DOE/SF/10737-1(Exec.Summ.)

# SOLAR REPOWERING/INDUSTRIAL RETROFIT SYSTEMS

## Category B: Solar Thermal-Enhanced Oil Recovery System

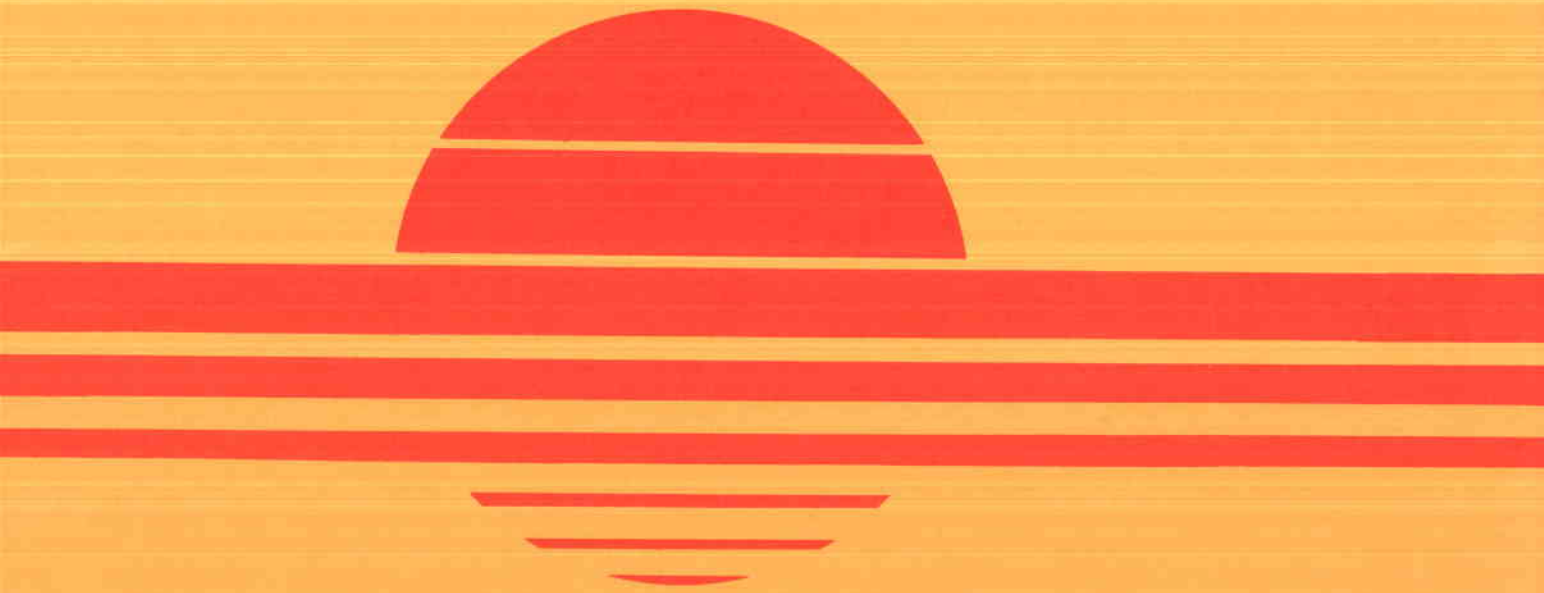
## Executive Summary

35

July 1980

Work Performed Under Contract No. AC03-79SF10737

Martin Marietta Corporation
Denver, Colorado



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# SOLAR REPOWERING/ INDUSTRIAL RETROFIT SYSTEMS

## Category B: Solar Thermal-Enhanced Oil Recovery System

**MARTIN MARIETTA CORPORATION**
**P.O. Box 179**
Denver, Colorado 80201

# FOREWORD

This document is issued in accordance with the provisions of contract DE-AC03-79SF10737, Solar Repowering/Industrial Retrofit Systems. The contract was extended by the United States Department of Energy/San Francisco Operations Office to the Martin Marietta Corporation, spanning the period from 28 September 1979 through 15 July 1980. Contract manager was Mr. Fred Corona of DOE/SFO and the technical monitor was Mr. Jim Gibson of Sandia Laboratories/Livermore, California. Other major elements of the contractor team were Exxon Research and Engineering Advanced Energy Systems Laboratory, Exxon Enterprises Solar Thermal Systems Division, Foster Wheeler Development Corporation and Black and Veatch Consulting Engineers.

This executive summary provides a brief overview of the entire project for the reader who desires a quick understanding of the purpose, nature and significant results of the study. The background and approach to the project are discussed and the proposed site is described. All project activities and results are summarized. The conceptual design is completely described and the pertinent economic evaluations are reported. A development plan and a site owner's plan are presented.

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# 1.0 EXECUTIVE SUMMARY

The Martin Marietta Corporation, in association with Exxon Research and Engineering Advanced Energy Systems Laboratory, Foster Wheeler Development Corporation, and Black and Veatch Consulting Engineers, submits this final report to the United States Department of Energy in fulfillment of contract DE-AC03-79SF10737 entitled Solar Repowering/Industrial Retrofit Systems. The purpose of the DOE Solar Repowering/Industrial Retrofit project is to devise workable, economic concepts for the implementation of solar thermal power systems to reduce the consumption of fossil fuels in existing electric power generating and/or industrial process heat facilities. In accordance with Category B, Industrial Retrofit for Process Heat Applications, we have developed a conceptual design for a central receiver solar thermal system for a thermal-enhanced oil recovery (TEOR) process in Exxon's Edison oil field near Bakersfield, California. When installed and operational, this system will displace the comsumption of 6,852 $m^3$ [43,000 barrels (bbl)] of oil per year.

## 1.1 BACKGROUND AND APPROACH

The concept described in this report represents a unique opportunity to help alleviate the ever-increasing energy problem the United States faces by attacking the problem from two fronts simultaneously. Not only does the solar TEOR (STEOR) concept offer the potential to significantly augment the efforts in petroleum conservation by reducing the need for consumption, but also serves to increase domestic production of oil with the attendant benefit of reducing our dependency on foreign oil sources.

Crude oil is found in many forms, from a very light fluid that is easily pumped to an extremely heavy and viscous material such as tar. The geologic formations in which the crude oil resides also vary considerable in their physical nature, ranging form relatively loose, permeable sands to very hard, impenetrable shales. The preponderance of oil produced in the past, as well as that now being produced, is light crude having an API gravity rating above approximately 25°. Light crude is easily produced by the conventional pumping technique with normal ground pressure moving the crude to the well bottom. Oil from the middle east is mostly light crude, with an API rating of about 35°.

Although large portions of light crude sources in the United States have been depleted, vast quantities of heavy crude (below 20° API) remain. It has been estimated that perhaps 30 billion or more barrels of heavy crude oil deposits are contained in the states of California, Kentucky, New Mexico, Texas and Utah alone. Much of this resource remains untapped, but very large reserves exist where lighter crude was previously produced and depleted. In many cases oil fields have been abandoned when pumping ceased to be economically productive. Standard pumping methods can produce only a small portion (up to about 1/3) of the oil in most reservoirs.

The high viscosity of remaining crude, coupled with the decrease in ground pressure resulting from previous production and the high flow resistance of the formation, is the major factor that has caused many oil fields to become economically nonproductive.

As available crude oil reserves have been depleted and prices have escalated, several means of enhancing production rates have been conceived, including steam injection, chemical injection and in situ combustion. The most cost effective process, and that in use in the Edison field, is injection of steam into the ground. Crude oil-fired boilers generate steam (75 to 80% quality) at output temperatures in the range of 232 to 354oC (450 to 670oF). The steam is then injected into the ground in the "stimulation" mode (perodic injection, with recovery taking place between injection operations). As further field depletion occurs, the steam "drive" mode (in which injection is continuous and recovery occurs simultaneously from adjacent wells) may be implemented to maintain economical production rates.

This conventional steam injection process has two adverse characteristics that limit both economic and performance potentials. First, the steam generators consume large amounts of the very resource they are used to recover. Current estimates indicate that for every 0.48 $m^3$ (3 bbl) of oil produced by the thermal EOR process, up to 0.16 $m^3$ (1 bbl) is consumed in combustion to produce steam. Also, the Fuel Use Act of 1978 will further inhibit the use of conventional thermal recovery processes by requiring single boilers over 100 MBtu in size or multiple boiler installations of more than 250 MBtu to use coal or renewable fuels. Second, existing air quality standards, particularly in California, require costly methods of combustion gas treatment that further inhibit the efficiency of the process. From this standpoint, it is most unfortunate that virtually all heavy crude oil contains large amounts of sulphur--the oxides of which are among the most severe pollutants contained in combustion gases. It is believed that air quality and other environmental standards will become more stringent over the entire country and may ultimately prevent economical recovery of these vast reserves of crude oil unobtainable by conventional pumping technology.

The central receiver system described here was designed specifically for Exxon's field, but the potential utilization of this STEOR technology has much more far-reaching implications. Of the previously mentioned states containing abundant reserves of heavy crude oil only one--Kentucky--perhaps has insufficient insolation for the economical use of STEOR in the near future. The other four states are all located in the sun belt of the southwest where conditions are very conducive to effective implementation of solar thermal systems. Presently most of the nation's heavy crude production is taking place in California where over 500,000 barrels per day of crude in the 10 to 20° API range is produced. If only 20% of this production that now utilizes crude-fired boilers for steam injection is repowered by central receiver solar thermal systems, up to 12 million barrels of oil can be conserved each year.

## 1.2 SITE DESCRIPTION

The site selected for this design study is the Edison oil field in Kern County, California. The Edison field is located approximately 7 miles southeast of Bakersfield at the south end of the San Joaquin Valley. The latitude is about 35° north. Figure 1.2-1 shows the location relative to Bakersfield. The terrain is very flat (Fig. 1.2-2), is at an average elevation of 183 m (600 ft) above mean sea level and has a very slight slope of 1.5% from the northeast to the southwest.

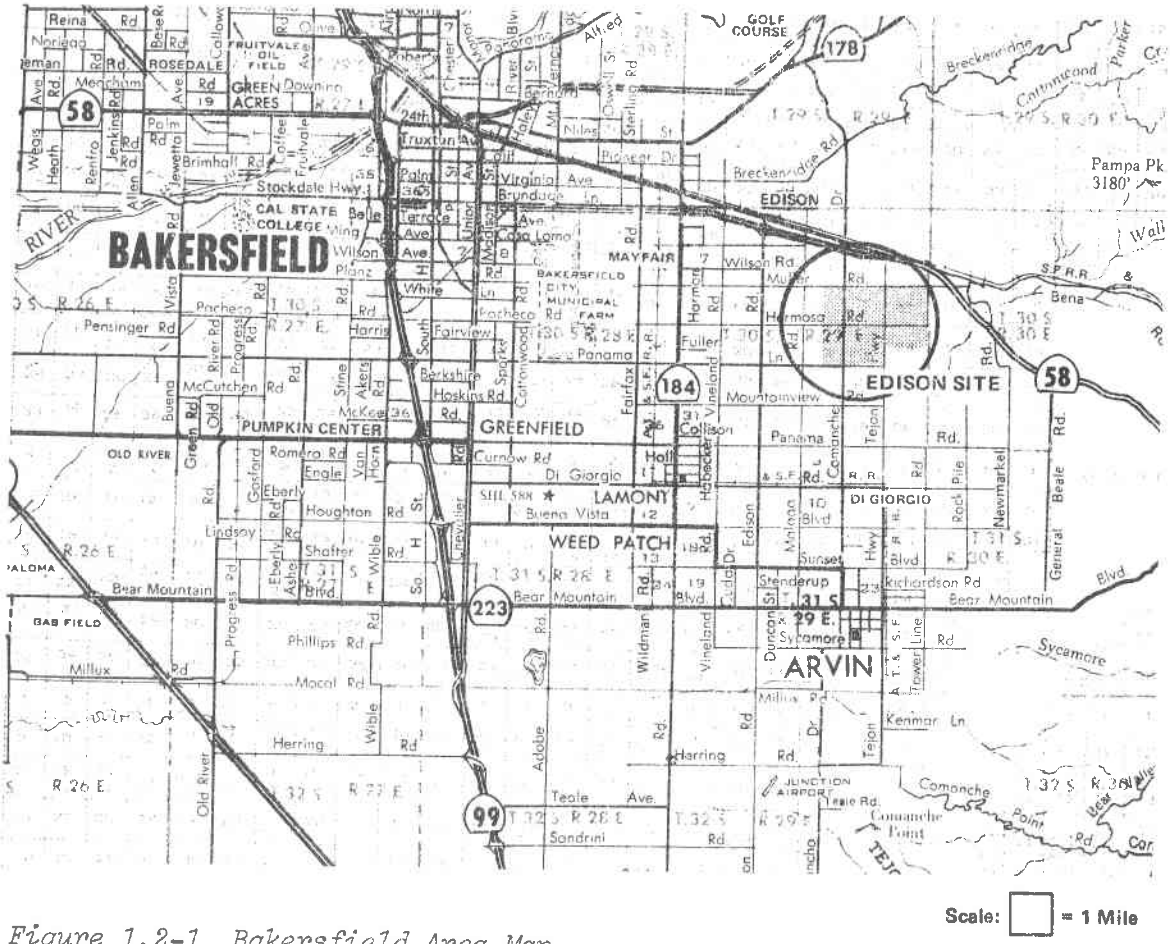


*Figure 1.2-1 Bakersfield Area Map*

A plat of the zone to be served by the STEOR system is shown in Figure 1.2-3. There are 121 producing wells on this site and another 121 are planned to be drilled. When the drilling program is complete, the average oil well density will be one well per 5059 $m^2$ (1.25 acres). The collector/receiver module will be located on lease 808794, which measures 805 m (2640 ft) by 402 m (1320 ft), and will also serve leases 808795, 808701 and 808699.

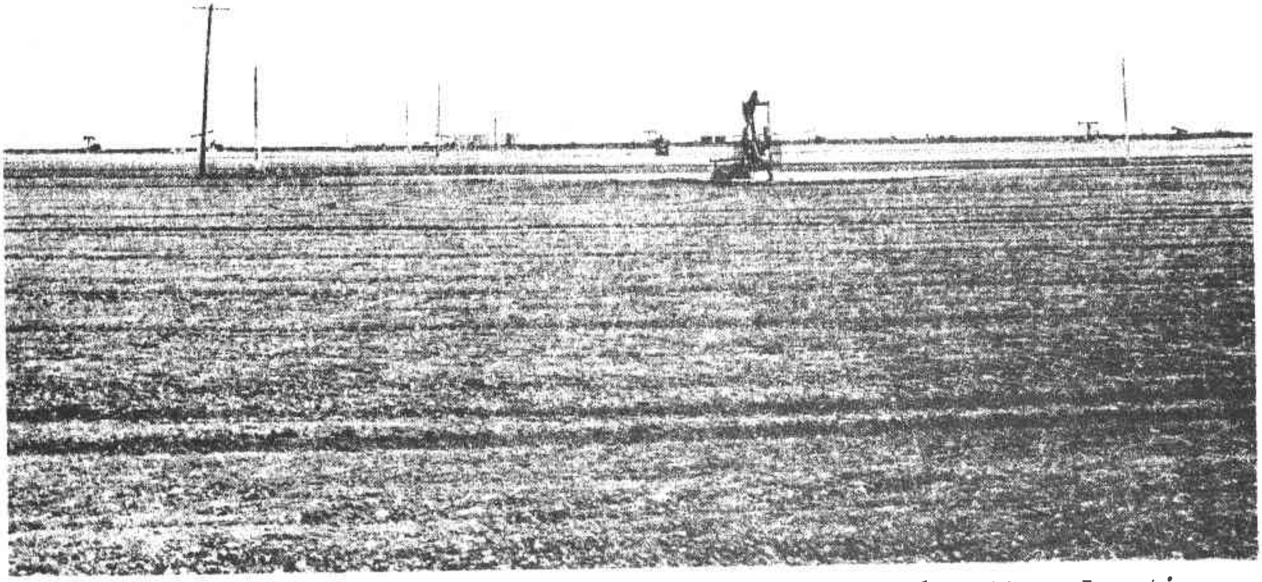


*Figure 1.2-2 Exxon's Edison Field Looking South from Tank Battery Location*

The annual average direct normal insolation in this general area of California ranges from 6 to 7 $kW/m^2$ per day. The closest location to the site for which detailed measured insolation data are available is Fresno, 174 km (108 miles) to the northwest, which averages 6.2 $kW/m^2$ per day. The climate is warm and semiarid. Average daily temperatures range from 9°C (48°F) in the winter to 29°C (84°F) in the summer. Cumulative precipitation averages 15 cm (5.8 in.) annually, nearly all of which is in the form of rain.

Exxon presently uses two crude oil-fired boilers, each rated at about 7.3 MWt (25 MBtu/h output power, in their steaming operations. The boilers, fuel and feedwater storage tanks and feedwater treatment module are all portable units that can be moved about the field. The system is presently operated in the steam stimulation mode. Steam is injected into a single well at a time continuously for about 7 days, then the well is capped and allowed to soak for about 4 days. After pumping is resumed, the initial production rate is several times greater than before the injection process (Fig. 1.2-4). The production rate declines with time until the next steaming cycle is performed. The interval between stimulations for any given well varies from one to several years. Exxon plans to double their steaming capacity and begin operating in the steam drive mode by 1986.

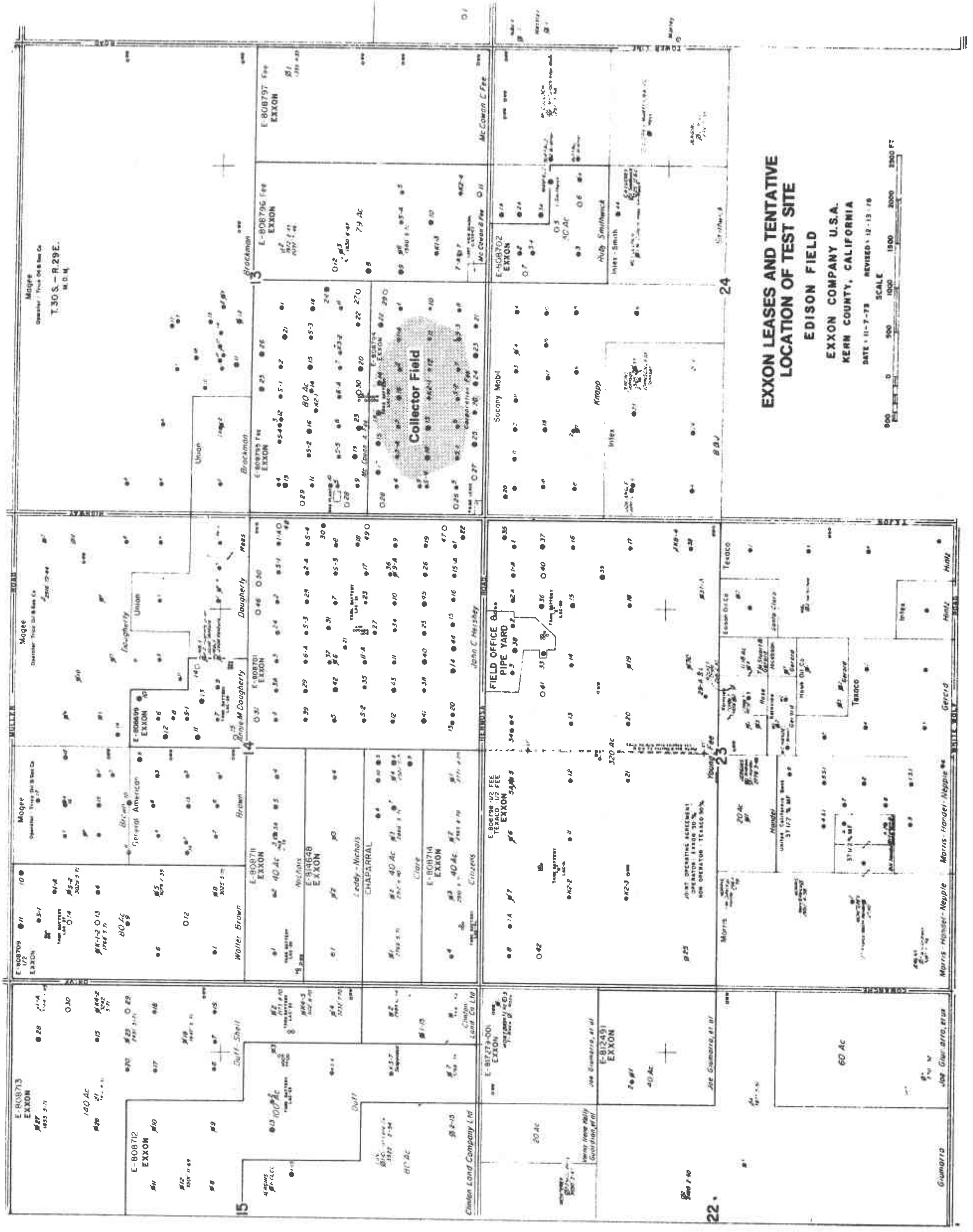


Figure 1.2-3 Edison Field Plat

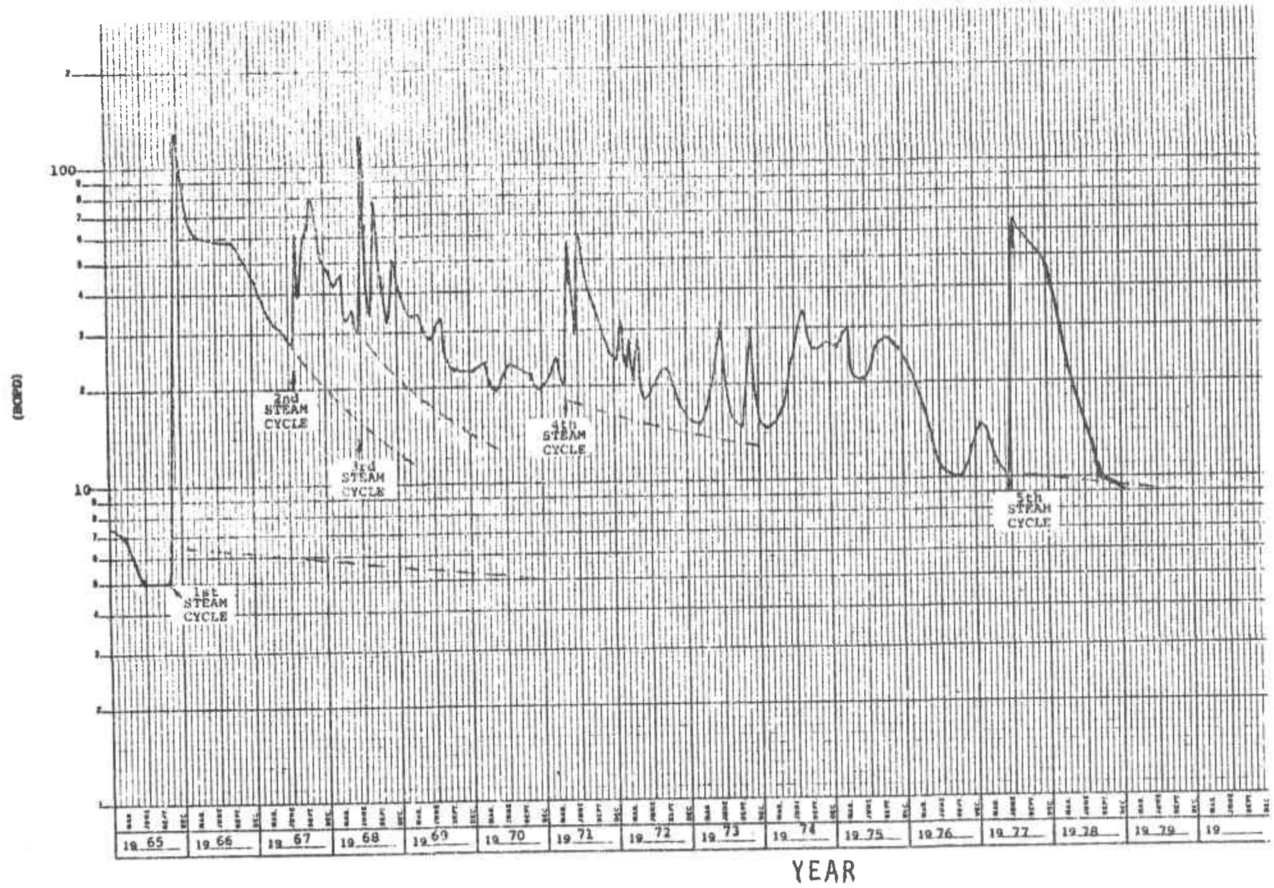


*Figure 1.2-4 Typical Production History for Steam Stimulation Cycles*

## 1.3 PROJECT SUMMARY

The concept of using central receiver solar thermal technology to power a steam injection-enhanced oil recovery process is very clearly in concert with the programmatic goals set for the DOE solar repowering industrial retrofit project. More specifically, our design for a solar thermal system installation at the Edison oil field will provide a valid demonstration of the feasibility of building and operating solar power hardware in an industrial environment, while at the same time offering a real potential for the economic displacement of significant petroleum comsumption in the near term.

The potential total energy requirements for steam injection EOR operations in this country are enormous. Exxon has estimated that in Kern County, California alone, there is a potential for 1670 MWt ($5.7 \times 10^9$ Btu/h) of installed solar capacity by the year 2000. This compares with estimates of over 9000 MWt ($30.7 \times 10^9$ Btu/h) of total steaming capacity necessary by that time. The proposed Edison installation will provide less than 0.1% of that requirement. When considering the total steaming capacity necessary to support heavy crude production in the rest of California and the other states of the sun belt, one can reasonably project an ultimate power requirement on the order of 100,000 MWt ($341 \times 10^9$ Btu/h).

From a technical standpoint, EOR is a most compatible application for central receiver solar thermal systems. Thermal storage will not generally be required for such installations, eliminating what is normally a costly and complex part of solar thermal systems. Likewise the operational requirements of the STEOR process are simple and not stringent as compared with electrical utility and many other process heat applications. From an installation standpoint, the oil field environment is generally well-suited to central receiver technology. Locations are predominantly in nonurban areas with little or no activities of potential interference involved. Large areas of relatively flat, uncongested land are normally available. Clearances for wellhead pumps, equipment and operational access are easily accommodated in the collector field layout. A clear illustration of this compatibility is the active agricultural operations that are frequently carried on in producing oil fields, including Edison.

The solar energy conversion process we have conceived is based on sound, proven technology and presents virtually no risk to implementation of an operational system by 1985. The development of reliable, low-cost heliostats is well under way, and the ability to operate and control an entire collector field has been demonstrated by the operational Central Receiver Test Facility (CRTF) at Albuquerque. By 1981, the Barstow Central Receiver Solar Thermal Power System Demonstration plant will be operational, adding even more experience and maturity to heliostat and control-system technical state of the art. The natural-circulation steam generator in our cavity receiver concept is backed by many years of design and operational experience in commercial applications and has been successfully demonstrated through the design, fabrication, and operation (under both infrared simulated and actual solar conditions) of 1- and 5-MWt prototypes.

In assessing the cost and economic issues related to implementation of an operational central receiver solar thermal system at Edison, we have tried to be realistic in identifying and including all items of design, procurement, fabrication and operation. We are well aware that the ultimate acceptance by, and penetration into, the commercial market place will depend entirely on a visible demonstration that the capital and O&M cost projections can be met. To generate and publish a cost estimate that is overly optimistic would be counterproductive to our long-range interests in the creation and participation in a viable, productive solar thermal power equipment industry.

We are most encouraged that our realistic costing approach has shown that a central receiver STEOR system is favorably competitive with the present crude oil combustion process even in the near term (see Section 1.5). At an installed cost of $14.0 million, and using the SNLL fuel cost escalation rate of 12%, our solar thermal system exhibits a break-even period of 13.5 years as compared to the existing fossil system. Considering a lower fuel escalation rate of 10%, the break-even point moves out to 18.5 years and the annualized costs of power are approximately $24/MWt for the central receiver system as compared to $28 to $36/MWt (10% and 12% escalation respectively) for the fossil system.

It is important to note that the recently imposed windfall tax on oil production revenues, which is included in our economic projections, actually penalizes the solar alternative in these comparisons. Since the tax reduces the net return to the producer of oil sold, there is more of an economic incentive to consume the oil in process heat generation than there would be without the tax.

## 1.4 CONCEPTUAL DESIGN DESCRIPTION

This design concept utilizes the central receiver type of solar thermal power conversion technology to generate the steam necessary for recovery of the heavy crude oil at the Edison field. Major elements of the system are shown schematically in Figure 1.4-1. The absence of a need for thermal storage capability and the moderate steam temperature requirement for the TEOR process results in a relatively simple system with well-defined interfaces. The collector field consists of individually driven heliostats that reflect and concentrate the solar radiant power into a tower-mounted twin-cavity receiver. Water is pumped from an existing well at Edison, treated, then piped to the receiver where the radiant imput power is absorbed by the generation of steam. Water enters the receiver at 15.6°C (60°F) and wet steam exits at 297°C (567°F) and 82% quality.

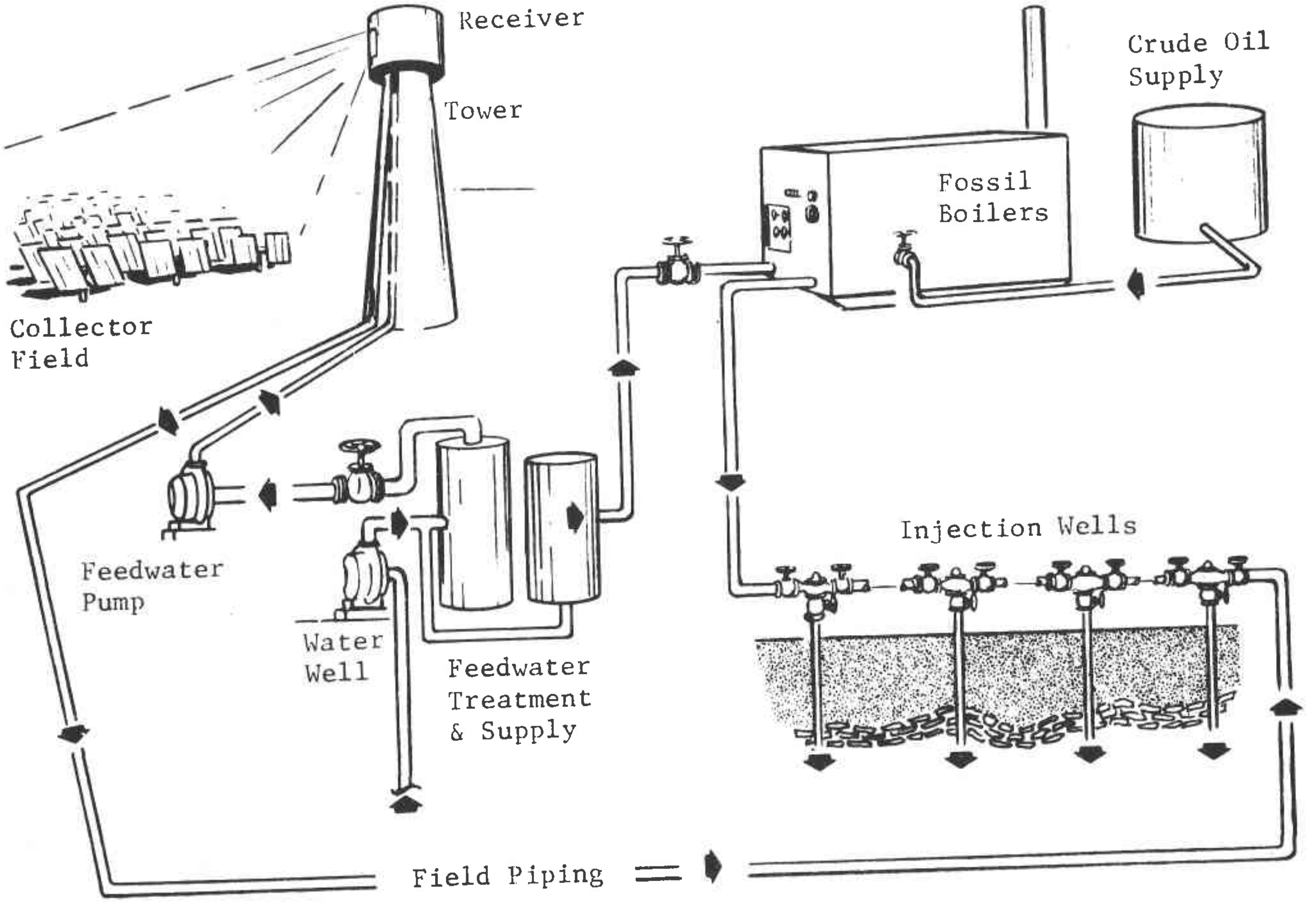


*Figure 1.4-1 Process Schematic*

The solar power system is sized to produce 29.3 MWt (100 MBtu/h) in the form of steam at the system design point (noon on February 27) at an insolation of 0.95 kW/m. This corresponds to an annualized average output of 6.4 MWt (21.8 MBtu/h) that will provide about 25% of the total planned steam requirement at Edison. The option of building an identical collector/receiver module on lease 808795 would increase the solar contribution to about 50% of the required process energy.

The collector field consists of 818 heliostats arranged on lease 808794 of the Edison oil field as shown in Figure 1.4-2. In the layout and placement of heliostats, adequate clearances are provided for oil well equipment and operational access. The heliostats are arranged generally in a 2.32 rad (150°) north circular sector to project power into a twin-cavity receiver. The quantity of 818 heliostats is based on a reflective area of 49.05 $m^2$ (528 $ft^2$), which was specified for this project. Heliostats of other sizes, such as the Martin Marietta second-generation unit at 56.9 $m^2$ (612 $ft^2$), could be used in this system without greatly affecting the indicated boundaries of the collector field or the receiver design. The Barstow pilot plant prototype unit (Fig. 1.4-3) illustrates a representative heliostat configuration.

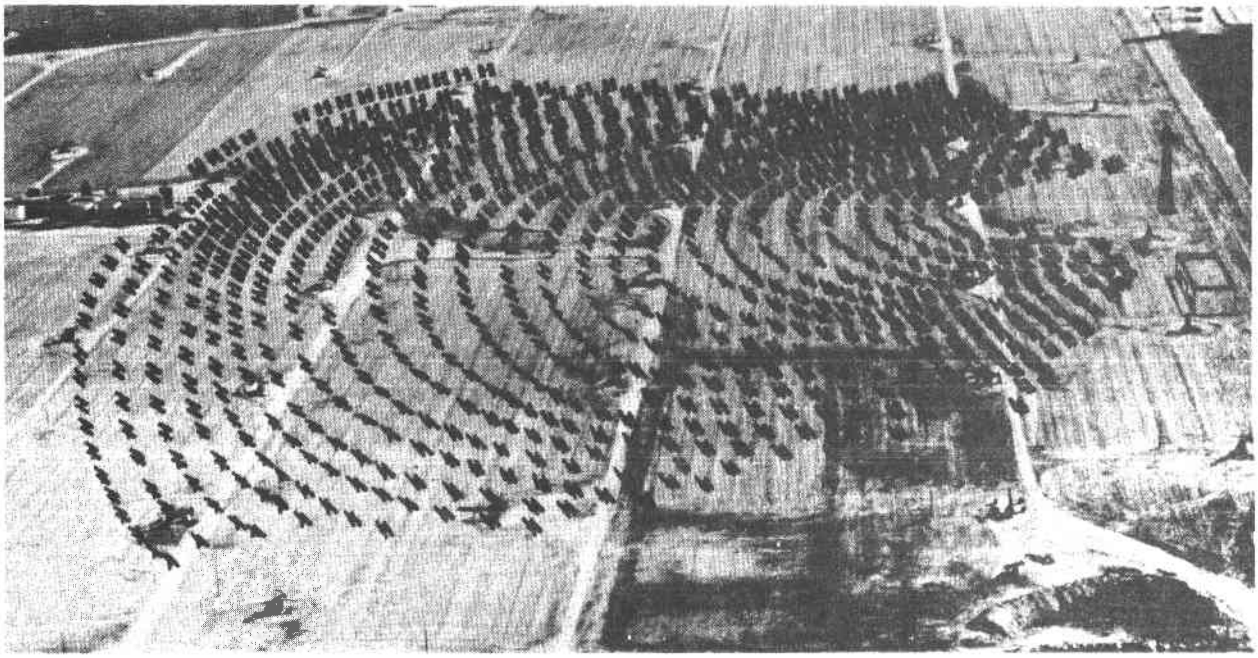


*Figure 1.4-2 Solar Enhanced Oil Recovery*

The proposed receiver concept is a twin-cavity natural-circulation steam generator. Figure 1.4-4 shows a simplified plan view of the twin-cavity receiver. The side-opening cavities, equipped with aperture doors, have a high energy abosrption efficiency and low thermal

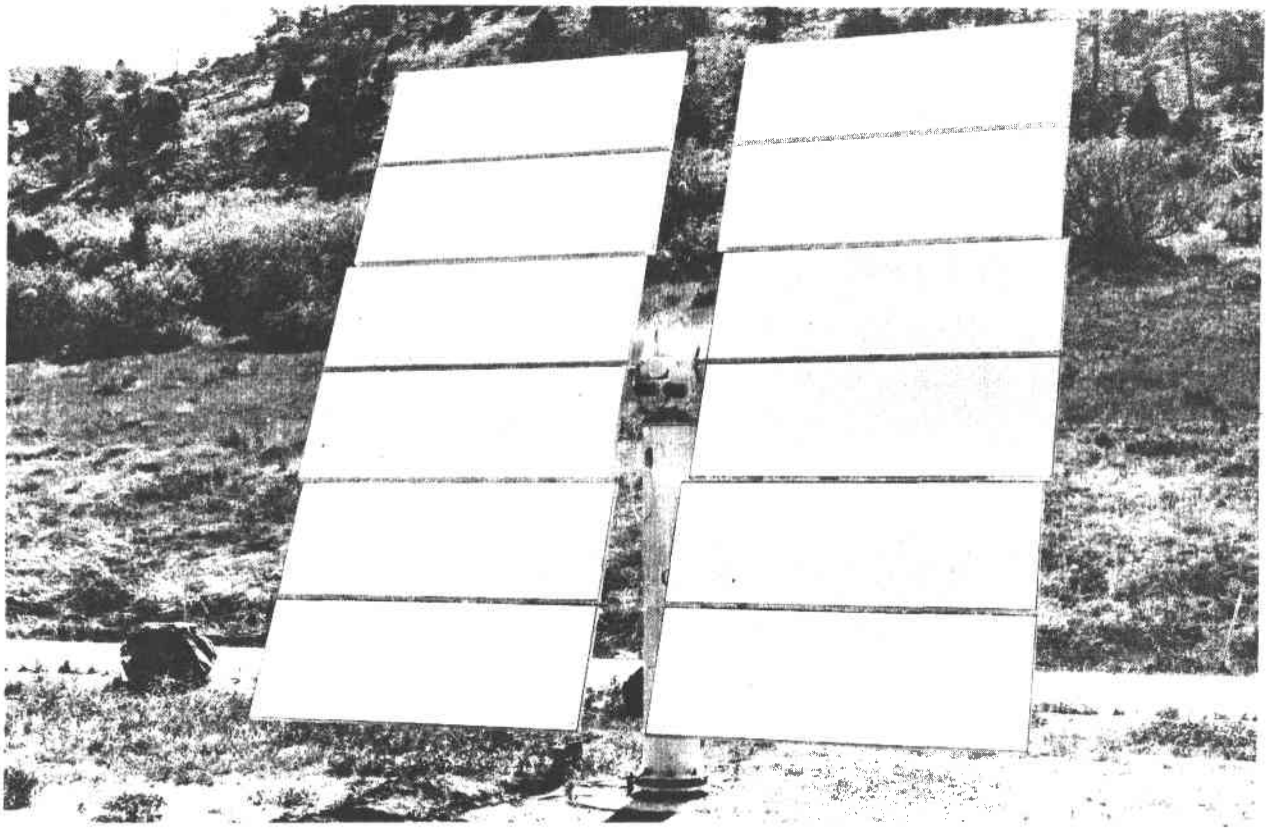


*Figure 1.4-3 Prototype Barstow Heliostats*

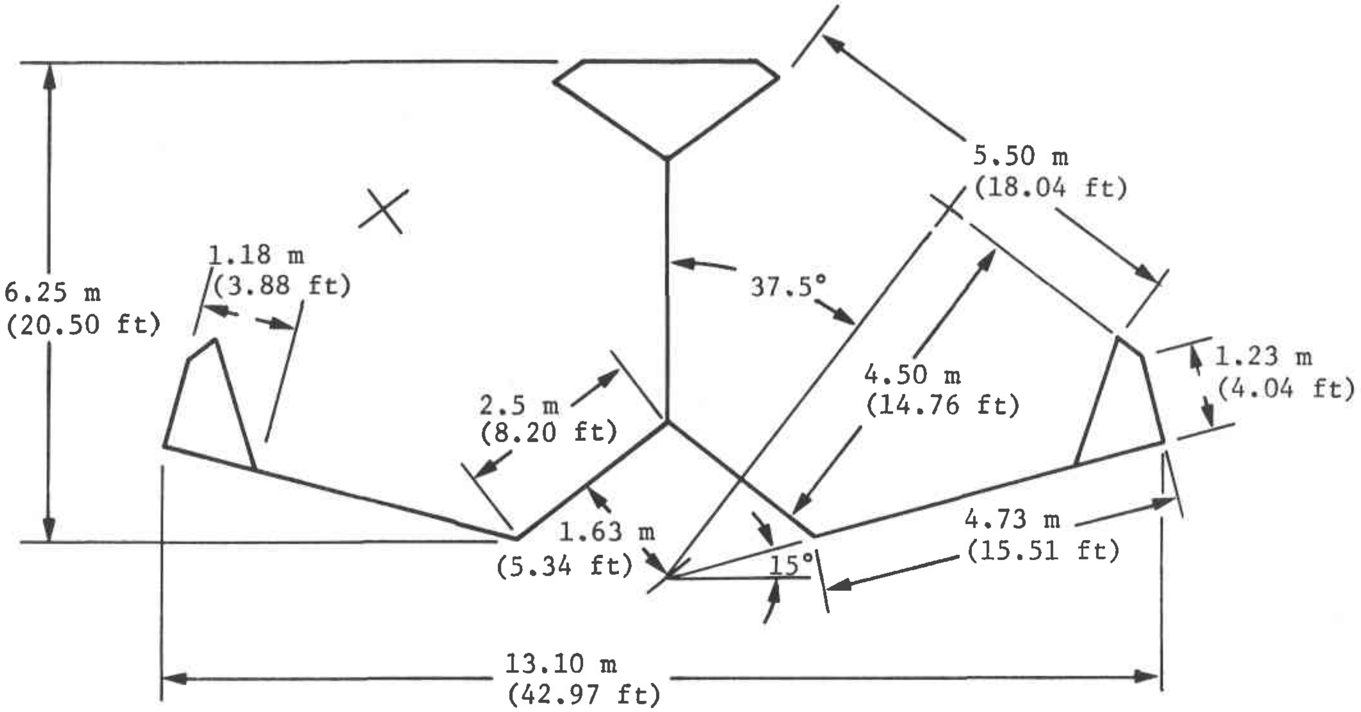


*Figure 1.4-4 Simplified Plan View of Twin-Cavity Receiver*

losses, both while in operation and overnight when the cavity doors are closed. Natural circulation was selected because it is simple and easily adapted to the given configuration. Also, natural circulation has a history of high reliability and eliminates the forced-circulation pump and associated costs. Natural circulation is inherently self-compensating for energy input variations. A natural-circulation receiver is also relatively tolerant of impure feedwater because of its large tubes, low tube-exit steam quality, large water inventory, and drum blowdown capability.

The natural-circulation type of solar receiver has been well-proved through the design, construction, and test of two complete working units with 1- and 5-MWt capacities. These receivers have amply demonstrated thermal and hydraulic stability as well as ease of control under very severe transient and steady-state operating conditions. Both receivers have been operated using infrared lamp radiation to simulate solar imput, and the 1-MWt unit was operated very successfully in the environment of the CNRS solar furnace at Odeillo, France.

The function of the field piping subsystem is to transport steam from the receiver outlet to the injection wellheads. Approximately 12 wells will be injected in parallel at any given time. This injection pattern will move gradually through the oil field at the rate of about 3 wells per year over the 26-year operational life of the system. The feeder lines to the wells connect to a common manifold that is fed by both the solar thermal system and the three fossil boilers. The routing of the trunk line from the receiver and the progression of the injection well pattern have been established on the basis of minimizing total installed length of pipe. Pipe diameters and insulation design were selected on the basis of minimizing costs, while maintaining reasonable pressure drop and heat loss characteristics.

Some of the key features of the STEOR system are summarized in Table 1.4-1.

## 1.5 SYSTEM PERFORMANCE AND ECONOMIC FINDINGS

Performance of the STEOR system was evaluated using three validated computer models--MIRVAL, TRASYS and STEAEC. The MIRVAL and TRASYS programs were extensively used to calculate the design point (noon, day 58) and off-design point performance of the collector and receiver subsystems. Performance parameters were developed from these performance estimates for input to the STEAEC system simulation model to evaluate the annual performance of the STEOR system with insolation and weather data representative of the Edison site.

*Table 1.4-1 Conceptual Design Summary*

1. Prime Contractor: Martin Marietta Corporation

2. Major Subcontractors: Exxon Research & Engineering, Foster Wheeler Development, Black & Veatch Consulting Engineers

3. Site Process: Thermal-Enhanced Oil Recovery Using Steam at 270 - 285°C (518 - 545°F)

4. Site Location: Edison Oil Field - Bakersfield, California

5. Design Point: Noon on February 27, Insolation of 0.95 kW/m$^2$

6. Receiver

   Receiver Fluid: Water/Steam
   Configuration: Twin Cavity
   Type: Natural Circulation
   Elements: Preheater and Boiler
   Output Fluid Temperature: 297°C (567°F)
   Output Fluid Pressure: 8274 kPa (1200 psia)
   Tower Height: 90m (259 ft)

7. Heliostats

   Number: 818
   Individual Mirror Area: 49.05 m$^2$ (528 ft$^2$)
   Cost: \$230/m$^2$ (\$21.36/ft$^2$)
   Type: Generic - Second Generation
   Field Configuration: 2.62 rad (150°) North Field

8. Storage: None

9. Total Project Cost: \$14,033,467 (\$230/m$^2$ Heliostat Cost)

10. Construction Time: 1.5 Years

11. Solar Plant Contribution at Design Point: 29.3 MWt

12. Solar Fraction - Annual: 25.1%

13. Annual Fossil Energy Saved: 44,058 Barrels at 5.800 x 10$^6$ Btu/Barrel

14. Type of Fuel Displaced: Heavy Crude Oil at 5.93 x 10$^6$ Btu/Barrel

14a. Annual Energy Produced: 55,870 MWh$_t$ (190,684 MBtu)

15. Ratio of $\frac{\text{Annual Energy Produced}}{\text{Total Heliostat Field Area}}$: 1.39 MWht/m$^2$

16. Ration of $\frac{\text{Capital Cost}}{\text{Annual Fuel Displaced}}$: $\frac{\$\ 14{,}033{,}467}{74{,}301\ \text{MWht}} = \$188.87$ MWht

17. Site Insolation (direct normal)

   Annual Average: 2.26 MWh/m$^2$
   Source: SOLMET TMY for Fresno, Ca
   Site Measurements: Start Date: 1/1/80, Continuing
   Total Horizontal Insolation Sensor
   Direct Normal Insolation Sensor

The STEOR system design point output is 29.3 MWt (100 MBtu/h), based on a reference insolation level of 950 W/m$^2$. The overall design point system efficiency, defined by power available to the injection wells divided by 950 W/m$^2$ times the mirror area, is calculated at 76.9%. This high efficiency is due to the north field configuration (field efficiency = 81.7%) and the cavity receiver configuration (receiver efficiency = 94.2%).

The annual system performance was calculated using the SOLMET typical meteorological year (TMY) insolation and weather data for Fresno, CA, the nearest SOLMET station and typical of San Joaquin weather patterns. The average daily insolation, based on the SOLMET data, is 6.21 kWh/m$^2$. The annual STEOR system stairstep is shown in Figure 1.5-1. As depicted on the stairstep, the STEOR system has an average annual efficiency of 61.5%, providing a total of 55,870 MWht (190,684 MBtu) to the injection wells.

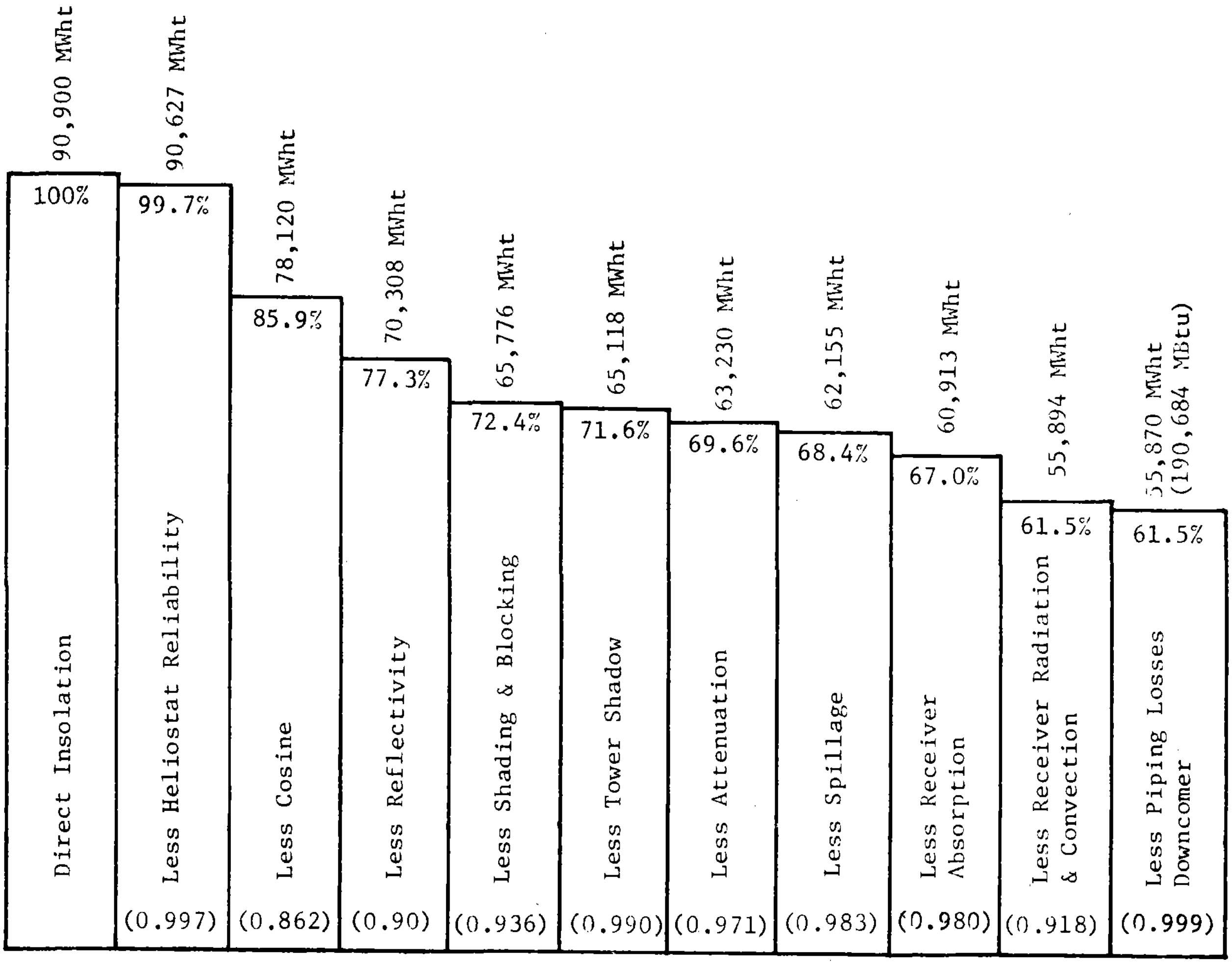


*Figure 1.5-1 Annual System Efficiencies*

The yearly output from the STEOR system is equivalent to displacing 685 $m^2$ (43,092 bbl) of oil burned in a conventional boiler of the type currently used in TEOR operations. Over the 26-year projected operating period, a total of over 178,000 $m^3$ (1.1 million bbl) of oil would be displaced, in addition to the heavy oil production resulting from the solar-produced steam injected.

With the steadily increasing price of oil, this oil displacement enables near-term economic viability of solar thermal EOR systems, even with heliostat costs in the \$230 to \$275/$m^2$ range. Installed heliostat costs of \$230/$m^2$ were used as a baseline "post-Barstow" heliostat cost, with a total STEOR system cost of just over \$14,000,000 as shown in Figure 1.5-2. The STEOR system was then compared to a conventional oil-fired steamer using two fuel cost scenarios. The first of these fuel cost scenarios assumed that the oil produced at the site (and burned in the steamer) was valued at the present world oil price, \$5.06/MBtu (\$30.00/bbl), escalating at 2.8% over a base inflation rate of 7%, and subject to all applicable ad valorem, royalty and windfall profits taxes. The second fuel cost was provided by Sandia Laboratories, calling for a fuel cost of \$4.00/MBtu, escalating at 4% over the base rate of inflation, given as 8% per year.

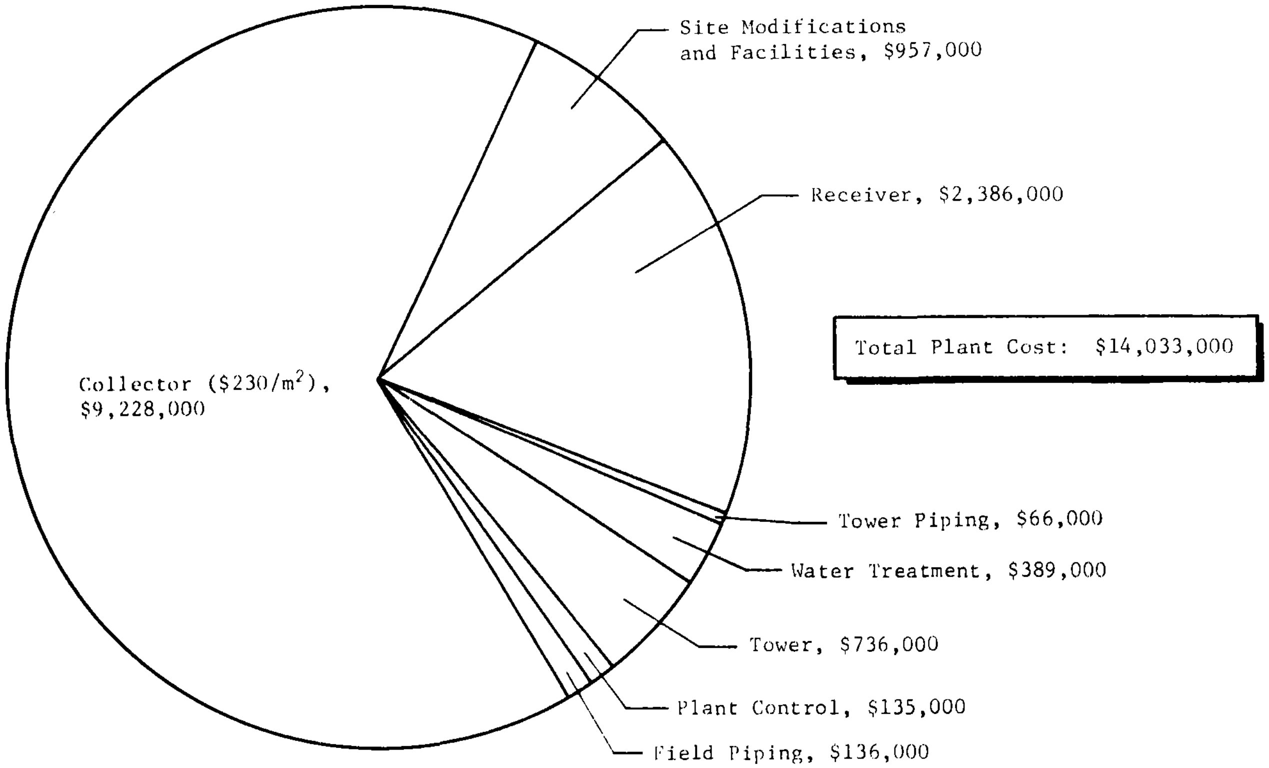


*Figure 1.5-2 STEOR Construction Cost Estimate (1980\$)*

Table 1.5-1 shows the significant (15 to 30%) reduction in the levelized cost of energy achieved with the STEOR over the 26-year operating life.

*Table 1.5-1*
*Levelized Cost of Energy Results, Baseline Economics, 1980$*

| | Conventional Oil-Fired Steamer | Solar Thermal System |
|---|---|---|
| World Oil Price Economics | \$27.88/MWht<br>(\$8.17/MBtu) | \$23.89/MWht<br>(\$7.00/MBtu) |
| Sandia-Supplied Fuel Costs | \$35.53/MWht<br>(\$10.41/MBtu) | \$24.26/MWht<br>(\$7.11/MBtu) |

Using the world oil price economics, the STEOR break-even operating period of 18.5 years is less than the projected (baseline) steam drive operating period of 26 years; using Sandia-supplied fuel costs and escalation, the STEOR system breaks even in just over 13 years.

The near-term economic viability of the STEOR system is perhaps better illustrated in Figures 1.5-3 and 1.5-4, examining both heliostat break-even costs and break-even oil escalation rates. As shown in the first

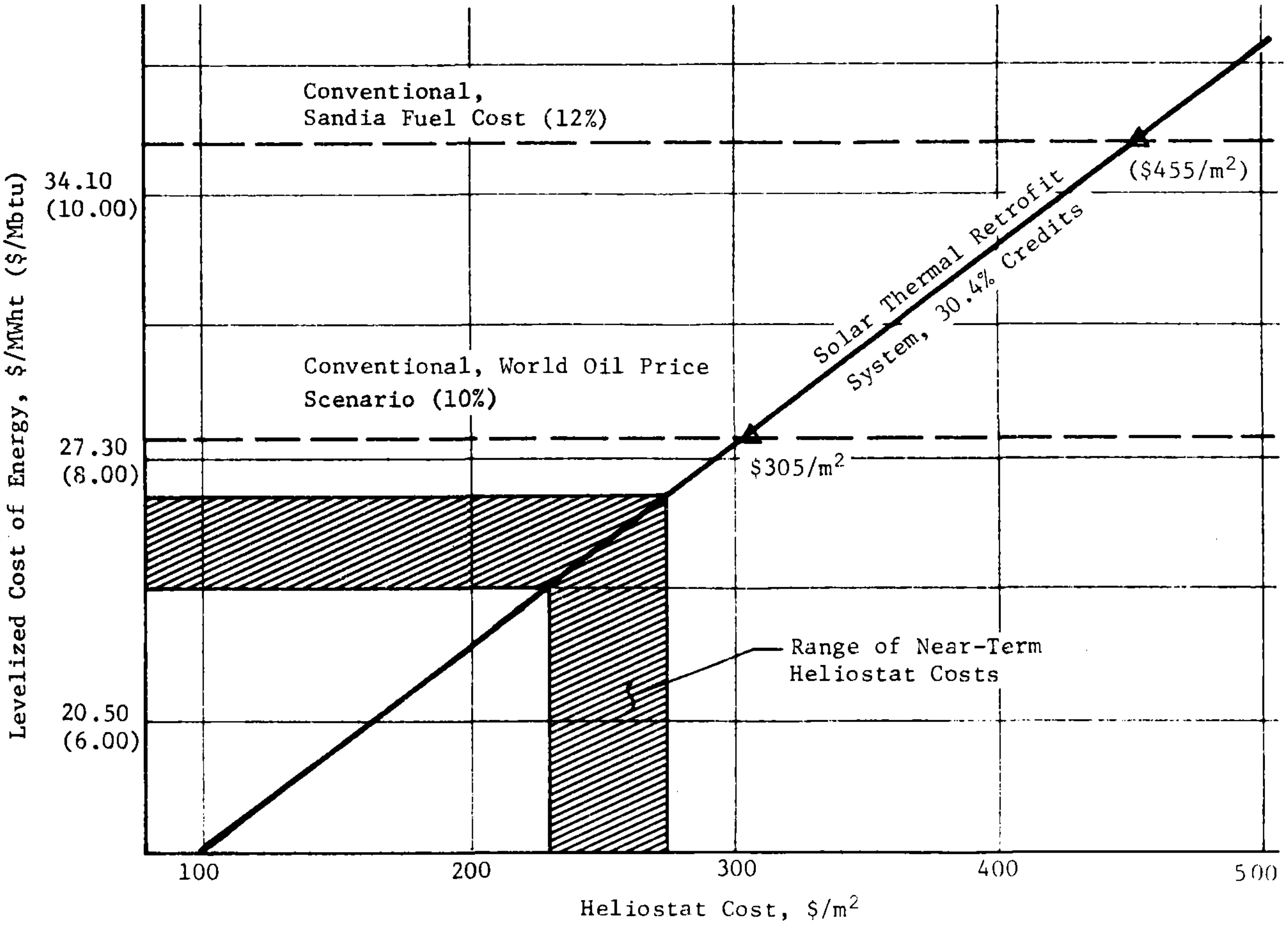


*Figure 1.5-3 Effect of Heliostat Cost on Energy Cost*

figure, the STEOR system remains economically viable with heliostat costs as high as \$450/m$^2$ using an oil escalation rate of 12%. Although the break-even heliostat cost (including 15% rate of return) is reduced to \$305/m$^2$ using the more conservative world oil price scenario, it is still above the range of the realistic post-Barstow heliostat costs shown in the figure.

The interrelationship of break-even heliostat cost and oil escalation rates is shown in Figure 1.5-4. For both fuel cost scenarios, the break-even oil escalation rate can be easily determined: for the baseline \$230/m$^2$ heliostat cost, the STEOR system remains viable for escalation rates as low as 8.6%.

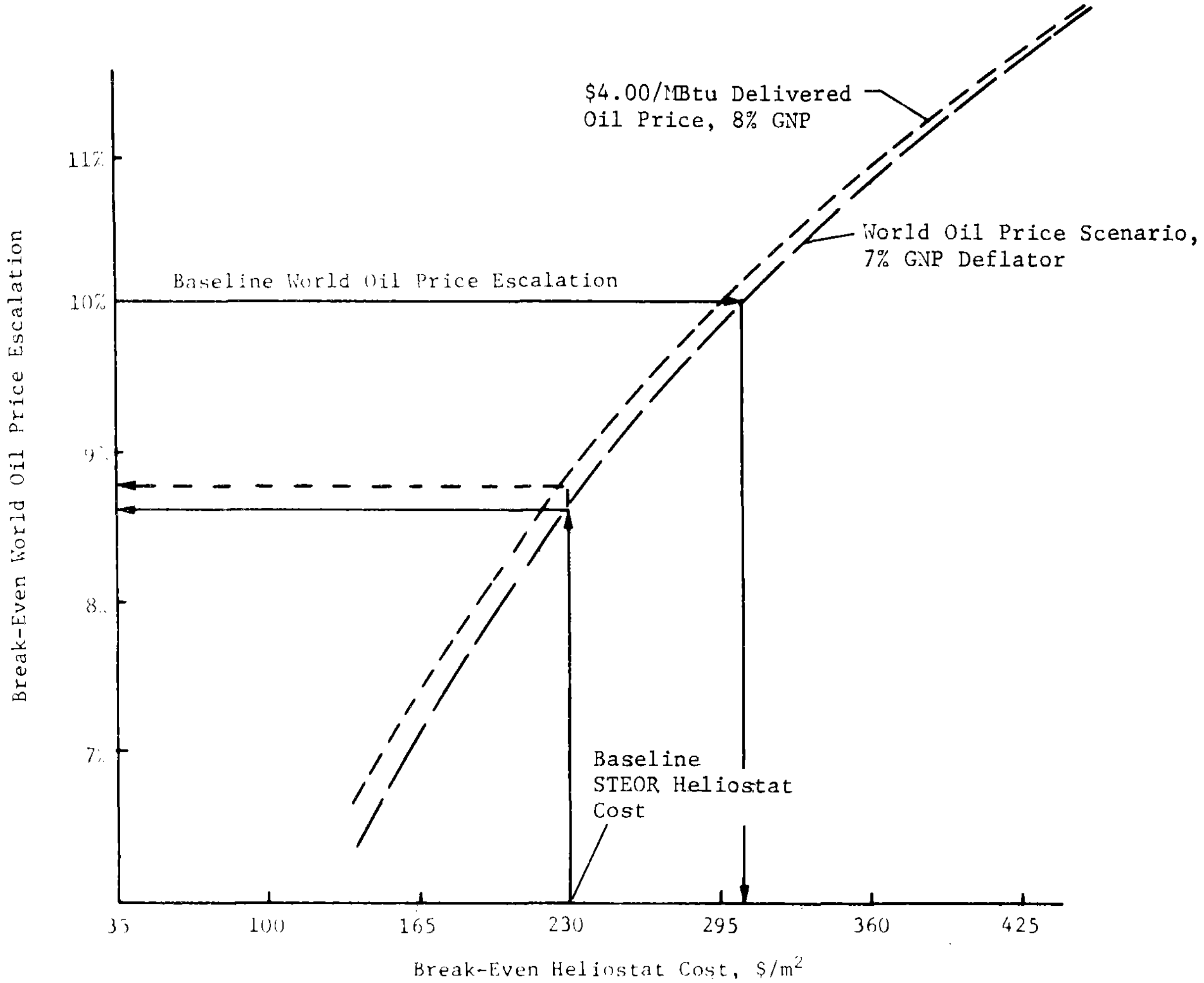


*Figure 1.5-4 Break-Even Heliostat Cost/Oil Escalation Rate*

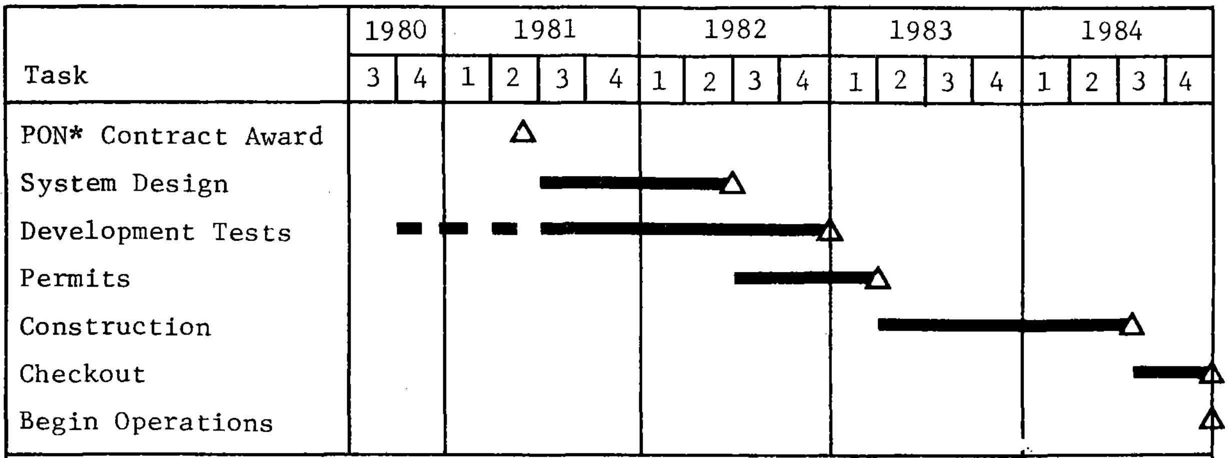
The overall result of these economic analyses can only lead to a single conclusion--using realistic near-term heliostat costs, the solar thermal EOR system described in this study is an economically viable alternative to conventional oil-fired TEOR systems.

## 1.6 DEVELOPMENT PLAN

The development plan represents a guideline for evolving the solar thermal-enhanced oil recovery system from its present state of a conceptual design to a fully installed and operating hardware system at the Edison field. System development will be implemented as a joint Exxon/DOE project, and is consistent with the basic objectives and milestone criteria presented in the DOE Solar Repowering/Industrial Retrofit Plan issued by the San Francisco Operations Office in January 1980.

The word "development" as used this report is construed to include not only the kinds of activities related to resolution of design, hardware and/or process uncertainties, but also the tasks of detailed design, procurement, fabrication, installation and checkout that are necessary to produce an operational facility. It is significant that no hardware or process technologies are involved in this conceptual design that have not been demonstrated in operating systems. Only two test activities are included in the development plan. The first is a steam drive evaluation to be performed at the Edison field to determine the optimum operational strategy for future TEOR production. This will be conducted even if solar hardware is not to be installed. The second test planned is an operational demonstration of the Martin Marietta 5-MW receiver using the same feedwater quality found at the Edison site.

A schedule of the key milestones contained in the development plan is shown in Figure 1.6-1.



* Program Opportunity Notice.

*Figure 1.6-1 Development Schedule*

## 1.7 SITE OWNER'S ASSESSMENT

In spite of the conceptual nature of this study and the paucity of operational and cost data, Exxon believes that the solar central receiver technology should be feasible for use at the Edison field. A technical central receiver system demonstration in an operational environment is necessary for users to have confidence in the performance, cost, and reliability of this system. Then, if as projected, a reasonable return on capital expended can be achieved, the solar thermal-enhanced oil recovery systems should make a significant penetration into the enhanced oil recovery operations.

While Exxon has no other active TEOR sites in California, we have estimated as part of DOE contract DE-AC03-79CS30307 that a solar potential of 1670 MWt (5700 MBtu/h) of installed steam capacity will exist in the Kern County area alone by the end of this century to help recover known heavy oil reserves.

Further opportunities will exist in other heavy oil-producing areas including Texas and Venezuela. At the Edison field, it may be possible to more than double the size of the heliostat field as demand for steam increases, depending on economic and geologic factors that have yet to be determined.

The conceptual design presents no severe or unusual safety or operational requirements and can be accommodated in the oil field production environment. The STEOR system should result in reduction of total ultimate atmosphere emissions, with the only negative impact being the loss of some 80 acres of farmland.

Two restrictions on energy use face Exxon at the Edison site--restrictions imposed by the California Air Resources Board on emissions from fossil-fired steamers, and restrictions on use of oil imposed by the Fuel Use Act of 1978. Solar systems could assist in meeting both of these restrictions as an increased demand for heavy oil causes an increase in the use of TEOR in California.

The development plan and schedule presented are technically feasible and do not involve any special problems. Exxon would prefer to have the project continue using a variety of tax incentives or accelerated depreciation schedules in the manner of the currently available, but time-limited, tertiary incentive revenue program rather than as a series of DOE contracts. This would permit private industry to take the lead in the project with government assistance in sharing the risk of a new and largely operationally unproven but very promising technology.

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