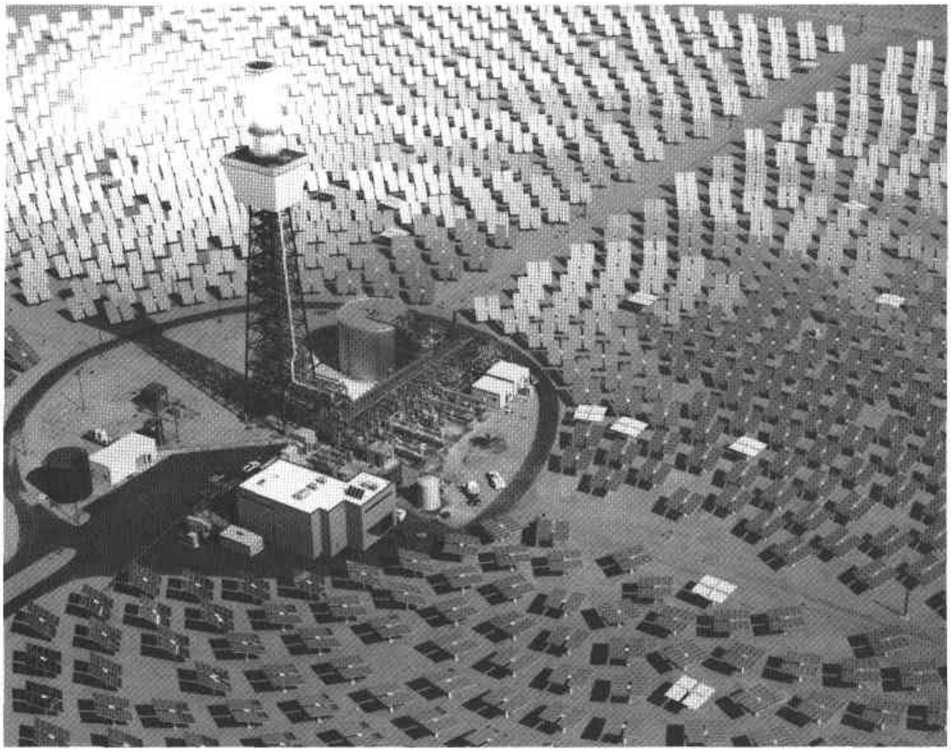
Solar plants today are more efficient, more durable, and less expensive — thanks to new technologies and materials developed since their crude forerunners harnessed solar heat. For these reasons, and because of serious environmental concerns, the time has come where the development of solar thermal plants may supplement conventionally fueled plants.

Department of Energy Experimental Projects

Concentrated solar radiation is now used for generating electricity, industrial process heat, and air-conditioning. It is used in systems ranging in size from 25 kilowatts to multimegawatt sizes. The following successful industrial experiments show the diversity of solar thermal technology.

10 MW_e Pilot Plant (Solar One)

This 10-megawatt pilot electric-power plant is a team project that is cost-shared by the Department of Energy, industry, and utilities. Begun in 1979, this first-of-a-kind experiment was conceived to demonstrate the

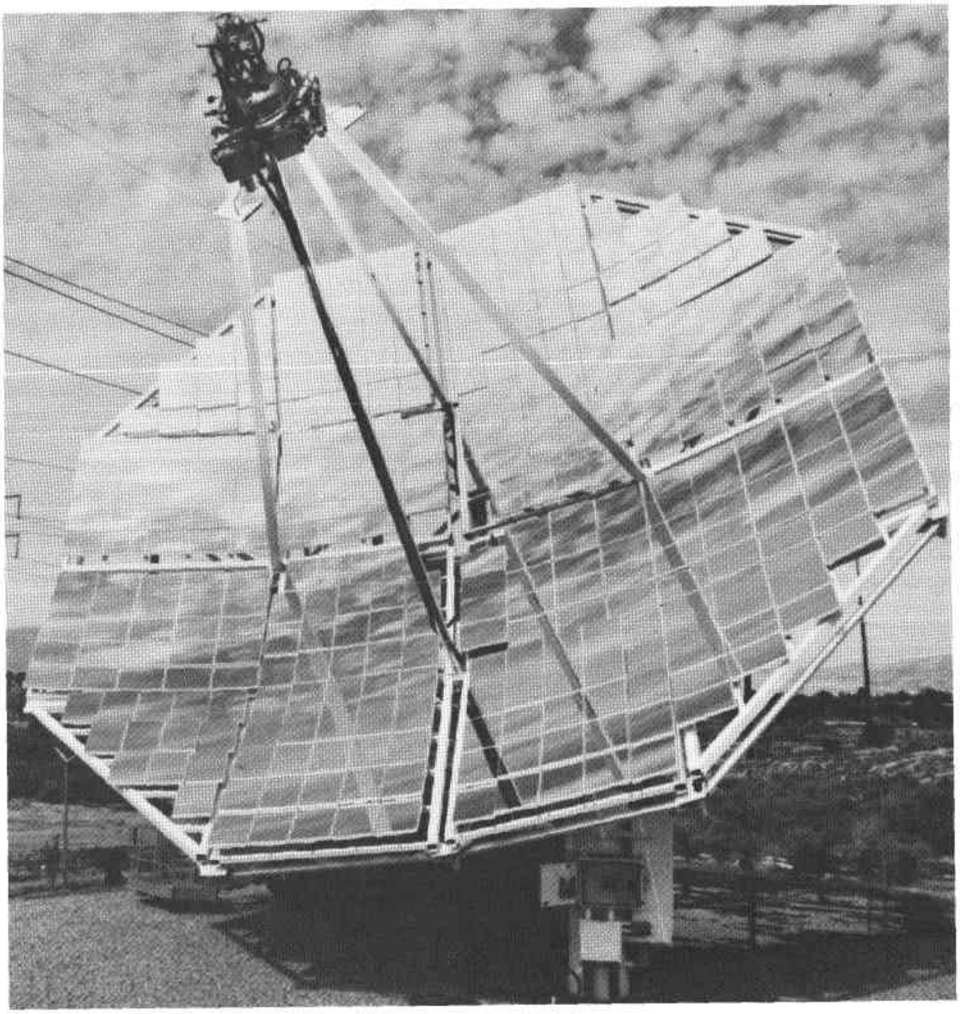


Solar One 10 MW_e Central Receiver

technical feasibility of converting solar thermal energy into bulk electric power. Solar One began operation in April 1982, successfully completed its testing and evaluation phase in July 1984, and is in a 3-year power-production phase providing operational data and electric power for Southern California Edison customers.

The 200-foot receiver tower is surrounded by a circular array of 1,818 heliostats (sun-tracking glass mirrors), each about 22 feet on a side. Solar radiation from these heliostats heats the 45-foot receiver atop the tower and produces 960°F steam in one pass. Solar One, originally designed to generate 10 megawatts of electric power, has produced up to 12 megawatts under the best of conditions. Solar One has demonstrated not only the technical feasibility of the concept but also the ability to accurately predict the performance of central receiver systems.

The Barstow area receives an average of about 9½ hours of sunlight a day, and when surplus heat is available, a 150,000 cubic foot thermal storage tank is heated to provide up to 7 megawatts of electric power for 4 hours after sunset. The rated 10-megawatt output of the plant provides electric power for a community of several thousand homes and is supporting commercial and industrial needs.

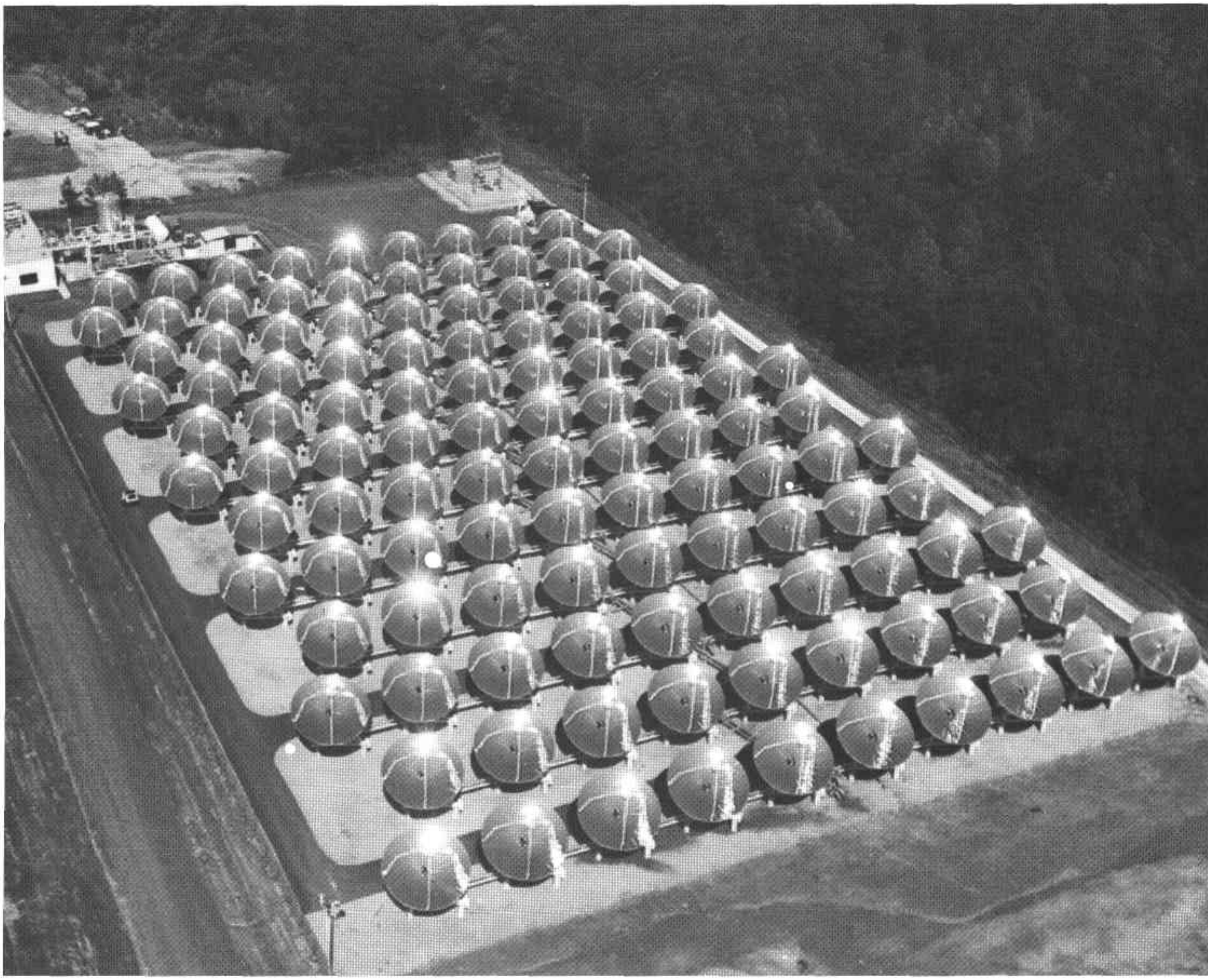


Vanguard Dish Stirling Module

Vanguard Dish Stirling Module

One of the more important solar thermal power experiments, the Vanguard parabolic dish experiment at Rancho Mirage, California, set a world record of 29.4% net efficiency in converting solar energy to electricity. It was recognized as such by being included as one of the hundred most outstanding technical innovations of 1984 by *Industrial Research* magazine.

Vanguard used a 36-foot-diameter parabolic dish concentrator and a Stirling engine to generate 25 kilowatts of electric power. A cooperative experiment by the Department of Energy and Advanco Corporation, it demonstrated not only high efficiency but the advantage of modularity. As many dishes as desired can be linked together to produce the amount of energy that is required for the need.



Solar Total Energy Project

Solar Total Energy Project (STEP)

The Solar Total Energy Project in Shenandoah, Georgia has demonstrated the diversity of solar thermal technology. Total energy refers to use of waste heat from electric power generation to meet other energy requirements. The STEP system incorporates 114 parabolic dish collectors (each with a 22-foot diameter) and a steam-powered generator to produce up to 400 kilowatts of electric power, 1,400 pounds of steam at 350°F, and 257 tons of air-conditioning per day for use in the adjacent Bleyle textile mill.

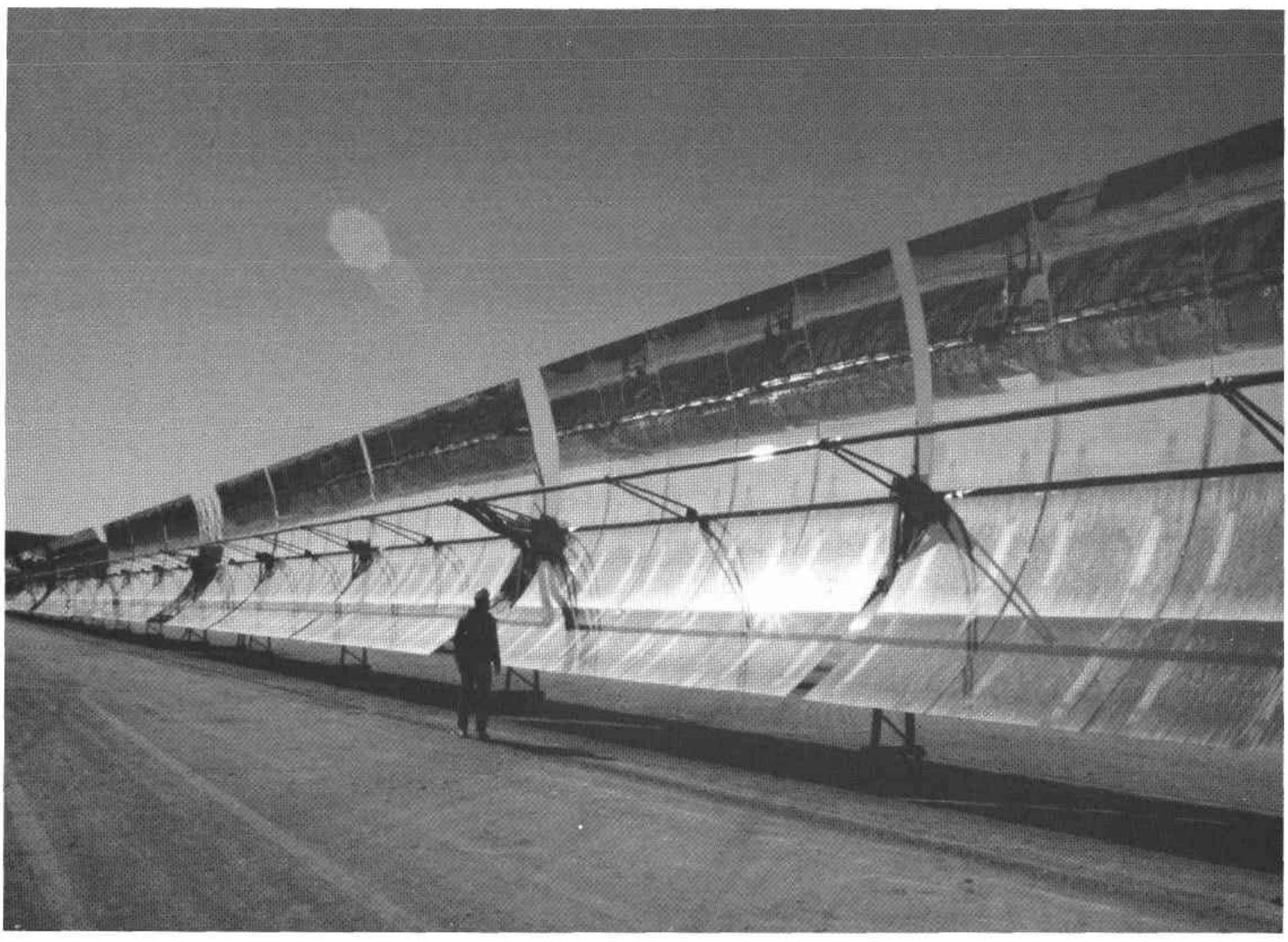
Operation of the Shenandoah solar total energy system begins with circulation of heat-transfer fluid through the receiver tubes at the focal point of the collectors where solar energy heats it to 750°F. The fluid is then pumped to a heat exchanger where it boils water and superheats steam to drive a turbine generator and produce electricity. Medium-pressure steam is extracted from the turbine for knitwear pressing, and the low-temperature steam exhaust from the turbine is used to chill water for air-conditioning.

Private Sector Commercial Projects

Solar Energy Generating Stations (SEGS 1 and 2)

Of the various solar thermal technologies, parabolic troughs are the most commercially available, with a number of manufacturers able to produce them. The largest solar plants built to date are the Solar Energy Generating Stations, SEGS 1 and 2, designed and built by Luz Engineering to produce electric power for sale to the Southern California Edison Company.

These Luz plants total 45 MW_e with a total parabolic trough collector area of nearly 2,500,000 square feet. Oil in the piping is heated to 590°F and is used to generate saturated steam. The steam is then superheated to 780°F using independent natural gas fired superheaters. This combination of solar and fossil fuels makes SEGS 1 and 2 a hybrid system with a maximum efficiency. Large thermal storage tanks provide several hours of operation after sunset.



SEGS 2 — Parabolic Trough

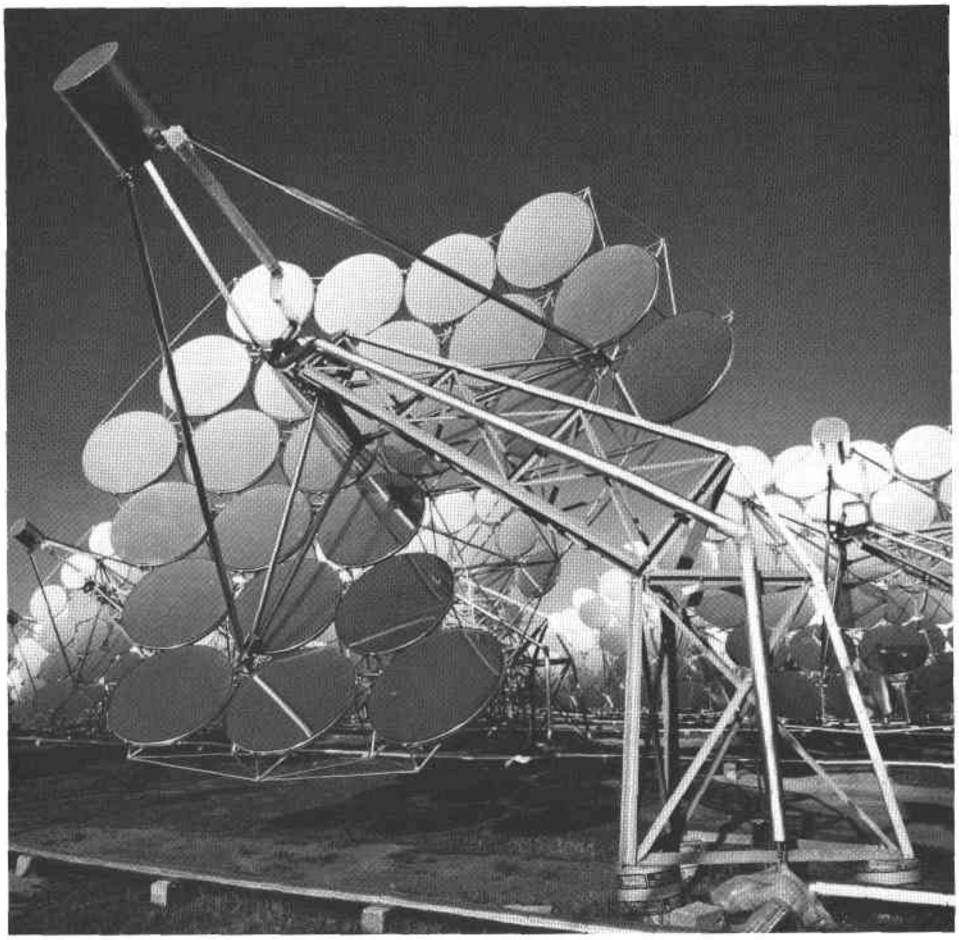
SOLARPLANT I

The LaJet 4.4-megawatt SOLARPLANT I in Warner Springs, California successfully demonstrated a much larger application of parabolic dish technology. A privately funded plant, the LaJet system makes steam for two turbine generators, using an array of 700 dish concentrators. Each concentrator consists of 24 five-foot diameter plastic parabolic mirrors that use a weatherized disposable polymer film.

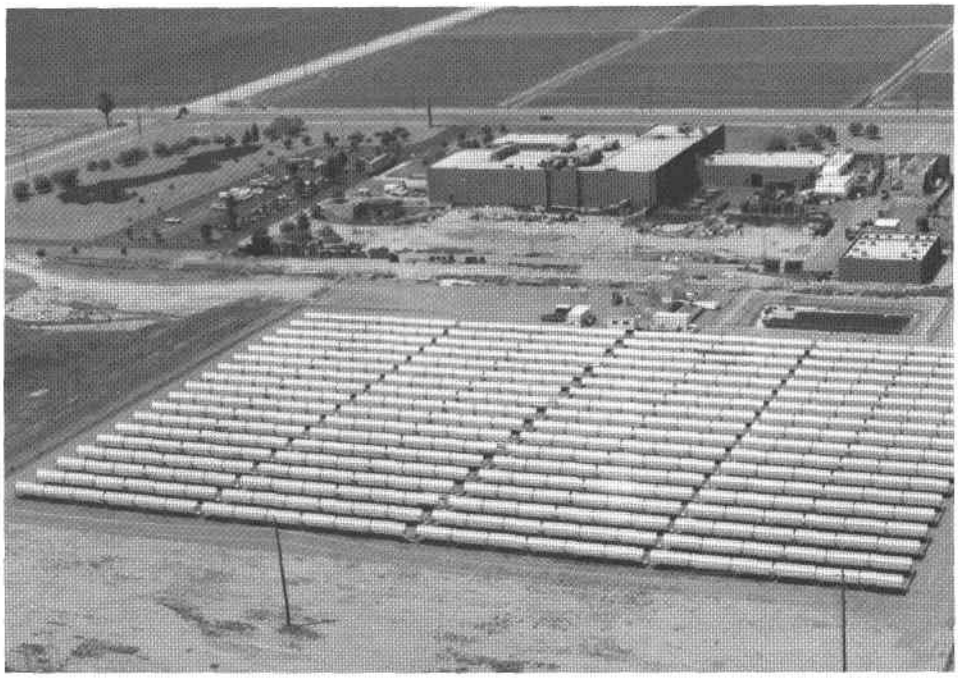
Gould Hot Water System

In addition to electric power, industry uses a very large amount of steam, hot water, and various gases for heating, drying, and other manufacturing processes. These represent additional opportunities for solar thermal energy, and a large number of industrial applications of heat energy experiments have been carried out by the Department of Energy. A recent privately funded industrial process heat facility designed and installed by Solar Kinetics, Inc. and operated by Gould, Incorporated consists of more than 60,000 square feet of collectors and a heat storage system to provide most of the Gould plant's 200°F hot water.

These recent solar thermal experiments and industrial demonstrations have proved the technical feasibility of the various concepts and resolved a number of material and operational problems. Remarkable progress has been made and the promise for the future is excellent.



SOLARPLANT I



Gould IPH Plant

Economic Notes on Solar Thermal Systems

Energy economists sum up all the various costs over the life of a conventional power plant to establish the price of delivered energy, and this is the yardstick that solar thermal energy must be measured against. For the present, a solar plant typically has a higher initial capital cost; but this is partially offset by a lack of fuel costs over its lifetime. Because these plants are modular in nature, they can be built to incrementally add electric or heat production capacity. Thus, even though these plants cost more per kilowatt of capacity, studies have shown that they can still be considered economical in certain situations. Ongoing research and development has the potential for significantly reducing the cost of solar thermal systems and improving their competitiveness in the future. Penetration and widespread use of solar power will be governed by the cost of solar systems compared to the cost of other energy options. The intangible costs of coal and nuclear power, sulfur/carbon monoxide emissions, and nuclear waste disposal must also be considered when the cost of energy is compared.

Solar thermal plants can be built quickly thus avoiding high interest costs over the many years it can take to build conventional coal or nuclear power plants. Rapid response to need, and early completion of new capacity provide added advantages, as suggested by the 12-month construction time of the SEGS 1 plant.

The technical feasibility of solar thermal technologies has been amply demonstrated by the remarkable progress already achieved. Effective market penetration now depends on increasing efficiency and reliability while further lowering costs of materials and component parts. Success in these areas will result in competitive costs for solar thermal systems and add a new dimension to our energy resources.

At its present cost of about 13 to 20 cents per kilowatt-hour, solar electricity can match conventional costs only in specific cases. Wider success will require lower initial costs, improved efficiency and reliability, and reduced operating and maintenance costs. Reaching the DOE Solar Thermal intermediate goal of 8 cents per kilowatt-hour for electric power and $9 per million Btu of industrial process heat will make solar thermal energy a competitive option for a broad range of applications for the future.

Where Do We Go From Here?

The long-term future of solar thermal energy is assured, drawing as it does on a resource that will be available long after all economically recoverable fossil fuels are exhausted. However, work remains to establish solar energy as an economical option to traditional energy sources in the near term.

To reach this goal, new ideas which offer the potential for dramatic improvements in solar thermal technologies are being pursued. These new ideas address the following critical areas.

Reflectors

When Solar One was built, the cost of its heliostats amounted to 60% of the total cost of the power plant. Advanced heliostats are now three to four times as large as the original heliostats (150 square meters instead of 40 square meters). This reduces the cost of heliostats by about 40%, and that of foundations, drive motors, and electronic controllers by a like percentage.

In addition, the heavy silvered glass, 10 lb/ft^2, of the original heliostats is being replaced with lightweight silvered plastic, 2 lb/ft^2. This permits even lighter and simpler supporting structures. One such design is the stretched membrane, in which the reflective material is stretched over a metal rim much as fabric is stretched over a rim to make a drum. Small stretched membranes are being used in the LaJet SOLARPLANT I parabolic dishes. Further development of membrane reflectors for heliostats and dishes should lead to larger, more efficient designs at lower cost.

Receivers (Central Receiver Technology)

Another innovative approach is to reduce the size and weight of solar power plant receivers with materials and fluids that absorb more energy. This approach yields a smaller, lighter receiver at less cost. As an example, advanced receivers using molten salt or sodium as heat-transfer fluids will be as little as 20% the size of the steam receiver of Solar One. As with the advanced heliostats, these improved receivers will require lighter, less expensive supporting structures. The new fluids can also be stored at high temperature and low pressure for plant operation during long hours of reduced sunlight.

Engines (Dish Technology)

The Vanguard module has demonstrated the very high conversion efficiency of sunlight to electricity for dish technology. The addition of membrane concentrators will significantly reduce the cost of dish systems. However, the critical area of engine reliability remains to be improved. Work continues on improving the Stirling engine used in the Vanguard, as well as two innovative engines: (1) a free-piston Stirling engine design, and (2) a thermoelectrochemical cell in which spent chemicals are regenerated by solar energy to produce electricity. Each of these new concepts has almost no moving parts and should be very reliable. They have the potential for making dish systems of high reliability and efficiency at lower costs.

New Applications

Research is also under way to increase the number of potential applications of concentrated solar energy. Thus far, nearly all solar thermal applications have converted the concentrated solar energy into heat to be used in industrial processes or for conversion to electricity. The solar spectrum is very complex, however, consisting of moderately energetic photons in the infrared wavelengths and the high-energy photons in the ultraviolet. It may be possible to use the high-energy portion of the spectrum in new ways.

A university research team has found that certain hazardous waste chemicals can be efficiently destroyed with concentrated solar energy. Research is exploring unique changes in the properties of materials irradiated with solar energy, including the strengthening of those materials. Other potential applications include renewable fuels, such as hydrogen derived from water by photolysis. Strategic chemicals, such as ammonia used to make fertilizer, can be produced from air and water using concentrated solar energy. Thus, concentrated solar energy has the potential, if it can be collected and converted economically, to satisfy many of our energy needs.

Future Prospects

The 1980s have seen a world-wide oil glut that has reduced the feeling of urgency toward developing new energy options, such as solar thermal technologies. Our fossil fuel supplies are finite, however, and the supply decreases daily. Solar thermal technologies (central receivers, parabolic dishes and parabolic troughs) have the potential for harnessing substantial renewable energy resources for our country. By capturing the sun's radiation and converting it to useful forms of energy, this can become an integral and environmentally acceptable part of our energy supply in the coming decades.

The accomplishments of experiments such as Solar One and the early commercial thermal power plants, as well as the potential for producing vital fuels and chemicals, are encouraging as we look to the future. As our reserves of fossil fuels decrease, solar thermal technologies can provide an energy option to help fulfill future needs.

Glossary of Solar Thermal Terms

Absorber (Receiver) — omponent of a solar thermal system that absorbs and converts solar radiation into heat.

Central Receiver System — A solar thermal system using an array of sun-tracking mirrors called heliostats to concentrate solar radiation onto a common receiver.

Concentration Ratio — Ratio of solar collector area to absorber area.

Distributed Receiver System — A solar thermal system in which each collector has its own attached receiver.

Heat-Transfer Fluid — Liquid or gas circulating through a receiver to absorb the sun's heat.

Heliostat — A two-axis tracking mirror for reflecting the sun's rays onto the central receiver of a solar thermal system.

Hybrid System — An energy conversion system that can be operated by solar energy and fossil fuel.

Insolation — Available solar radiation. At the Earth's surface, maximum solar radiation is about 1,000 watts per square meter.

Single-Axis Tracking — Sun-tracking system capable of moving in one direction, e.g., in an east-west direction.

Solar Energy — Energy generated by a helium fusion reaction within the sun and radiated from the sun in all directions.

Thermal Energy Storage System — A tank or other container filled with liquid or solid material for storing solar heat for later use.

Total Energy System — An energy system that uses waste heat from the generation of electricity to satisfy additional energy needs such as heating and cooling.

Two-Axis Tracking — Sun tracking system capable of full asimuth and elevation motions.

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