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Solar Cogeneration Assessment Report of Solar Central Receiver Cogeneration Conceptual Design Study Projects

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SOLAR COGENERATION ASSESSMENT REPORT OF SOLAR CENTRAL RECEIVER COGENERATION CONCEPTUAL DESIGN STUDY PROJECTS

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ABSTRACT

In mid-1980, the Department of Energy solicited proposals for conceptual designs and economic studies applicable to central-receiver-based cogeneration facilities. Seven proposals were selected and have been completed. This document contains a brief description of the conceptual design, a summary of the prime contractor's economic analysis, and the site owner's assessment for each project. In spite of the many variables that make absolute comparisons impossible, the projects indicate that solar central receiver cogeneration has a number of promising applications and merits further study in selected areas.

PREFACE

The cogeneration work described in this report resulted from contracts through the San Francisco Operations Office of the Department of Energy. This report is not designed to be an in-depth evaluation or assessment of either the entire Solar Cogeneration Program or the individual proposals. Most of the material in this document was taken from the final reports published by the contractors. Although I have summarized the economic analyses made by the prime contractors, I have not attempted to verify or perform an independent analysis of system performance, project costs, or economics. The "Results and Conclusions" are my own. If original intents and meanings have been misconstrued through paraphrasing or condensing, it has occurred inadvertently.

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SOLAR COGENERATION ASSESSMENT REPORT

Introduction

The term "cogeneration" refers to those systems in industry that produce electrical or mechanical energy, or both, in combination with useful thermal energy. Because cogeneration systems deliver electrical energy and process heat more efficiently than systems that deliver this energy separately, cogeneration conserves fossil fuel. Fuel usage is further reduced if solar thermal capabilities are added to a fossil-fueled cogeneration facility.

In a solar cogeneration system, a solar central receiver is integrated into a new or existing cogeneration facility (Figure 1). Solar cogeneration not only can save fuel, but also can lower capital cost per unit energy consumed because of the efficient use of the collected solar energy. Thus, a solar cogeneration system can reduce industry's dependence upon nonrenewable and imported fuels.

Recognizing the value of this system, the Department of Energy (DOE) initiated the Solar Cogeneration Program within its Solar Thermal Central Receiver Program. The objectives for the Solar Cogeneration Program were twofold: to develop solar central receiver technology, and to demonstrate this technology as early as possible through near-term applications. Solar cogeneration systems offer industry additional central receiver system options, thereby generating increased industrial participation in solar thermal technology.

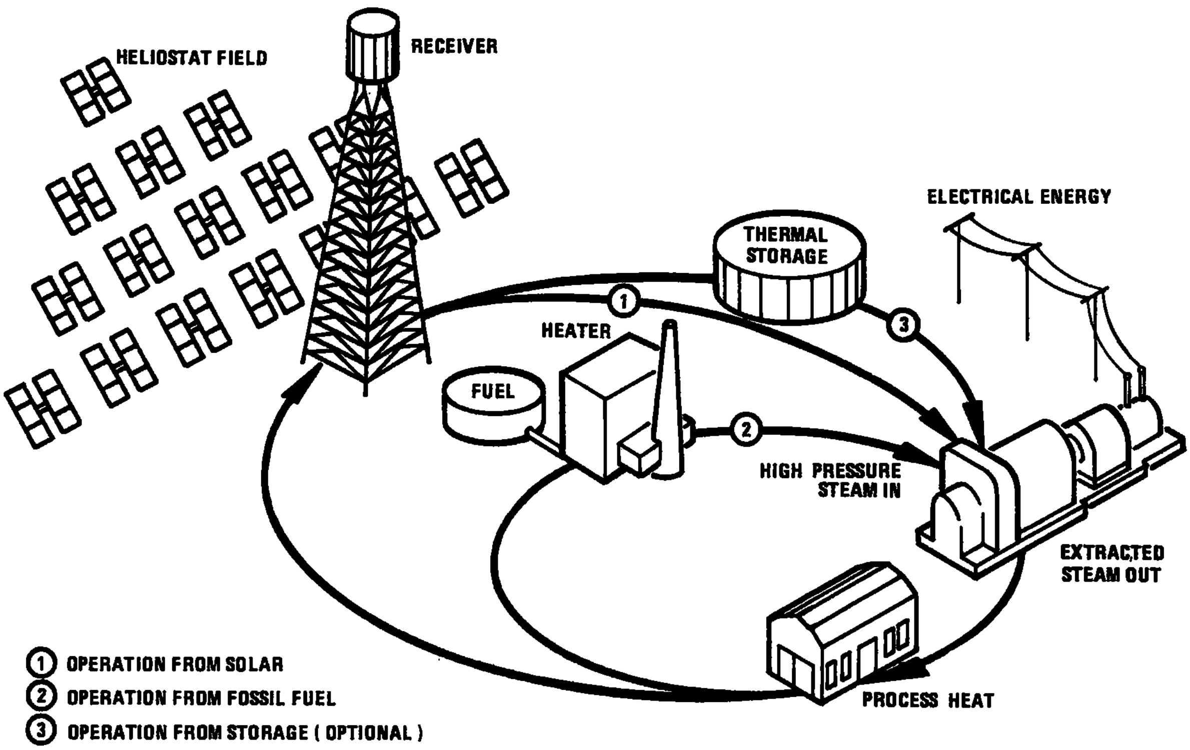


Figure 1. Schematic of a Solar Cogeneration Facility

Program Development

In the late 1970s, studies of solar central receiver systems indicated that solar cogeneration had good potential for industrial and utility applications. During the same period of time, energy legislation favorable to cogeneration was enacted.

First, the provisions of the National Energy Act of 1978 discouraged the use of natural gas and petroleum in electrical power plants and major fuel-burning installations. The Act also provided tax credits for investing in equipment that used renewable energy resources (e.g., solar). Second, the requirements of the Power Plant and Industrial Fuel Use Act (FUA) effected a significant regulatory cost burden on organizations building installations in areas where environmental or other concerns prevented the use of coal or other alternate fuels. Since solar cogeneration facilities are not classified either as electrical power plants or major fuel-burning installations, they are exempt from the requirements of the FUA.* This exemption gives solar cogeneration facilities advantages over other types of electrical power plants or major fuel-burning installations. Third, the Public Utilities Act of 1978, PL-95-617, Section 210, requires the Federal Energy Regulatory Commission to prescribe "such rules as it determines necessary to encourage cogeneration and small power production."

In response to the studies and this legislation, DOE in mid-1980 solicited proposals for site- and application-specific conceptual designs and economic studies applicable to central-receiver-based cogeneration facilities. Seven proposals were selected for negotiation. Awarded from September 1980 through January 1981, the contracts initiated the development of solar cogeneration conceptual design studies and the definition of subsequent development plans. The San Francisco Operations Office of the DOE managed the projects; Sandia National Laboratories, Livermore, served as technical monitor, and The Aerospace Corporation acted as technical advisor. Mid-term reviews were held from February to April 1981, and all projects were completed by September 1981. The final reports have been released to the DOE Technical Information Center in Oak Ridge, Tennessee, and are available through the National Technical Information Service in Springfield, Virginia.

*See the proposed rules for implementation, published Aug. 31, 1979.

The seven cogeneration proposals cover a wide range of geographical areas (Figure 2) and address several potential applications: sugar cane processing, natural gas processing, enhanced oil recovery, sulfur mining, copper smelting, and space heating and cooling. Each designer-user submitted a proposal for a particular industrial or commercial use.

This section summarizes the seven proposals. For each project, a brief description of the conceptual design is provided, followed by a summary by the prime contractor's economic analysis. The economic analyses were made by the individual contractors on the basis of estimated project cost and performance, and information from the site owner; no independent economic analyses were performed. Site user assessments, taken directly from the contractor's final reports, are also included for each project.

Tables I-V present the key aspects of the projects. These data are excerpted from the published final reports. Some inconsistencies exist (with the project costs in particular*), and direct comparisons should be made with caution. The costs per unit energy or power are not comparable.

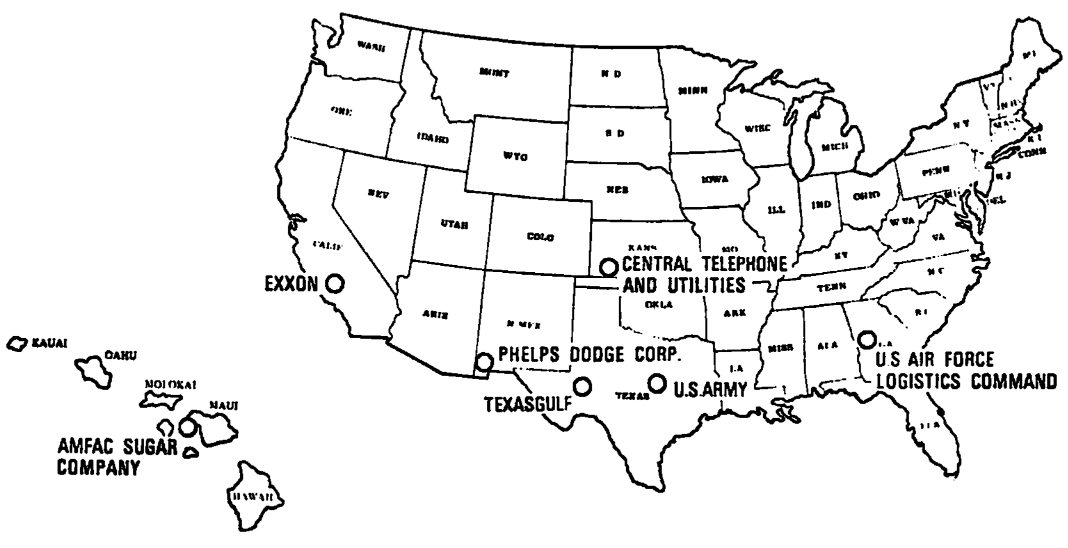


Figure 2. Solar Cogeneration Facility Sites

*For more information on the project costs, see the Results and Conclusions section.

TABLE I. SOLAR COGENERATION PROJECTS: PROJECT/SITE DATA SUMMARY

PROJECT/SITE DATA	PRIME CONTRACTOR/USER						
	BGI/AMFAC	B&V/CTU-WP	EXXON/EXXON	GE/TEXASGULF	G&H/PHELPS DODGE	MDAC/FORT HOOD	WESTINGHOUSE/ ROBINS AFB
Prime Contractor	Bechtel Group Inc.	Black & Veatch Consulting Engineers	Exxon Research & Engineering Co.	General Electric Co. Advanced Energy Programs Dept.	Gibbs & Hill Inc.	McDonnell Douglas Astronautics Co.	Westinghouse Electrical Corp. Advanced Energy Systems Div.
Project Manager	Jack R. Darnell	John E. Harder	Patrick Joy	Howard E. Jones	Robert Prieto	Robert P. Dawson	Robert W. Devlin
Subcontractors	Amfac Sugar Co. (George E. St. John)	Central Telephone & Util.- Western Power (E. C. Rhodes)	Martin Marietta Corp. (Martin Brzeczek)	Texasgulf, Inc. (Ken Bishop)	Phelps Dodge Corp. (Michael Shaw)	Stearns-Roger (W. R. Lang)	Heery & Heery, Inc. (R. A. Yelvington)
	Northrup Inc. (Roy L. Henry)	Babcock & Wilcox Co. (O.W. Durrant)	Badger Energy Inc. (Carl Silverman)	Brown & Root Dev. Co. (Pete Karnoski)	Boeing Engineering Const. Co. (Donald Zimmerman)	Univ. of Houston Energy Lab (L.L. Vant-Hull)	Foster Wheeler Dev. Corp. (S. F. Wu)
	Foster Wheeler Development Corp. (S. F. Wu)	Foxboro Co. (J. C. Barlow)	Pacific Gas and Electric Co. (Harold Seielstad)				
Site and Location	Pioneer Mill Co., Ltd., Lahaina, Maui, Hawaii	Cimarron River Station, Liberal, KS	Exxon Edison Field Bakersfield, CA	Comanche Creek Sulfur Mine, Fort Stockton, TX	Phelps Dodge Hildalgo Smelter, Playas, NM	Fort Hood Army Base, Killeen, TX	Robins AFB, Warner Robins, GA
Site Latitude Longitude	20°54'N 156°42'W	37°10'N 100°45'W	35°18'N 118°50'W	30°52'N 102°55'W	31°46'N 108°31'W	31°07'N 97°43'W	32°36'N 83°36'N
Elevation, m (ft)	37 (120)	802 (2630)	180 (600)	913 (2995)	1318 (4385)	242 (796)	93 (306)

TABLE II. SOLAR COGENERATION PROJECTS: PLANT DATA SUMMARY

PLANT DATA	PRIME CONTRACTOR/USER						
	BGI/AMFAC	B&V/CTU-WP	EXXON/EXXON	GE/TEXASGULF	G&H/PHELPS DODGE	MDAC/FORT HOOD	WESTINGHOUSE/ROBINS AFB
Process	Sugar Cane Processing	Natural Gas Processing	Enhanced Oil Recovery	Sulfur Mining	Copper Smelting	Space Conditioning, Domestic Hot Water	Process Heat Space Conditioning, Domestic Hot Water
Fluid	Steam	Steam	Steam	Saturated Water	Hot Air	Steam	Steam
Process Temp.°C (°F)	135 (275)	204 (400)	293 (560)	177 (350)	527 (980)	121 (250)	178 (353)
Existing Turbine Type	GE Double Automatic Extraction	GE Tandem Compound Double Flow Nonreheat Condensing					
Added Turbine Type			Single Reheat Condensing	GE Uncontrolled Extraction	Five Gas Turbines 2-Shaft Indirect Firing	MTI Axial Steam Rankine	Commercial Back Pressure
Turbine Rating	9375 KVA 8400 KWe	44 MWe	20.4 MWe	3.5 MWe	11330 KVA (ea) 10.2 MWe (ea)	570 KWe	1000 KVA 725 KWe
Turbine Inlet:							
Temp., °C (°F) Press., MPa (psia)	399 (750) 5.96 (865)	510 (950) 8.72 (1265)	538 (1000) 8.27 (1200)	483 (900) 5.2 (750)	816 (1500) .4 (58)	399 (750) 4.9 (715)	399 (750) 5.96 (865)
Extraction and/or Exhaust Temp., °C (°F)	260 (500) 135 (275)	204 (400)	38 (100)	325 (617) 61 (141)	527 (980)	172 (342)	186 (366)

TABLE III. SOLAR COGENERATION PROJECTS: SYSTEMS DATA SUMMARY

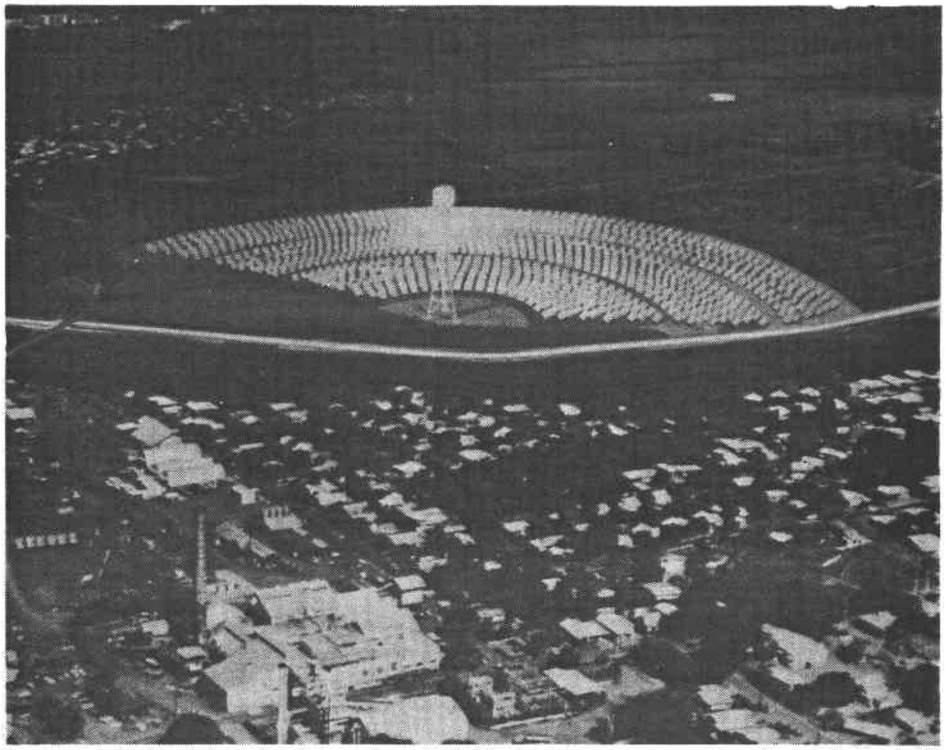
SYSTEMS DATA	PRIME CONTRACTOR/USER						
	BGI/AMFAC	B&V/CTU-WP	EXXON/EXXON	GE/TEXASGULF	G&H/PHELPS DODGE	MDAC/FORT HOOD	WESTINGHOUSE/ ROBINS AFB
Collector System:							
Collector Field Configuration	North 150° Sector	North 156° Sector	North 180° Sector	North 108° Sector	Surround	North Assymetrical	North Assymetri-cal
No. of Heliostats	815	1057	3295	588	10,441	242	251
Size of Heliostats, m^2	52.8	52.77	57.4	52.8	49.89	56.84	52.77
Total Mirror Area, m^2	43,000	55,780	189,133	31,030	521,000	13,755	13,245
Land Area, Acres	42.3	55	321	41	410	11.9	15.5
Utilization Ratio mirror m^2/land m^2	.25	.25	.15	.19	.314	.29	.21
Receiver System:							
Fluid	Water/Steam	Water/Steam	Molten Salt	Water/Steam	Air	Hitec (molten salt)	Water/Steam
Configuration	Two-Cavity	External, Circular	Two-Cavity	External, Flat Panel	Four-Cavity	Cavity Cone	External, Flat Panel
Type	Natural Circulation, Recirculation, Super Heater	Forced Circulation, Recirculation, Super Heater	Forced Circulation, Recirculation	Normal Circulation, Recirculation, Saturated Boiler	Forced Cirulation Once-Through	Cavity Cone, Forced Circulation Once-Through	External Flat Panel, Natural Recirculation, Super Heater
Output Power, MW_t	26.2	37.1	115.4	19.8	270	8.7	8.8
Annual Output MWh_t	57,100	66,000	243,600	48,400	650,000	13,800	10,900
Output Temp.,°C (°F)	438 (820)	520 (968)	566 (1050)	272 (521)	816 (1500)	454 (850)	410 (770)
Output Press., MPa (psia)	6.85 (994)	11.07 (1605)	2.5 (360)	5.65 (820)	.4 (58)	.1 (15)	6.1 (890)
Efficiency, D.P. (Annual)	.91 (.89)	.89 (.86)	.91 (.85)	.93 (.91)	(.85)	.91 (.89)	.88 (.81)
Tower Type	Tubular Steel	Structural Steel	Reinforced Concrete	Structural Steel	Reinforced Concrete	Structural Steel	Structural Steel
Tower Height, m(ft)	72 (236)	74 (244)	137 (450)	69 (225)	184 (604)	53 (175)	54 (178)
Storage System: Thermal Storage	None	None	Salt	None	Slag	Salt	None
Amount of Storage, MWh_t	---	---	380	---	4080	20	---

TABLE IV. SOLAR COGENERATION PROJECTS: ENERGY DATA SUMMARY

ENERGY DATA	PRIME CONTRACTOR/USER						
	BGI/AMFAC	B&V/CTU-WP	EXXON/EXXON	GE/TEXASGULF	G&H PHELPS DODGE	MDAC/FORT HOOD	WESTINGHOUSE/ ROBINS AFB
Design Point	Equinox 1 pm	Mar 21 Noon	Day 189 Noon	Equinox Noon	Winter Day	Fall Equinox Noon	Winter Soltice Noon
Insolation:							
Design Peak, w/m^2	950	950	950	950	950	940	950
Annual Average, $KWh/m^2/day$	6.85	6.1	6.22	7.12	6.63	4.7	4.25
Solar Contribution:							
Design Point							
Electrical, MWe	3.4	15	20.4	2.2	46	.6	.68
Mechanical, MW_m	.3	---	---	---	---	---	---
Process Heat, MW_t	17.1	3.7	13.2	16.1	54.2	3.5	7.9
Annual							
Electrical, MWhe	7,400	20,000	43,000	5,500	108,000	800	600
Mechanical, MWh_m	423	---	---	---	---	---	---
Process Heat, MWh_t	22,000	13,500	105,600	39,300	533,000	10,100	9,600
Solar Efficiency, Rec out/field insolation							
Design Point	.63	.70	.65	.67	.55	.67	.69
Annual	.53	.58	.55	.60	.52	.52	.54
Cogeneration Utilization Efficiency, Annual %	53	41	60	79	79	76	75
BBL of oil saved, Annual (equiv.)	36,600	48,100	139,500	40,100	436,000	9,700	8,300
Type of fuel saved	No. 6 Fuel Oil	Natural Gas, Coal	Heavy Crude	Natural Gas	Oil, Coal	Natural Gas	Natural Gas, Oil
Annual Energy/Mirror Area, MWh/m^2	1.33	1.18	1.29	1.56	1.25	1.00	.82
Solar Fraction:							
Design Point	.50	.25	.60	.17	---	1.00	.35
Annual	.13	.10	.50	.04	.80	.68	.06

TABLE V. SOLAR COGENERATION PROJECTS: COST DATA SUMMARY

COST DATA	PRIME CONTRACTOR/USER						
	BGI/AMFAC	B&V/CTU-WP	EXXON/EXXON	GE/TEXASGULF	G&H/PHELPS DODGE	MDAC/FORT HOOD	WESTINGHOUSE/ ROBINS AFB
Project Cost, million 80$	31.1	33.2	120	20.7	425	19.1	11.0
Heliostat Costs, $/m^2	383	215	203	260	145	260	260
Cost/Fuel Displaced, $/MWh	500	410	510	300	570	1160	780
Cost/Annual Receiver Energy, $/MWh	550	500	490	430	650	1380	1010
Cost/Peak Receiver Power, $/KW	1190	900	1040	1040	1570	2200	1200
O&M Cost, Annual 1980 $K O&M, % of Capital	406 1.6	135.6 .4	2400 1.8	252 1.2	1500 .3	97.4 .5	166.4 1.5



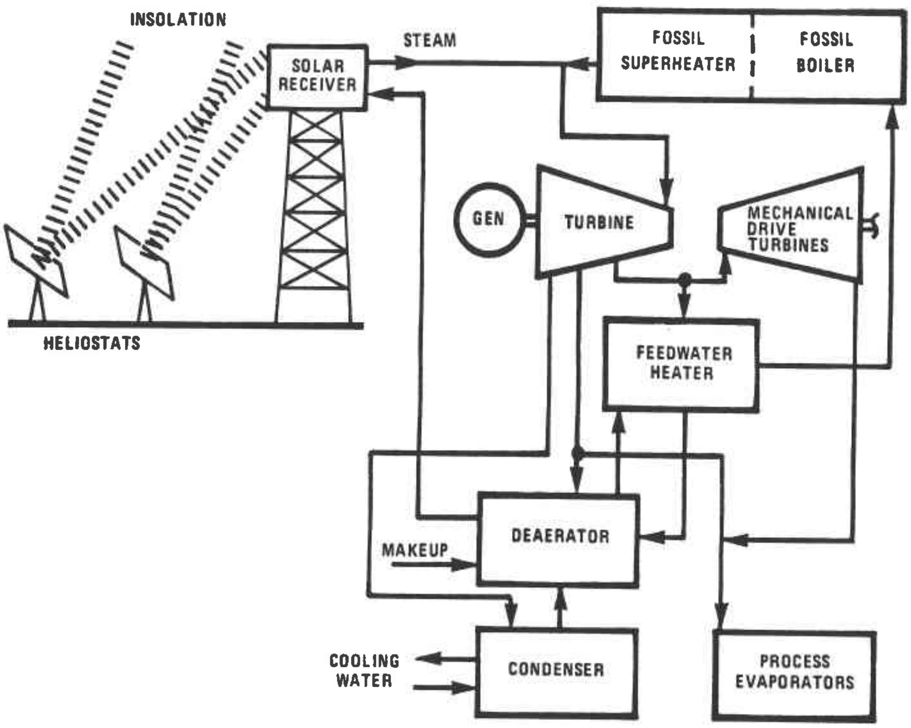


Figure 3. Pioneer Mill Company's Sugar Factory Solar Cogeneration Project

PIONEER MILL COMPANY, LTD.
Lahaina, Maui, Hawaii

Prime Contractor: Bechtel Group, Inc.

Subcontractors: Amfac Sugar Co.; Foster Wheeler Development Corp., Northrup, Inc.

Receiver Type/Fluid	Cavity/Water	Net Output Power From Solar	17.1 MWt 3.4 MWe 0.3 MWm
Receiver Output Power	26.2 MWt		
Number of Heliostats	815	Equiv. BBL of Oil Saved Annually	36,600

Project Cost in Millions (1980$) 31.1

Description

Pioneer Mill Company, Ltd., a subsidiary of Amfac Sugar Company, operates a sugar factory that processes sugar cane into raw sugar and molasses. The mill has an existing cogeneration facility that supplies both steam for mechanical drive turbines and process evaporations, and electric power for irrigation pumps. The mill consumes #6 oil to supplement the use of bagasse (the cellulose residue of the processed sugar cane) in the existing dual-fired boiler in order to produce steam at 5.87 MPa and 400^{o} C.

The object of this project was to retrofit a solar central receiver system to the existing cogeneration facility. The solar retrofit requires adding a north collector field of 815 heliostats, a tower-mounted receiver, and a steam and condensate pipeline approximately 1000 m long connecting the receiver with the existing plant. The two-cavity, natural-circulation water/steam receiver operates in parallel with the existing boilers and supplies about 45% of the total steam demand for the factory at design point. Bagasse is diverted from the boilers to the storage house where it is reclaimed when solar-produced steam is not available. Using bagasse eliminates the need for thermal storage and allows the displacement of about 73% of all the oil currently consumed during the nine-month harvest season (Figure 3).

Summary of Contractor's Economic Analysis

The economic viability of the solar facility at Pioneer Mill was analyzed on the basis of typical Amfac criteria and methodology. Two evaluation criteria were applied: the internal rate of return (IRR), and the investment that Amfac could support while achieving a specific hurdle rate. Amfac's choice of a 20% hurdle rate with equity financing represents an investment in a technology that is still developing and with which Amfac has no direct experience.

The economic analysis shows a calculated IRR of 4.5%, well below the required hurdle rate for the project. In order to achieve a return equal to the hurdle rate, Amfac could invest only 10% of the total amount required for the project.

Sensitivity analyses were performed to determine how changes in major parameters could affect the economic results. A new economic scenario, incorporating improvements in several of these parameters, was then developed and analyzed. The results indicated that at a more mature stage of solar technology development, and in combination with higher displaced fuel costs, higher escalation rates, and a longer project lifetime, a cogeneration system could potentially meet Amfac's investment criteria. Other considerations--including the desirability of energy independence for Hawaii and the continental U.S., and the possibility of the creative financing of such a project--were also important factors in the overall assessment of the project's viability.

Site Owner's Assessment

1.8 SITE OWNER'S ASSESSMENT

Amfac's overall project evaluation is positive, especially for an emerging technology. Amfac's assessment can be divided into three related but but separate areas - technology, operations, and economics.

1.8.1 Technology

The basic technology is perceived to be sound and worthy of Amfac's continued efforts in attempting to reduce our severe oil cost. The interface with existing equipment and the utilization of familiar technology (water/steam) raise the level of acceptance of the technology. The design incorporates features which allow existing mill operations to continue uninterrupted despite supply uncertainties with the solar system. All of these features increase the confidence level in the technology.

1.8.2 Operations

In the decisions pertaining to actual operations of such a system with partial government funding, the operational flexibility provided in the design should remain under the control of the mill operating personnel to maximize sugar production. The inclusion of a visitors center is a most desirable feature to reduce visitors interference with mill operations.

Additional site specific data is required on heliostat life, cleaning requirements, etc. to reduce the level of uncertainty in operations and maintenance (O&M) cost estimates. While additional data are also needed on long term receiver cycling effects and O&M cost, these data need not be site specific and will likely be available from the Barstow pilot plant.

1.8.3 Economics

The economic considerations of the project will almost exclusively determine Amfac's equity participation in the construction of the project.

If Amfac's initial risk could be reduced by equity participation tied to actual final demonstrated results, then greater Amfac equity participation would potentially be possible. This could be accomplished through reimbursable grants tied to actual realized revenues or savings. Such an unique financing arrangement would result in the government asuming a greater portion of the risk on this first project using new technology but not necessarily assuming a disproportionate share of the total investment. Greater industry participation would be possible under these circumstances and, with a portion of the initial government funding being returned on successful projects, it is likely that more projects could be funded within given budget limits.

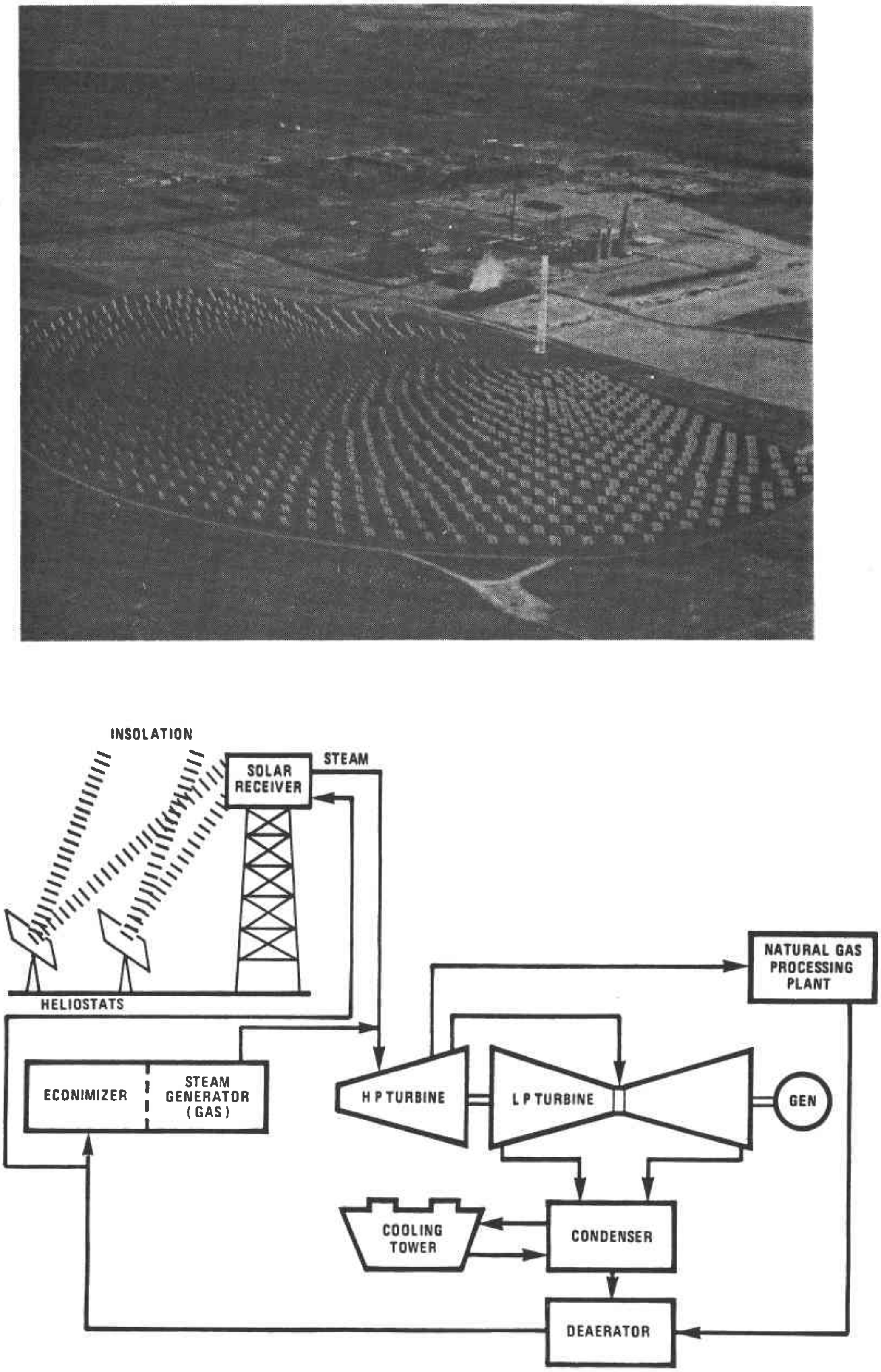


Figure 4. Central Telephone & Utilities-Western Power's Cimarron River Station Solar Cogeneration Project

CENTRAL TELEPHONE & UTILITIES-WESTERN POWER
Cimarron River Station (near Liberal, Kansas)

Prime Contractor: Black & Veatch Consulting Engineers

Subcontractors: Central Telephone & Utilities-Western Power; Babcock and Wilcox Co.; Foxboro Co.

Receiver Type/Fluid	External/Water	Net Output Power From Solar	3.7 MWt 15 MWe
Receiver Output Power	37.1 MWt		
Number of Heliostats	1,057	Equiv. BBL of Oil Saved Annually	48,100

Project Cost in Millions (1980$) 33.2

Description

The Central Telephone & Utilities-Western Power (CTU-WP) Cimarron River Station cogeneration facility provides a net output of 55 MWe for its customers on the CTU-WP grid; normally, 20 MWe and 15MWt of process heat are supplied to the National Helium Corporation, a natural gas processing plant.

A site-specific conceptual design was selected both to demonstrate the technical viability and to identify the economic potential of a solar cogeneration facility. A north field of heliostats redirects and concentrates solar energy onto an external, water/steam receiver that is mounted on a 74 m tower. The thermal energy absorbed by the receiver is transferred to the feedwater and steam, thus producing superheated steam at a pressure and temperature compatible with turbine inlet conditions. Steam from the gas-fueled boiler is mixed with steam from the solar receiver and delivered to the turbine. The turbine generator converts the thermal energy in the steam to electric energy. A portion of the steam flowing through the turbine is extracted as process steam for the National Helium Corporation. Energy storage is not included in the conceptual design (Figure 4).

Summary of Contractor's Economic Analysis

The economic evaluation of the solar cogeneration facility at Cimarron River Station was based on facility cost estimates and the Western Power fuel cost projections and economic criteria. For Western Power, the value of the solar facility addition is explicitly defined as the additional investment cost that Western Power could incur for the solar facility without increasing the system's revenue requirements. This additional investment cost equals the savings associated with deferred capacity, decreased fuel costs, and decreased operations and maintenance costs. The methodology for calculating the value of the solar facility was based upon standard utility long-range expansion planning procedures and criteria.

Results of the evaluation showed that the value to Western Power of the solar facility was about 30% of the solar facility cost. Thus, only a limited capital expenditure would be cost-effective within the utility's economic evaluation framework.

Results of a sensitivity analysis indicated that the value of the solar facility is largely insensitive to fossil fuel prices, solar facility life, or solar component costs. Given direct or indirect incentives for key solar components, the value of the solar facility to Western Power would increase. However, such incentives are not likely to result in a 100% share value for Western Power.

Site Owner's Assessment

1.8 SITE OWNER'S ASSESSMENT

Western Power is predominantly a gas burning utility, with oil as a secondary fuel; therefore, the oil embargo and severe gas curtailments of the mid-1970's have had a major influence on the system. This, along with the enactment of the Fuel Use Act of 1978 and the country's continued dependence on foreign oil, are indicators that other sources of energy must be developed.

Because gas and oil are depleting and expensive resources, the option of converting Western Power generating units to coal was reviewed. Use of coal at the Cimarron River Station would involve major reconstruction of the existing plant; but, the major deterrent to coal use is the fact that the existing plant is a 60 MW unit, which is far too small for economic coal conversion. The emission control equipment needed to meet environmental requirements and coal handling facilities for this size unit are just not an economic alternative.

Confronted with limited fuel options, the idea of solar energy stands out as an alternative energy source. For our application, it has several major advantages. First, the daily output curve of a solar plant is much like the system daily load curve. Secondly, it can be constructed faster and in smaller increments than a coal-fired plant. Third, it is readily adaptable to retrofit existing gas-fired facilities, shifting the source of energy from currently limited gas to infinite solar.

At the present time, relative cost appears to be the major disadvantage. Current solar capital requirements are not competitive with that required to build comparable coal-fired systems. The difference must be considered in planning actions despite the ultimate advantage of sparing finite fossil fuels and helping prepare for new avenues of energy supply. Western Power is hopeful that a cost sharing arrangement will be provided for supportive funds necessary to balance our cost and further develop solar energy.

The second solar problem is the loss of output caused by cloud interruptions. The operating problems caused by solar interruptions can be solved with an existing unit. One of the trade studies for this project considered potential storage systems. In all cases, the addition of storage only increased the lifetime cost and the complexity of the system. Western Power feels that parallel operation, at least in the development stages, provides a more flexible, more reliable and less expensive system. It should hold the most potential for economic solar applications in the near term.

The Western Power Cimarron River Station is in the heart of the high plains. It is surrounded by pastures, located in the Cimarron River Valley, 18 kilometers (11 miles) northeast of Liberal, along with two other major industrial complexes: National Helium Corporation and Panhandle Eastern Pipe Line Company. This remote location, along with its rolling landscape, is truly ideal for solar application. It has good access for construction and for the many interested visitors that the facility will attract.

The high plains area of western Kansas lends itself as an appropriate location for use of solar energy. Direct normal annual average insolation is approximately 6.1 kW/ m^2 day. The terrain is open and has vast areas that are basically unproductive. The installation of a large collector field will not significantly affect the local ecology, scenic attractions or other land uses. Due to the fact that solar power emits no pollutants, this project will not affect local air or water quality.

This conceptual design study has gone into considerable detail, examining the possibility of supplementing our Cimarron River Station's fuel supply with solar. The end result is a water/steam receiver system that parallels the existing gas-fired boiler. One of our major requirements in the beginning of the study was that the system must have very high reliability and assured performance. We feel that this system meets that requirement and is operable, reliable and a significant demonstration of solar potential.

Every effort has been made to design a system that is simple and cost effective. The water/steam technology has been well proven and, in Western's opinion, has the highest probability of being built on schedule and within budget. The simple design has helped reduce the risk of failure and of poor performance which would be very detrimental to the solar concept. Basic utility industry design will greatly simplify operator training, reduce operating problems and provide operation safety.

Western Power believes that realistic costs have been used and system benefits have been fairly assessed in the economic analysis. Even though the analysis does not show solar to be cost competitive, it should be noted that this is an R&D facility and, by continual systems improvements and volume production, the cost of solar could become competitive with oil or gas generation in the foreseeable future.

Western Power is enthusiastic about the study results. It is a system that will work; it will provide a creditable demonstration of the potential of solar energy; and it will make major advancements to solar technology and assist the commercialization of solar subsystems, thereby, improving solar's economic competitiveness.

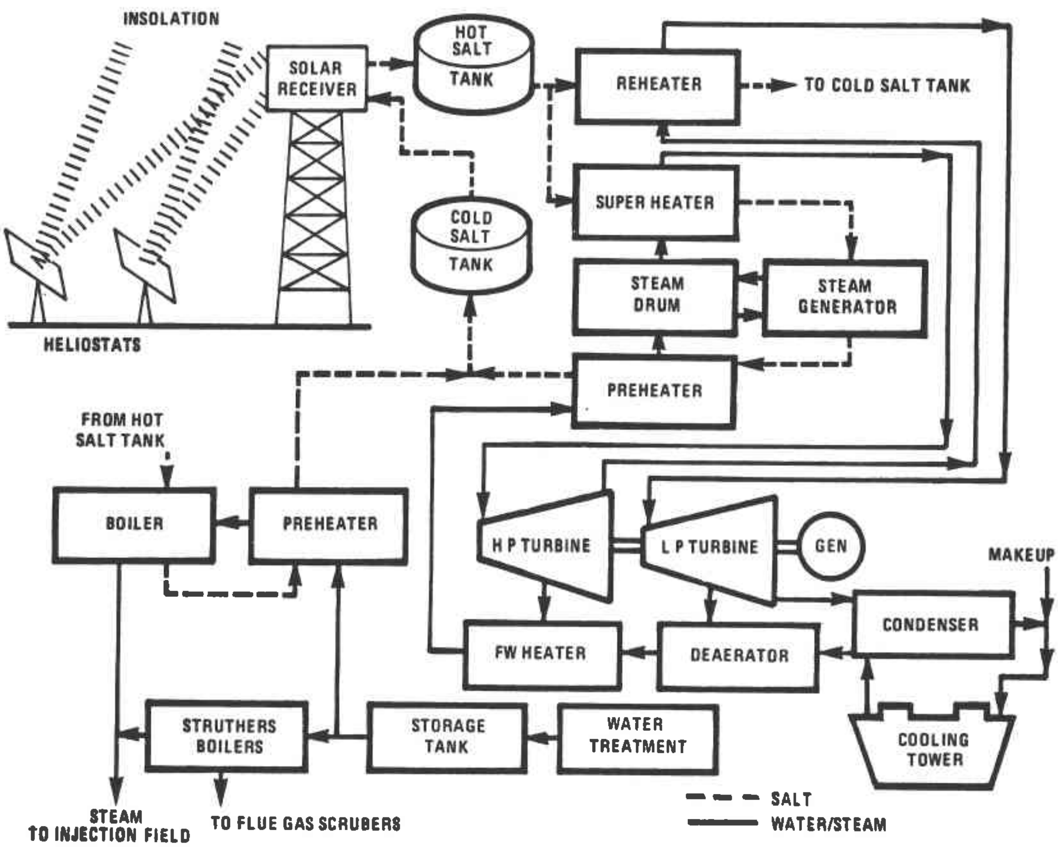


Figure 5. Exxon Corporation's Edison Field Enhanced Oil Recovery Solar Cogeneration Project

EXXON CORPORATION
Edison Field (near Bakersfield, California)

Prime Contractor: Exxon Research and Engineering Contract Research Office

Subcontractors: Martin Marietta Corporation; Badger Energy, Inc.; Pacific Gas and Electric Co.

Receiver Type/Fluid	Cavity/Salt	Net Output Power From Solar	13.2 MWt 20.4 MWe
Receiver Output Power	115.4 MW_t		
Number of Heliostats	3,295	Equiv. BBL of Oil Saved Annually	139,500

Project Cost in Millions (1980$) 120

Description

Exxon's Edison Field uses steam injection for enhanced oil recovery. Steam is injected into wells that are interspersed between oil-producing wells. The steam increases the field pressure and heats the oil, lowering its viscosity. This permits the oil to be pumped out of the ground at a faster and more economical rate. It also permits the recovery of oil that could not be retrieved by conventional pumping.

The design concept proposed by Exxon uses a solar central receiver system to generate steam for both enhanced oil recovery and the generation of electricity. The electricity produced is sold to Pacific Gas and Electric (PG&E). A north field of heliostats, occupying all the available land area, redirects the solar energy to a dual-cavity molten salt receiver mounted atop a 140 m tower. Stored in the hot tank of a two-tank storage system, hot molten salt is pumped to a steam generator that produced 13 MWt of steam for injection into the oil field 24 hours a day. Excess hot salt produces steam to generate electricity at a rate of 20 MWe during PG&E's peak demand period. The spent salt is returned to the cold tank (Figure 5).

Summary of Contractor's Economic Analysis

The estimated capital cost to design, construct, and start up the Exxon solar cogeneration facility was $120 million. In the economic analysis, the levelized energy cost of the solar cogeneration facility was compared to that of a conventional oil-fired steam boiler facility, one which would deliver the same amount of thermal energy to the enhanced oil recovery process. Levelized energy costs for both projects were equivalent at a solar capital cost of $100 million, assuming a 4% real fuel escalation.

In addition to capital and operation and maintenance cost uncertainties (which reflect the prototype stage of high-temperature solar system development), legislative uncertainties exist which can affect the tax credits, depreciation allowance, and electric revenues for solar cogeneration systems. Solar system cost predictions are thus much less accurate than those for conventional fossil-fired systems.

Compared to the oil-fired steam boiler facility, the solar cogeneration facility appeared to be an economic disadvantage. A number of economic scenarios were examined which would make the levelized energy costs of the solar project equal to or less than those of the conventional case. On the other hand, in a number of other economic scenarios, the solar facility had higher levelized energy costs than the conventional facility.

From Exxon's viewpoint, the uncertainties surrounding the solar facility project are much larger than the one that exists for the conventional case--namely, fuel cost escalation. Exxon feels it would be very risky to make a project decision in 1981: the economic climate in 1986 may make the solar project even less economically attractive than it appears today.

Site Owner's Assessment

1.8 SITE OWNER'S ASSESSMENT

Exxon will not pursue additional development of the Solar Cogeneration Facility at this time. The economic analysis conducted in this study shows the Solar Cogeneration Facility to be less attractive, for most cases studied, than the conventional oil-fired steam boiler. From an Exxon project viewpoint, the uncertainties surrounding the solar case are much larger than the uncertainty of the conventional case which is simply fuel cost escalation. Therefore, it is extremely risky to attempt to make a project decision in 1981 when the economic climate in 1986 may be considerably different and result in the solar project being even less economically attractive than it now appears. Major economic uncertainties affecting the Solar Cogeneration Facility at this time include the amount and certainty of revenues from the sale of electricity to PG&E (refer to Appendix D, Section A-18 for termination conditions), capital costs, solar tax credits and equipment depreciation allowances. Exxon does, however, endorse the results and conclusions of this conceptual design study of a Solar Cogeneration Facility at the Edison field. The design described in this report appears to be technically feasible, environmentally sound and provides an approach to meeting projected steam requirements at the Edison field without burning additional crude oil.

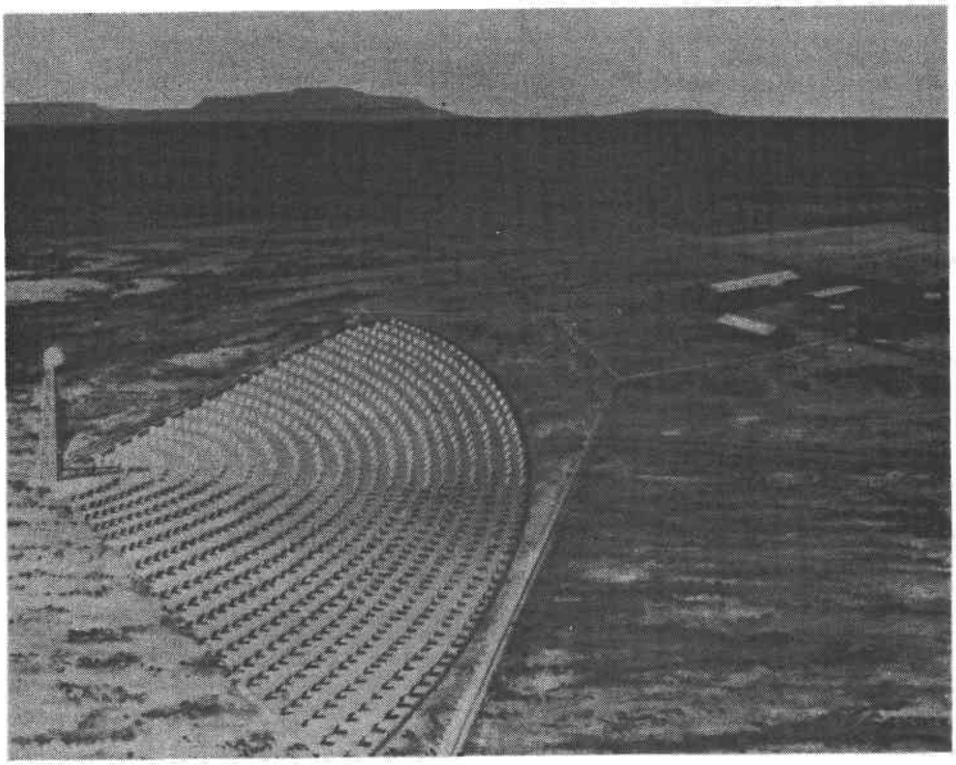
Although this design appears to be technically feasible, Exxon considers the demonstration of central receiver technology in an operational environment to be a necessary prelude to its widespread consideration and use in industrial process heat applications. Such demonstrations will provide important performance, economic and reliability data on central receiver systems and components. Systems demonstrations scheduled for near term operation in Barstow, Ca., and Almeria, Spain, coupled with DOE heliostat and receiver component development programs should provide valuable operational data.

Exxon has studied both the cogeneration approach and a simple solar process steam-only approach (Contract DE-AC03-79SF-10737) to provide steam for its enhanced oil recovery needs using solar central receiver technology. Within the accuracy of these conceptual design and cost studies, the solar steam-only approach appears to be more cost effective and less technically complex than the Solar Cogeneration Facility described in this report. This conclusion applies, of course, only to Exxon's enhanced oil recovery operations at the Edison field and the site specific solar designs which have been developed.

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 3200 MW_t (10,900 MBtu/h) of installed steam capacity could exist in the Kern County area alone by the end of this century to help recover known heavy oil reserves. This potential presumes reasonable land costs. Further opportunities could exist in other heavy oil-producing areas including Texas and Venezuela. At the Edison field, the Solar Cogeneration Facility should satisfy the projected increased demand for steam, although such demand depends critically on geologic and economic factors which are under evaluation.

The conceptual design presents no severe or unusual safety or operational requirements and could be accommodated in the oil field production environment. The Solar Cogeneration Facility could result in a reduction of total ultimate atmospheric emissions, with the only negative impact being the loss of some 320 acres of irrigated cropland.

Two restrictions on energy use face Exxon at the Edison site -- restrictions imposed by the California Area 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.



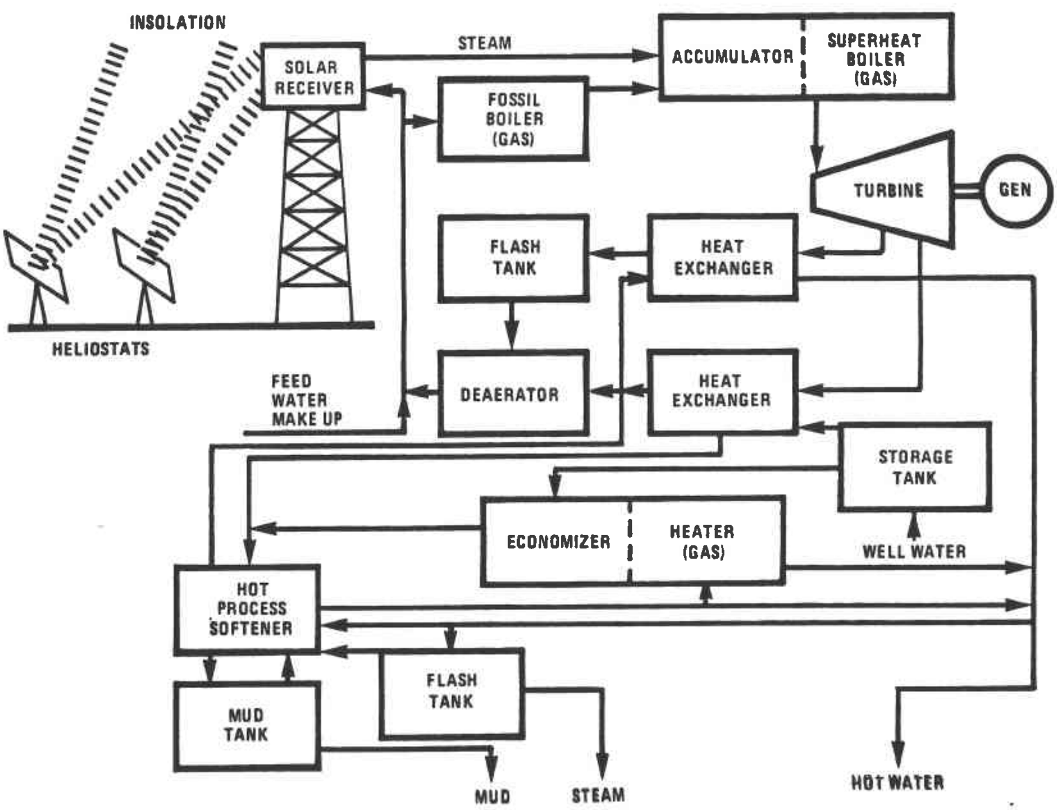


Figure 6. Texasgulf's Comanche Creek Sulfur Mine Solar Cogeneration Project

TEXASGULF COMANCHE CREEK SULFUR MINE
(near Fort Stockton, Texas)

Prime Contractor: General Electric Company, Advanced Energy Program Department

Subcontractors: Texasgulf, Inc.; Brown and Root Development, Inc.

Receiver Type/Fluid	External/Water	Net Output Power From Solar	16.1 MWt 2.2 MWe
Receiver Output Power	19.8 MW_t		
Number of Heliostats	588	Equiv. BBL of Oil Saved Annually	40,100

Project Cost in Millions (1980$) 20.7

Description

The Comanche Creek Sulfur Mine is in continuous operation, 24 hours a day, 365 days a year. The mine has eight gas-fired water heaters that generate the process heat required for mining sulfur; electricity is purchased from West Texas Utilities. The solar cogeneration facility would operate in parallel with a gas-fired package boiler to provide 100% of the mining operation's electrical requirements and 16.5% of the process heat requirements.

The conceptual design consists of a north field of heliostats that redirect the solar energy onto a flat, external receiver mounted on a 70 m tower. The receiver is a natural convection, saturated water/steam boiler. The outputs of the receiver and a gas-fired boiler are fed in parallel to an accumulator. The accumulator output is directed into a separate gas-fired superheater that raises the saturated steam to superheated conditions for entry into the turbine. Steam exhausted from the turbine preheats cold water. An extraction port on the steam turbine feeds a high-pressure heat exchanger that raises the process water temperature to 177° C for transport to the sulfur wells. The solar steam cycle is a closed loop operation; the process water, being of poor quality, is not recycled after it is pumped into the sulfur wells (Figure 6).

Summary of Contractor's Economic Analysis

Using Texasgulf financial assumptions, economic analyses were conducted to determine an after-tax discounted cash rate of return (DCRR), which considers the time value of money. Industry has traditionally calculated the return on investment on the basis of inflated cash flows over the projected lifetime of a facility. This approach leads to a calculated return on investment that is deceptively high during periods of high inflation. Another approach, which is beginning to receive widespread use, calculates the return on investment on the basis of a zero general inflation rate, while considering the cost escalation of specific items over general inflation. The latter approach was used to determine a more meaningful real return on investment.

Texasgulf could realize a DCRR of 10% if DOE cost shares 80% of the capital investment. However, the average cost of natural gas over the lifetime of the facility and the related electricity costs could be much higher than assumed, when one considers the near-term probability of natural gas decontrol as well as continued price escalation above general inflation. A rapid cost increase for natural gas would either result in a significantly higher return on investment for Texasgulf or allow a larger proportion of cost-sharing by Texasgulf, or both.

To assess the future potential of the solar cogeneration facility, Texasgulf conducted an economic assessment of a commercial (larger) solar cogeneration plant. The resulting economic analyses indicated that a reasonable return on investment may be obtained as heliostat costs decrease and natural gas and electricity costs increase. For example, an after-tax real discounted return on investment of 17.5% relative to the existing Comanche Creek Plant is projected at a heliostat cost of $136/m^2$ and an electricity cost of 8¢/kh. Similar analyses indicate that a commercial solar cogeneration plant would also have a significantly higher return on investment than a completely gas-fired cogeneration plant.

Site Owner's Assessment

1.8 SITE OWNER'S ASSESSMENT

Texasgulf's energy intensive operations such as sulphur mining and electrolytic metal winning, combined with the extraordinary increases in costs of hydrocarbon based energy, have created a corporate program in energy research and conservation. The plants at Texasgulf's operating sulfur mines were designed for maximum energy efficiency within the limits of a reasonable return on capital. As the price of natural gas in the past few years went from 7¢ per 1000 cubic feet to $2.50, alternate fuels were investigated. Coal and even a garbage derived fuel were considered as boiler fuel, but present plants could not be altered for solid fuel use.

One of Texasgulf's potash mines in Utah presently uses solar energy for evaporation and crystallization of potash salts. The sulfur division was ordered to study the possibility of solar heated water for Frasch process sulfur mining. The resulting internal Texasgulf study considered only a low temperature solar collector, one site, no cogeneration, and no storage. This was a very limited study and under imposed restraints, the return on investment appeared to be very low. These results did not eliminate Texasgulf's interest in solar energy and therefore, Texasgulf was eager to participate with General Electric and DOE in a search for an economical means of conserving energy. The Texasgulf Solar Cogeneration Program over the past year with Texasgulf working intimately with General Electric, BARDI, and DOE has investigated alternate locations, optimized size, cogeneration, storage, superheat, and produced a complete analysis of the project economics. The actual basic design of the plant is essentially complete and it is felt that energy savings have been maximized and facility costs minimized considering the limited amount of effort involved.

The economics of the Solar Cogeneration Facility (SCF), which are based upon near-term costs of solar hardware (heliostats) and fossil/electrical energy, indicate that significant DOE cost sharing will be required in order for Texasgulf to receive a reasonable return-on-investment. Texasgulf requires a higher return-on-investment than many other industries due to the higher risk involved with a natural resource type of business. Texasgulf, like any business, has a limited amount of capital funding for investment purposes. Therefore, investment decisions must be made by considering all potential investment opportunities and selecting those investments which will maximize the return of owner's equity. While Texasgulf could possibly receive a reasonable return-on-investment based upon funding a small portion of the capital cost of the SCF, the bulk of the capital cost would have to be provided by the taxpayer. The construction and operation of this SCF should provide a meaningful data base for future industrial usage of solar cogeneration which would most directly benefit industry, while indirectly benefiting the taxpayer. Texasgulf, therefore, feels that industry, the major potential beneficiary, should fund such activities rather than the taxpayer. Accordingly, Texasgulf has decided to terminate participation in the Solar Cogeneration Program at this time.

Texasgulf's participation in this current study has been a meaningful exercise which has established a good data base for the evaluation of solar cogeneration as a potential candidate for future installations. Participation in the study has eliminated Texasgulf's earlier concerns about the high risk of solar technology. After visiting the DOE Central Receiver Test Facility at Albuquerque, New Mexico, misgivings concerning safety and operational reliability have been eliminated. Almost by definition, a solar steam and electric plant will be a plus in environmental impact considerations. The solar cogeneration configuration developed during this study appears to be a practical application of solar energy in an industrial process requiring both low pressure steam or superheated hot water and electricity. This situation exists for most petrochemical and natural resource process industries, including Texasgulf's phosphate mine in North Carolina and the soda ash plant in Wyoming. Therefore Texasgulf will be able to utilize this study in the future to evaluate the economic competitiveness of solar cogeneration for new plants. As heliostat costs are decreased through mass production and other energy costs increase, it appears that solar cogeneration has good potential to become economically competitive with other more conventional energy systems.

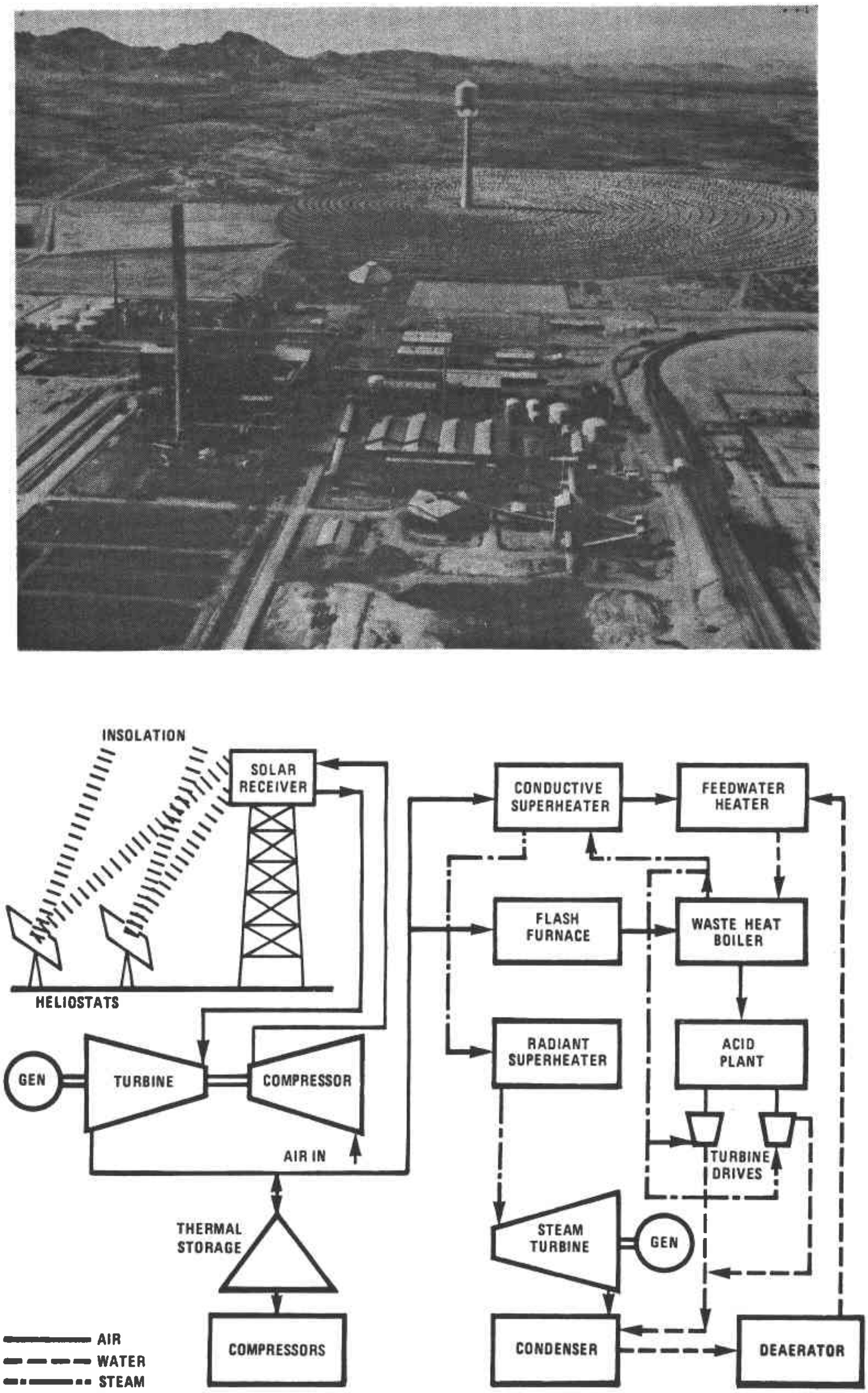


Figure 7. Phelps Dodge Corporation's Hidalgo Copper Smelter Solar Cogeneration Project

PHELPS DODGE CORPORATION
Hidalgo Copper Smelter (near Playas, New Mexico)

Prime Contractor: Gibbs & Hill, Inc.

Subcontractors: Phelps Dodge Corporation; Boeing Engineering & Construction Co.

Receiver Type/Fluid	Cavity/Air	Net Output Power From Solar	54.2 MWt 46 MWe
Receiver Output Power	270 MWt		
Number of Heliostats	10,441	Equiv. BBL of Oil Saved Annually	436,000

Project Cost in Millions (1980$) 425

Description

Every day, the Hidalgo Copper Smelter processes 2880 tons of dried and fluxed ore concentrate and, from that, produces 700 tons of copper. With a solar central receiver system, the smelter would increase its copper output by 90%.

A solar central receiver would supply up to 270 MWt of heated air for use in the smelting process, displacing about 75% of the present oil consumption. It would also provide the input to the gas turbines, thereby cogenerating up to 46 MWe. Waste heat from the smelter produces steam to generate an additional 25 MWe and 12,000 hp of motor power.

In the conceptual design, compressed air from cogenerating gas turbines is heated in a cavity receiver to 816^{o} C by a surrounding field of heliostats. The heated air is expanded in the gas turbines and then ducted to a thermal storage reservoir, which consists of a mound of waste slag from the smelter. The slag, covered with a layer of soil for insulation, operates similarly to a rock-bed storage system. Ambient air circulated through the slag becomes heated; the heated air is then ducted to the flash furnace of the smelter and to the superheaters. Waste heat is recovered from both operations by use of waste heat boilers and ore concentrate dryers (Figure 7).

Summary of Contractor's Economic Analysis

A discounted cash flow analysis is preferred by Phelps Dodge Corporation for the economic evaluation of alternative investments. Phelps defines "cash flow" as the amount of money remaining from gross revenue, net cost expenses, and taxes.

Discounted cash flow is determined by first discounting-out year cash flows by a given rate, thereby converting the cash flow to a present value sum, and then summing over the financial life. This sum is compared to the first-year equivalent outlay of equity capital. When balanced, the discounted rate becomes the discounted cash flow rate of return on internal investment, or DCF/ROI.

The investment is treated as an addition to an existing plant that produces a net differential in gross revenues, fixed and variable operations and maintenance costs, fuel and electricity savings, feedstock costs, insurance, property taxes, and income taxes. The discounted net differential cash flow is computed and equated to the net differential equity capital outlay.

Relative to the existing facility, the solar cogeneration plant is projected to show the following performance advantages:

- 90.4% improvement in copper output
- 90.4% increase in acid production
- 89.4% reduction in oil consumption
- 44.8% reduction in coal consumption
- 74.0% increase in electricity and motor-driven production
- 1.78% reduction in purchased electrical power
- 47.1% overall reduction in purchased energy per unit of product copper

The DCF/ROI is 52.4% with a capital cost of $425 million. The discounted payback time is 23 months. If the plant were to operate as designed, and the future were economically stable, the investment should be economically viable.

Site Owner's Assessment

1.8 Site Owner's Assessment

The Phelps Dodge Corporation's assessment of the Hidalgo Smelter Solar Cogeneration Study is provided in a letter to Mr. Robert Prieto, Project Manager, Gibbs & Hill, Inc. dated August 21, 1981. A copy of the letter appears on the following pages.

phelps dodge Corporation Western Engineering Department, P.O. Drawer C, Douglas, Arizona 85607
(602) 364-7521

21 August 1981

Mr. Robert Prieto
Project Manager
Gibbs & Hill, Inc.
393 7th Avenue, 2 Penn Plaza
New York, New York 10001

Subject: Hidalgo Smelter
Solar Retrofit Project
Site Owners Assessment
WED Job No. HP-009

Dear Mr. Prieto:

Phelps Dodge Corporation is pleased to have taken part in the preparation of the "Hidalgo Smelter Solar Cogeneration Study." This study has resulted in a unique and novel adaptation of high temperature solar energy to conventional copper smelting.

The immediate benefit of this study has been a substantial expansion of our basic understanding of the relationship of various smelting parameters to process air temperature. This has given further depth to studies we are undertaking toward justification of a coal fired process air preheater. This unit will afford the same benefits of hot process air with a substantial return on investment without some of the obvious risks of the solar retrofit.

Portions of the solar system specification would require further development for Phelps Dodge to seriously consider physical implementation of this facility. Specifically, these include the following:

1. The tower design requires review and extensive soil studies.
2. All features of the thermal energy storage system require extensive review and a pilot installation should be constructed.
3. Maintenance of mirror surfaces in the environment at Hidalgo has not been clearly established.
4. Further pilot studies should be done on the solar receiver concept.

Assuming successful investigation into these areas, we have concerns of a less tangible nature. Specifically, these are as follows:

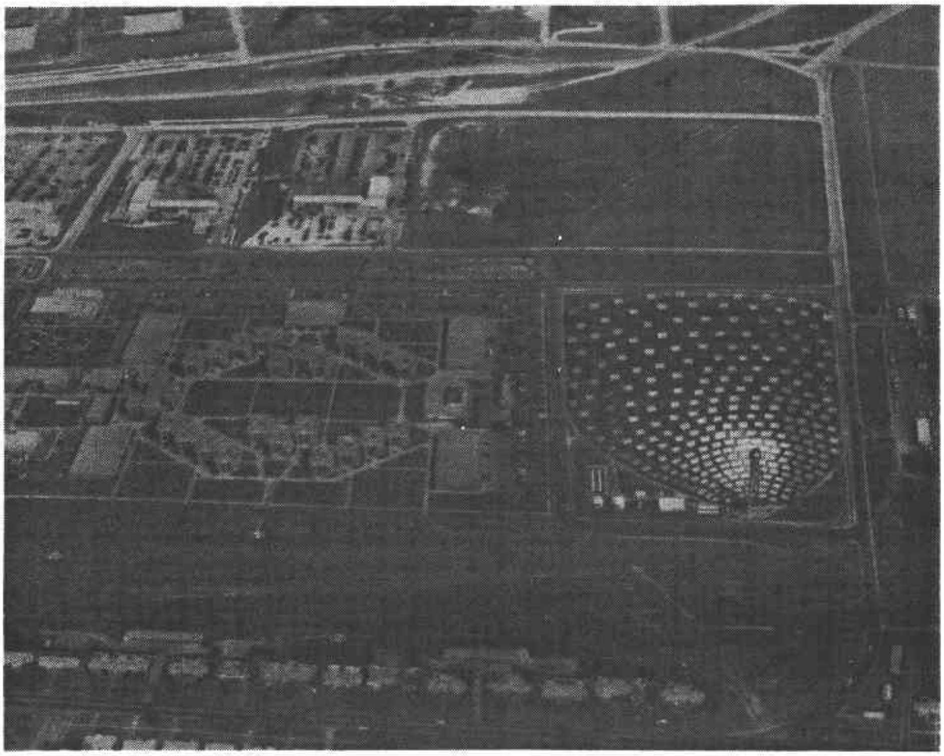
1. The economics of this project have roots in substantial tax credits; the long-term stability of which is questionable.
2. The medium-term pricing and availability of fossil fuel appears more optimistic than when this project began. This upsets project economics to some extent.
3. Ideally, due to a respectable return on investment, a consortium of concerns would construct this facility adjacent to the smelter and sell the hot process air and power to the smelter on a utility contract basis. This arrangement would minimize the capital at risk for Phelps Dodge and would allow government participation at a manageable level in the consortium.

Very truly yours,

R. W. Rice
Manager of
Engineering Services

RWR/vg

cc: Mr. L. R. Judd



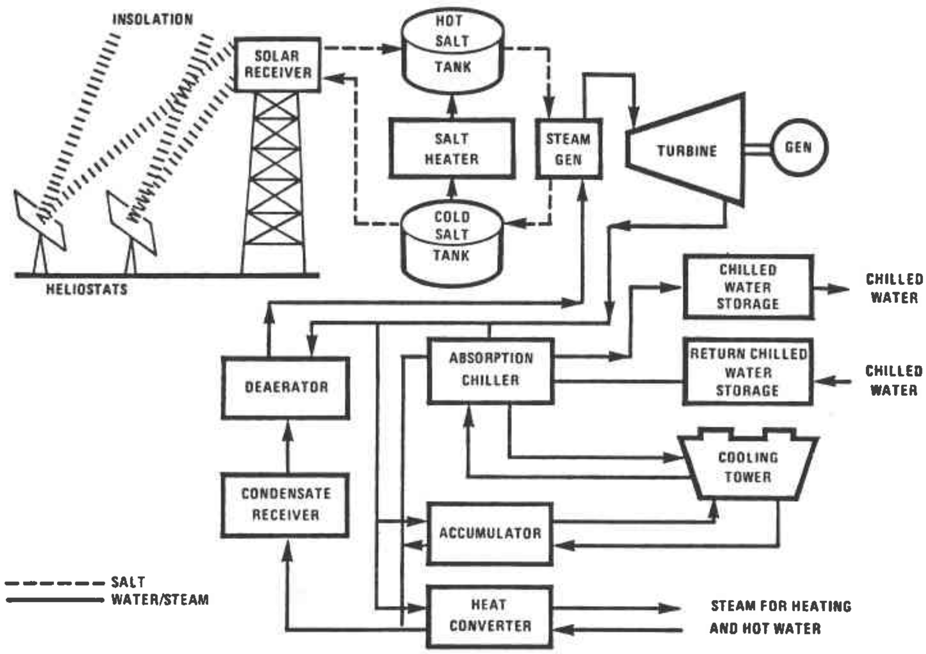


Figure 8. Fort Hood Army Base Solar Cogeneration Project

FORT HOOD ARMY BASE
Killeen, Texas

Prime Contractor: McDonnell Douglas Astronautics Co.

Subcontractors: Stearns-Roger; University of Houston

Receiver Type/Fluid	Cavity/Salt	Net Output Power From Solar	3.5 MWt 0.6 MWe
Receiver Output Power	8.7 MWt		
Number of Heliostats	242	Equiv. BBL of Oil Saved Annually	9,700

Project Cost in Millions (1980$) 19.1

Description

The Fort Hood Army Base solar cogeneration facility would benefit Complex 87000--a group of twenty buildings serving the housing, dining, and other needs of approximately 1650 soldiers. Texas Power and Light Company presently supplies the electrical energy for the complex. Thermal energy for room heating and domestic hot water is provided by gas-fired boilers in the central plant building. The proposed solar cogeneration facility would supply the complex with over 60% of its annual thermal energy needs and with over 100% of its yearly electrical energy requirements. The excess electricity would be distributed through the electrical grid for other Fort Hood uses.

In this design, the north field configuration of heliostats redirects up to 10 MWt of solar energy to a single-aperture, partial-cavity receiver. The absorbed heat is transferred by molten salt to the hot tank of a two-tank storage system; during prolonged periods of low or no insolation, a gas-fired salt heater generates heat for the system. From the storage tank, the hot salt is pumped through a natural-circulation-type steam generator to produce the operating steam for a 600-kWe-rated turbine-generator unit. Extracted steam from the turbine is sent to an absorption water chiller for space cooling, while turbine exhaust steam is used for space and water heating. In times of peak demand, water is available from chilled water and hot water storage tanks (Figure 8).

Summary of Contractor's Economic Analysis

Economic analyses were based on estimates of capital costs, operations and maintenance costs, and three different sets of economic factors: DOD Site-Specific Factors, DOE Specified Factors, and High-Side Factors.

The DOD Site-Specific Factors represent the actual displaced energy costs at Fort Hood as well as the standard factors used by the Army in economic assessments. The DOE factors are those specified by DOE. The High-Side Factors represent typical energy rates and those factors currently used in the economic assessments of similar facilities in California.

The value of displaced or avoided electrical and gas energy at Fort Hood is very low for two main reasons. The energy costs there are much less than national average costs, and both the electricity and gas utility companies have sliding rates for energy (the more energy used, the less expensive it becomes). Thus the initial net dollar savings per year are low--and so the initial economic findings are not encouraging. However, in later years with inflated energy costs, the dollar savings become substantial. Moreover, the amount of critical fuel savings is substantial; this savings should be considered independent of economics.

For the DOD Site-Specific case, the payback period is approximately 24 years, providing a small rate of return for a 25-year life and a larger one for a 30-year life. Net benefit values could result in a benefit-cost ratio greater than 1.0 based on current-year dollars. If a 10% discount is considered, however, the ratios are less than 1.0.

While the results are not quite as good with the DOE Specified Factors as with the DOD Site-Specific Factors, the results achieved with high-side rates are the best. In the high-side case, the payback period is 17 years and net benefit values range from $67 to $153 million, depending upon program life.

Site Owner's Assessment

This section presents an assessment of the proposed Fort Hood solar cogeneration facility by the Department of the Army at Fort Hood. These assessments have been made by representatives of the Engineering Plans and Services Division with the approval of the Directorate of Facilities Engineering at Fort Hood. The actual text received from Fort Hood is reprinted below with no editorial changes, deletions or additions. A summary of this information has been prepared by MDAC and is presented in Section 1.8 of this report.

8.1 ENDORSEMENT OF PROJECT RESULTS

Energy Supply and Demand Data - Month-by-month consumption data (natural gas and electrical) was provided to McDonnell Douglas Astronautics Company. Natural gas consumption has historically shown a good correlation to troop strength and may decrease based on energy conservation projects programmed for the administrative buildings in the 87000 block (FY 81) and the barracks (FY 83). The heating and cooling systems of the 87000 blocks would also be more efficiently controlled by a hardwired energy monitoring/control system (EMCS) programmed for FY 84 MCA funding. Future troop strength (hence natural gas consumption) should remain constant in the 87000 block. Electrical consumption in the 87000 block should also be reduced by these energy conservation measures; however, electrical demand has not shown a good correlation to troop strength as the density of air conditioning, computers, and other electronics expand. Anticipate a net increase in electrical consumption (less than 1% per annum).

Cogeneration System Feasibility - Design appears feasible and practical within current state of art. This installation particularly appreciates the fact the existing HVAC outside the central plant remains unaltered by the proposed design. The use of off the shelf items in the energy conversion equipment is also appreciated for ease of maintenance and parts availability. In summary, the design has considered simplicity while taking advantage of an expanding technology.

Operating and Maintenance Approach - While solar systems will ultimately become routine maintenance for installation personnel, the unique nature of the cogeneration plant and limited solar application to date would require extensive training of two or more maintenance personnel. Problems of backup personnel in the work force having "hands-on" experience could be encountered. This problem could be compounded by less than full time employment of the specially trained personnel at the solar plant. Diversion to other tasks at at installation as large as Fort Hood could mean a repairman with the required expertise might not be available when the solar systems require maintenance. Contract maintenance and operation of the plant should be considered for the early years of operation to gain good reliability/maintenance experience and until such time as the density of solar systems at Fort Hood justifies a good base of trained personnel in the installation work force. Contract should provide on-call response in addition to "normal duty hour" operation. Current staffing of the installation facilities maintenance workforce would not support full time operators/maintenance personnel for the plant, but could be augmented if funds were provided.

Economics - Fort Hood enjoys relatively inexpensive utility rates. These rates will increase as a result of inflation; the increases are difficult to predict because of the unknown influences of mid-East instability, ongoing exploration for fossil fuels, and alternative energy sources. However, it can be anticipated Texas utilities will continue to expand management programs that have been successful in the past in holding down rate increases. These low rates coupled with relatively expensive initial capitalization associated with solar systems have precluded 25 year life cycle payback of solar systems for other than domestic hot water at Fort Hood. The solar cogeneration plant also faces this competition and it would be doubtful such a system could compete on a dollar-for-dollar basis with conventional systems. Other factors such as expansion of the solar state of art, availability or off-shore energy sources, and encouragement of commercial application of solar technology should be considered in evaluating the economics of the cogeneration plant. These factors are not addressed in these user comments. The DOD and DA energy plans do endorse alternate energy sources where economically feasible. Also, they will cooperate with DOE in providing a test site for this solar project which is in the National interest.

8.2 ENDORSEMENT OF PROJECT WORTH

DOD Evaluation Criteria - As mentioned previously, the normal life cycle cost criteria would favor continued operation of the conventional systems in the 87000 Block. However, further consideration should be given to the demonstrative value of the project and the contribution of the project to the national goal of energy independence. If the initial capital costs were borne by another agency (Department of Energy, for example), DOD's remaining economic concern would be that the project save more energy dollars than it cost in added maintenance and operation. A demonstrated savings to cost (less initial construction cost) greater than 1.0 would be satisfactory. Past energy conservation criteria such as that associated with the Energy Conservation Investment Program (ECIP) are not necessarily applicable or required of the project. If DOD were to bear all or part of the initial capital cost, the project would be subject to a specific evaluation in which the then current DOD budget would be a primary consideration.

Expansion Potential at Complex 87000 - Current master plans being revised to request siting of two battalion headquarters (24,000 sq ft total) in the 87000 block; construction would be programmed FY 86 or later and will have separate heating/cooling plant not in central system. It is anticipated electrical demand may increase with trends toward additional word processing, computer, etc. (less than 15% over the 25 year life cycle). Other demands (normal gas) may decrease slightly due to energy conservation measures (5-10% over life cycle).

Additional Opportunities at Fort Hood - Excess electrical generation can be absorbed in the installation distribution system thereby reducing demand on the serving utilities company. Capacity of the concept solar plant does not appear adequate to absorb the energy requirements of adjacent facilities outside the 87000 block. It is also doubtful whether such expansion would be cost effective considering line losses, siting of the backup fossil heater, etc.

A 1980 Energy Conservation Study and System Plan addressed the need for total and selective energy plants and based on present and projected energy rates versus energy dollar savings, such plants did not meet ECIP criteria. An earlier (1976) study conducted by American Technological University addressed location of solar cogeneration plants similar to that being considered by this report. Based on that study concluded and the Fort Hood Master Plan, few areas of 15 or more acres are immediately adjacent to large barracks complexes. There are at Fort Hood two barracks complexes similar in design and layout to the 87000 block; one (27000 block) is surrounded by permanent construction, the second (39000 block) has an open area adjacent but major changes in the Master Plans would be needed to accommodate a heliostat field. Solar cogeneration plants of capacities much larger than the one considered by this report could be used to provide energy to the 5136 sets of family quarters and a large industrial complex contemplated in a planned revision of the Master Plan (more detailed study would be needed to determine space availability for heliostat fields). One of the major problems associated with the use of large solar systems is the need for large land areas for collector fields. Because of this, more emphasis must be placed on using roof tops or placing collectors above parking areas.

Opportunities at Other Bases - Other installations having better insolation rates and higher utilities rates than Fort Hood would experience shorter payback periods particularly installations experiencing longer and colder winters with shorter, cooler summers. The modular barracks design of the 87000 block could be found at other Army installations and the available area for the heliostat field might permit more optimum design of the field and receiver. Certainly the location of the initial plant at Fort Hood would provide the advantage of results that would be transferable to other installations with greater confidence given more optimum conditions at the other installations. "If it will work at Fort Hood, it will work anywhere."

8.3 OPERATION, SAFETY AND ENVIRONMENTAL IMPACTS

Operation and Maintenance Capabilities Versus Requirement - Fort Hood currently faces a maintenance backlog (BMAR) in excess of $120 million. Past reductions in force and austere budgets have precluded facilities maintenance other than emergency repairs. The future looks brighter - more people in the installation workforce and more appropriate operating budgets - but the backlog will take many years to reduce to acceptable levels. If the solar cogeneration plant is built at Fort Hood serious consideration should be given to separately funded contract maintenance and operation particularly in the early years (see 8.1 for more discussion on availability of maintenance and operational personnel). The washing of the heliostats could constitute a serious manpower drain if rapid, highly automated washing techniques are not provided (summer dust fallout from West Texas dust storms combined with the caliche dust generated by tracked and heavy wheeled vehicle movement at Fort Hood would degrade collector efficiency quite rapidly if not countered by heliostat washing).

Helicopter Safety Interfaces - The Fort Hood Aviation Safety Office has expressed the following concerns:

a. The cogeneration plant as proposed will eliminate a western approach to Hood Army Airfield, thereby reducing the primary corridor to approximately 150 meters. This is too narrow an area for helicopter traffic.

b. More data/study should be presented, to include results from a similar field near Albuquerque, NM, as regards the glare potential to transiting aircraft. Would ground vibrations from artillery impact in nearby firing ranges add to off targeting of the heliostats and resultant glare potential? If yes, safety of flight could be further reduced.

c. The 175 foot tower located 3,400 feet from the end of the active runway at Hood Army Airfield could hamper aircraft operating under tactical conditions, in inclement weather, and making instrument approaches using the least reliable systems (Automatic Directional Finder (ADF) at nearby Hood Army Airfield.

d. If an aircraft inadvertently flew between the heliostats and the collectors at a certain angle, the aircraft and occupants could receive burn/ heat damage from the heliostat rays.

e. The glare from the receiver would present a distraction to aviators approaching Hood Army Airfield.

f. The heliostat field (approximately 15 acres) will deny aviators an open area for emergency landings.

Environmental Impacts - Several questions remain unanswered as to the environmental impact of the design. The heliostat washing solution has not been determined hence not assessed. The surfacing under the heliostat could contribute to dust problems if not treated with a protective; if hard surfaced, drainage would have to be accommodated. The question of environmental impact requires more extensive investigation in final design and an extensive, former environmental assessment would be required of the designer.

8.4 PRODUCT DEVELOPMENT PLAN AND SCHEDULE

The plan and schedule appear realistic and are compatible with long range plans at Fort Hood. No major facilities are sited in the proposed project site; relocation of existing parking lot, picnic area, and trees in the heliostat site would be required and have been addressed by the concept design.

8.5 ENERGY PROBLEMS AND PLANNING STRATEGIES

No unique energy problems are experienced or foreseen at Fort Hood at this time.

8.6 ALTERNATIVE SYSTEMS

Alternatives to Solar Cogeneration System - As mentioned in paragraph 8.2, a 1980 study did not identify any total or selective plants having sufficient energy savings to warrant funding at Fort Hood. Barring any unanticipated increase in natural gas and electrical rates above the prevailing inflation rate, the conventional systems currently installed in the 87000 block are the only alternative to solar cogeneration system.

Acceptability of Central Receiver Solar Technology - If the energy demands of the 87000 block could be economically met from an inexhaustible source (solar) without giving up 15-20 acres to heliostats, that would be preferred. Given today's solar technology and the need for relatively large collector fields, the proposed design is accepted and supported at Fort Hood as a necessary step in the evolution to broad application of solar energy.

8.7 NOT USED

8.8 ACCEPTABILITY ASSESSMENT

DOD/Fort Hood Acceptance - The concept design has not been coordinated throughout DOD and therefore comments regarding DOD acceptance would be inappropriate. It suffices to say DOD has actively supported Presidents Carter's and Reagan's objectives to reach energy independence for strategic as well as economic reasons. There would, therefore, be acceptance of the objectives of the solar cogeneration plant - saving energy while expanding the use of inexhaustible source. Within Department of the Army, and certainly at the Fort Hood level, there has been general acceptance of the solar cogeneration approach since early studies conducted by American

Technological University and Westinghouse. The only restraints on Fort Hood/ DA support and participation have been monetary ones brought about by the austere operating budgets of the last decade.

Local Community Acceptance - Local acceptance should be almost universal based on several factors:

Any major construction at Fort Hood is seen as not only a temporary influx of money to the local economy but also as a further indication of the permanence of the installation.

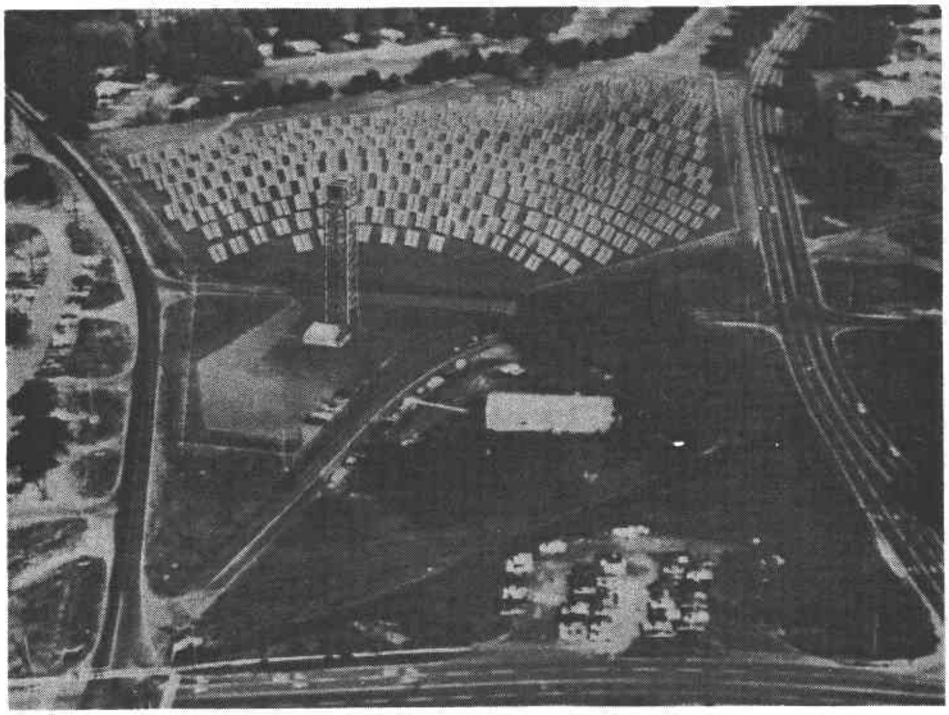
Outstanding community relations exist between Fort Hood and the surrounding communities. Major issues affecting the installation, including controversial ones, have always been openly discussed with local community leaders, organizations, etc., hence a spirit of trust has developed.

The unique aspects of the solar cogeneration plant will publicize Fort Hood and the surrounding communities.

Solar power does not have the negative environmental aspects associated with nuclear, coal, strip mined ores, etc.

This support could be eroded if the potential energy savings are "over sold" or exaggerated. Early release of factual information will pave the way for acceptance in Central Texas.

In summary, we at the installation level, believe solar power is the way of the future and the sooner we can "get with it" the better -- however, our enthusiasm for the task must be tempered by the real world problem of operating budgets and maintenance backlogs.



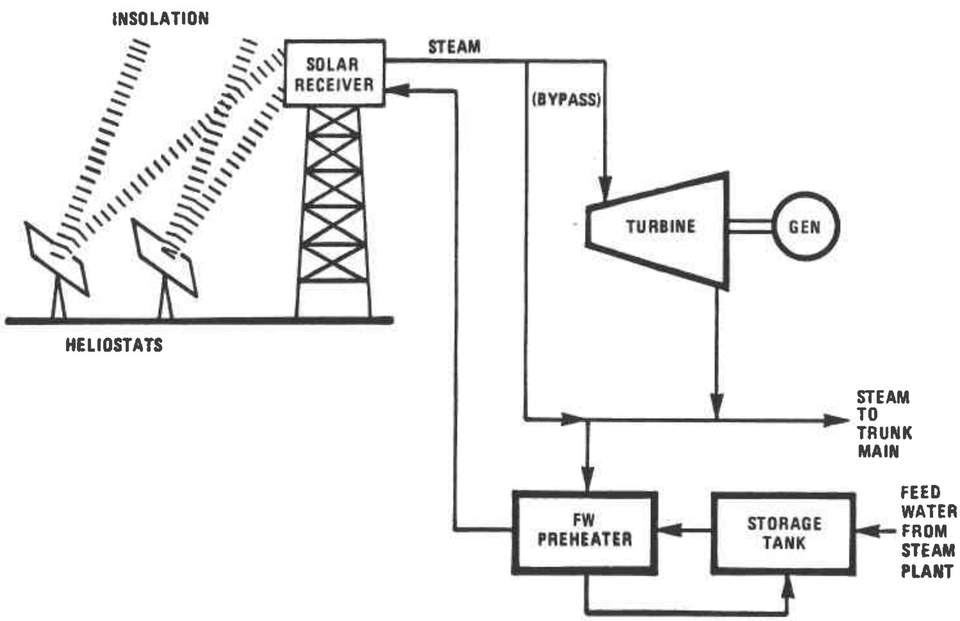


Figure 9. Robins Air Force Base Solar Cogeneration Project

ROBINS AIR FORCE BASE
Warner Robins, Georgia

Prime Contractor: Westinghouse Electrical Corporation

Subcontractors: Heery & Heery, Inc.; Foster Wheeler Development Corp.

Receiver Type/Fluid	External/Water	Net Output Power From Solar	7.9 MWt 0.7 MWe
Receiver Output Power	8.8 MWt		
Number of Heliostats	251	Equiv. BBL of Oil Saved Annually	8,300

Project Cost in Millions (1980$) 11.0

Description

The section of Robins Air Force Base that the solar cogeneration facility would serve is currently supplied with central steam for space conditioning and water heating by four boiler-plants. Steam is used for space heating in the winter, absorption cooling in the summer, and some industrial process loads. A Georgia Power Company substation located nearby provides a 10 MW electrical distribution system.

In the conceptual design, a north field of heliostats redirects solar energy to an external, flat-panel receiver. This water/steam central receiver, based upon natural-circulation receiver boiler technology, provides main steam to the turbine generator. The turbine-generator output is about 750 kWe. Exhaust from the turbine is directed into the base steam trunk, supplementing the output of the boiler plant (Figure 9).

Summary of Contractor's Economic Analysis

The economic assessment of this solar facility was based on the methodology and economic assumptions defined by the United States Air Force Energy Conservation Investment Program (ECIP). This approach is basically a present-worth analysis of nonrecurring capital costs, recurring operations and maintenance costs, and recurring benefits resulting from reduced energy usage. In this economic assessment, several scenarios were evaluated to portray economic worth under different economic assumptions.

A marked improvement in the evaluation results occurred when multiple installations were considered: the benefit-cost ratio increased from 0.32 to 1.0 after only 65 installations. Similarly, the payback period decreased from 67 years to 25 years after 65 installations, and to 17 years after 300 installations.

The Air Force economic scenario showed that with a benefit-cost ratio of 8.2, the Air Force would obtain a payback of the initial owner's costs in about 4 years.

The DOE economic scenario showed a benefit-cost ratio of 0.33 with a payback period of about 26 years, if the Air Force provided the owner's costs and the on-going operations and maintenance costs.

Considering 10 and 12% differential escalation rates instead of the CIP 8% rate increased the benefit-cost ratio from 0.36 to 0.44 and 0.58.

When natural gas costs were assumed equal to oil costs, the benefit-cost ratio increased from 0.32 to 0.9, and the payback period decreased from 67 to 17 years.

Westinghouse believes that with only a modest capital investment, considerable technological advances in solar energy systems could result from installing and operating the solar cogeneration facility at Robins Air Force Base.

Site Owner's Assessment

1.8 SITE OWNER'S ASSESSMENT

1.8.1 ENDORSEMENT OF PROJECT RESULTS

The United States Air Force has for many years recognized the importance of energy conservation and the application of innovative and latest state of the art energy technology. Considerable attention has been focused on facility energy which accounts for approximately 29 percent of the total energy used by the Air Force. For installation operations, average annual energy use per gross square foot of floor area is to be reduced 20 percent in existing buildings and 45 percent in new buildings by FY 1985 as measured from the FY 1975 usage level; and, in existing buildings, energy-conservation retrofits are to be installed by 1990 and consumption of petroleum-based fuels reduced by 30 percent. Alternative energy sources are to provide, by FY 1985, at least 10 percent of the energy used in Air Force installations, and renewable energy sources, at least 1 percent; energy consumption levels are to be identified and monitored through metering and energy audit/survey programs; and potential energy conservation measures are to be identified.

The solar cogeneration facility at Robins Air Force Base will assist the Air Force in meeting these goals.

To this end, Robins Air Force Base and the Air Force Logistics Command are prepared to support the solar cogeneration facility by:

a. Providing sufficient land area for the collector field and tower

b. Closing Seventh Street between "B" Street and Robins Parkway

c. Providing additional land area for the collector field currently utilized for the 14th tee of the golf course

d. Considering the proper course of action for the acquisition, use, or elimination of Building No. 760 (the Band Building)

e. Approving the removal of the trees in and at the sides of the collector field

Long range plans for Robins anticipate an expansion of facilities in the area of the solar cogeneration facility. This will increase the process steam load for Steam Plant No. 4. The solar cogeneration facility would provide relief for these additional load requirements.

The above endorsement is consistent with the understandings and agreements reached between Westinghouse and Air Force personnel during the first meeting at Robins in January 1981, at the "User Review of Site Specific Configuration" meeting held on 11 March 1981 at Robins and the "Mid-term Review" meeting held at Robins on 30 April - 1 May, 1981.

1.8.2 ROBINS AIR FORCE BASE BENEFITS FROM THE SOLAR COGENERATION FACILITY

Located in the heart of middle Georgia, Robins Air Force Base, is the home of the Warner Robins Air Logistics Center (WR-ALC) one of five Air Force Logistics Command (AFLC) industrial-logistics complexes in the U.S. Warner Robins ALC ensures the readiness of operational forces by providing worldwide logistics management for over 40 major weapons systems, including the C-141 and C-130 cargo aircraft, helicopters, various missiles, the F-15 Air Superiority Fighter and over 190,000 items used on every aircraft in the Air Force inventory. Warner Robins ALC is also the Avionics Center for the Air Force, and the Air Force technology repair center for gyros, airborne electronic equipment, life support systems, and propellers. Headquarters, Air Force Reserve, the Strategic Air Command 19th Bombardment Wing and various Air Force tenant organizations are also located at this 8,855 acre installation, which employs nearly 15,000 civilian employees and is the largest industrial complex in Georgia. The large work force, highly specialized equipment and industrial processes, and extensive facilities make Robins AFB one of the largest and most important concentrations of Air Force resources in the United States.

As a major logistics installation, Robins Air Force Base depends heavily upon energy in quantity to accomplish its immense logistics mission. For years, AFLC activities like WR-ALC have increasingly relied upon a plentiful supply of low cost energy to service a variety of Air Force logistics needs. Management action has been particularly intense during the past decade to increase system effectiveness and work force productivity by exploiting new mechanized methods, system automation, and high-technology concepts. This trend has been exemplified at Robins by the employment of modern metal cutting, forming and heat-treatment maintenance facilities, new mechanized material handling systems, and the extensive use of environmentally-controlled areas for computer data processing, airborne electronic component repair, corrosion control work, and other functions. The result has been an era of enchanced productivity and operational responsiveness, accompanied by an increased reliance upon the energy "factor of production."

Energy-intensive AFLC activities have been severely affected by the nationwide energy cost-supply problem. The decline in domestic oil and natural gas production, complicated by the growing national dependence upon unreliable, high-priced foreign energy sources, has had a pronounced impact on the Air Force activities as well as private industry. Costs have climbed steeply since the early seventies for electric power, fuel oil, and natural gas, with the cost growth expected to continue in the future. Vigorous energy conservation measures have been effective in most cases in reducing energy consumption. Total energy costs have risen, nevertheless, because of increases in utility rates.

Robins AFB and other Air Force activities are responding to today's energy challenge with emphasis on improved energy effectiveness on several fronts. A number of specific programs are under way to carry out Executive Order 12003, which requires a 20 percent reduction in energy in existing facilities by 1985.

Building Energy Technical Surveys (BETS)

Robins was one of the first Air Force installations to implement building energy audits using a computer simulation model, which resulted in Military Construction Program actions in FY 80, 81, and 82. Projects in this context include conventional energy savings measures, such as adding insulation, storm windows, etc., as well as technical improvements in heating and cooling systems. Improvements to 30 buildings, costing $1.5 million, have been awarded to date. Energy conservation improvements in 16 other buildings are now under design.

Energy Monitoring and Control System (EMCS)

The EMCS is the latest state of the art in centralized computer control of utilities energy consumption. Construction now under way will complete connection of the EMCS to all major Robins facilities. The system allows central control for manual and programmed turn-off and turn-on of air conditioning, heating and other equipment. The EMCS also provides monitoring of steam pressure, chilled water temperature, room temperature, air flow, metering capability, and preventative maintenance information. The EMCS will play a major role in meeting energy goals at Robins.

Energy Curtailment Contengency Plan

To prepare for the increasing threat of energy shortages, Robins developed and published in April 1980 a comprehensive energy curtailment contingency plan to deal with possible energy shortage scenarios.

Industrial Solar Applications

A solar energy system to purify aircraft fuel tank purge fluid was locally designed and installed in 1977 as one of the first industrial solar applications in the Air Force. Prior to the installation of this system, purge fluid (a high flash point oil which is used to "wash out" aircraft fuel tanks to reduce explosion hazards) became contaminated with more flammable aircraft fuel after repeated use, and the flash point would drop below the minimum safety level. This contaminated fluid was then sold for a fraction of its original cost. With the solar system, the purge fluid is now reclaimed and purified for repeated use. The purge fluid is purified by flowing through the solar panels for heating and then to an aeration tank where the more volatile fuel components are evaporated off and condensed for other uses. The project paid for itself the first year and at current purge fluid prices now saves the taxpayer over $41,000 per year. In addition to this project, Robins AFB recently completed construction of a $1.0 million solar energy system for the aircraft corrosion control facility. The system utilizes 1,580 m^2 (17,000 ft^2) of flat-plate collectors to produce 60-82°C (140-180°F) water, which in conjunction with a 473 m^3 (125,000 gallon) storage tank, is used for aircraft corrosion treatment of C-130, C-141 and F-15 aircraft. The system will supply virtually 100 percent of the 12 million liters (3.2 million gallons) of hot water required annually for these aircraft.

Energy policy at Robins AFB and with AFLC, as exemplified in the above initiatives and other actions, is to support national energy objectives by becoming more energy efficient, reducing dependance on critical fuels and by shifting to alternative sources. The Westinghouse proposed Solar Cogeneration Facility will make a major contribution to the base energy program by reducing base reliance on nonrenewable energy sources. This application of advanced energy technology will also be of considerable value to the direct logistics mission of the base by servicing the south end of the base and particularly the Directorate of Maintenance Avionics Centers in Buildings 640 and 645, the Base Hospital and Robins Community Center. Maintenance facilities in the vicinity of the proposed solar site operate five days per week, three shifts per day, and weekends during the day shift. The weekend work is required for performance of scheduled avionics work load with existing equipment and facilities. This tends to spread out our energy utilization and will enable the proposed solar facility to fully contribute at all periods of energy generation. The electrical power generation will be especially beneficial because of the consistently growing peak demand. Based on previous experience with solar energy, base officials, including the using activity and the Base Civil Engineering organization, are very enthusiastic about developing and implementing a solar cogeneration application. There is no doubt that the solar cogeneration facility will assist Robins in the long range AFLC goal to be energy self-sufficient for the industrial processes by the year 2000.

1.8.3 COMMENTS ON OPERATION, SAFETY, AND ENVIRONMENTAL IMPACTS AND BENEFITS

RAFB and Air Force Logistics Command personnel have maintained an intimate knowledge of the conceptual design of the cogeneration facility with a continual surveillance of the compatibility of the design with existing operating staff capabilities, safety considerations for the facility and its interaction with the utilization of the surrounding areas, and the environmental benefits and/or impacts.

During the execution of this design RAFB personnel have reviewed and influenced the content of the facility specification with respect to safety requirements, reviewed the tower location and height in relation to similar structures (water towers) and existing flight paths, provided local data for the environmental criteria section for the Facility Specification and advised on specific actions to initiate environmental deliberations. Based upon the above actions, the user is confident that appropriate actions have been taken for the conceptual design phase and that the proper background has been established to expect success from on-going work relative to operational, safety and environmental issues.

1.8.4 COMMENTS ON PROJECT DEVELOPMENT PLAN AND SCHEDULE

The development plan presented in Section 7.0 of this report has been reviewed by the user to determine whether the role assigned to the user is desirable within the context of the total plan. The roles, authority and responsibilities as outlined in that section are endorsed by the Air Force Logistics Command and RAFB as a desirable arrangement worthy of support. The owner costs associated with accepting that user role are also agreeable to the Air Force Logistics Command. The schedule for operation in 1986 is deemed satisfactory although an expedited schedule would be preferred by the user. Earlier operation can be achieved either of, or a combination of, two ways. First, a contract start date prior to October 1982 would improve the operation date on a day for day basis. Second, an implementation of a "fast-track" schedule in which aggressive early committments to long-lead procurement items are pursued could shorten the design and construction period by an estimated six to nine months. Efforts to achieve these improvements is desirable.

Results and Conclusions

The DOE Solar Thermal Central Receiver Program was expanded to include cogeneration applications. Conceptual design studies for seven solar cogeneration facilities have been completed.

This effort has provided DOE and industry with

- definitions of possible solar cogeneration facilities
- preliminary estimates of system performance and costs
- preliminary estimates of the technical, economic, institutional, regulatory, and environmental benefits of, as well as barriers to, solar cogeneration facility projects
- preliminary estimates of development test requirements, costs, and schedules for subsequent demonstration projects
- an indication of potential user cost-sharing arrangements with DOE for subsequent demonstration projects

Each prime contractor developed a unique conceptual design for the proposed project and, from this design, evaluated the performance and estimated the project cost. Then, using the estimated project cost and economic assumptions, criteria, and methodology supplied by the site owner-user, the prime contractor performed an economic analysis for the project.

While the conceptual design affected the estimated project cost, certain cost factors also influenced some conceptual designs. The high cost of heliostats had a significant effect on the design of at least one solar cogeneration facility. Design options such as thermal storage became limited because thermal energy from solar was found to be more expensive than energy derived from fossil fuels.

These limiting features represent only one obstacle to an evaluation and comparison of the cost estimates for the seven projects. Variations in the following project aspects severely restrict such a comparison:

- solar technology features
- solar central receiver sizes (8.7 MW_t to 270 MW_t)
- modifications to the existing facilities (from simple tie-in to major additions and system capacity upgrades)

- geographic locations and site specifics

- particular industries and industrial processes

But the diversity in physical plant characteristics is not the sole deterrent to a comparison of cost estimates. Each contractor estimated project costs at different levels of cost-estimating. Furthermore, cost factors included in some estimates were not included in others; some factors were not considered at all. The following examples illustrate the different cost-estimating methods.

1. Consumables and start-up costs were included by one contractor in the construction cost estimate and by two contractors in the owner's cost estimate. Only one contractor directly identified these costs. The remaining contractors gave no indication if these costs were included in their project estimates.

2. Two contractors did not submit separate owner's cost estimates, and they did not indicate whether the total estimate included owner's costs. For those projects that specified owner's costs, the definition of those costs could differ. Some owner's costs may therefore be included in the construction cost estimate.

3. Construction management and procurement costs did not always appear separately. These costs may have been included with direct, engineering, or owner's costs.

4. The fee was not always shown separately and may or may not have been included in engineering and construction management costs.

5. Interest during construction was included in one estimate but not in others.

6. Working capital was not identified.

7. Major omissions and arithmetic errors can be found in some of the cost estimates.

8. The items included in the specified cost codes were not uniform among the various projects. Also, the cost of the solar add-on was not readily identifiable from the cost of nonsolar components or additions.

Although these various project cost factors affect cost comparisons, they may not significantly affect the original economic analyses made by the prime contractors. According to those analyses, projects ranged from having negative value to being economically attractive. However, from an objective point of view, one must remember that the economic analyses were also made on different bases. Comparing the economic value of one plant with that of another must be done with caution.

The economic analyses for the individual projects show the following:

- Pioneer Mill Company, Ltd.: Given more mature solar components (lower heliostat costs) and higher fuel oil costs, this project has potential economic value.

- Central Telephone & Utilities - Western Power: On the basis of Western Power's economic evaluation framework, the CTU-WP facility has negative economic value.

- Exxon Corporation Edison Field: When compared to an oil-fired steam boiler facility, the solar cogeneration facility at Exxon's Edison Field is an economic disadvantage. Exxon's view of the economic value of their project was very pessimistic, even though with increased incentives the value can increase substantially.

- Texasgulf Comanche Creek Sulfur Mine: According to the economic assessment of a commercial solar generation plant at the Comanche Creek Sulfur Mine, this project has potential economic value if solar component costs decrease and fossil-derived energy costs increase.

- Phelps Dodge Corporation Hidalgo Copper Smelter: If the solar cogeneration plant were to operate as designed, this project could have potential economic value and pay for itself in 23 months. These results appear overly optimistic in favor of solar. Comparisons with an equivalent fossil plant were not made. Further consideration of several specification and economic issues are necessary as well.

- Fort Hood Army Base: Although the results of the Fort Hood project were hopeful, the initial economic findings are not encouraging and lack promise of developing real economic value.

- Robins Air Force Base: The project at Robins Air Force Base was viewed with enthusiasm by the Air Force. Given the right set of conditions, this facility has potential economic value.

In summary, the economics of the solar cogeneration projects are strongly dependent on several variables, including heliostat costs, fuel costs, fuel escalation rates, plant life, operation and maintenance costs, federal and state tax credits, the potential user's method of calculating benefits, and cost of electricity. Although the cost differences may not significantly affect the results of the economic analyses, they do affect any attempt to verify whether the capital cost per unit energy is less for cogeneration than for conventional systems. A better method to identify the exact nature of the various costs should be derived and specified for future studies.

Involving the potential user in the conceptual design studies was an important element in industry evaluation. Several plant owners were very skeptical at the beginning of the conceptual design process but became convinced that central receiver technology is a viable source of renewable energy. Even so, users maintain that the economics are not presently attractive without more favorable tax and legislation incentives. Some form of creative financing will be required before central receiver technology penetrates the industrial sector.

With so many variables, it is impossible to make absolute comparisons among the seven cogeneration projects and arrive at a single conclusion or recommendation. The results do indicate, however, that solar central receiver cogeneration has a number of promising applications and merits further study in selected areas.

APPENDIX A. SOLAR COGENERATION REPORTS

These final reports provide information on the seven solar cogeneration projects completed in FY1981. They are the result of a DOE Request for Proposal (No. DE-RP03-80SF10768) for the "Conceptual Design of a Solar Central Receiver System Integrated with a Cogeneration Facility."

Each report contains an executive summary, a main body, and appendices in one or more volumes. They also include facility descriptions, conceptual design details, system performance, economic findings, development plan, and site owner's assessment.

1. DOE/SF/11431-1. Conceptual Design of a Solar Cogeneration Facility at Pioneer Mill Co., Ltd. Final Report, August 1981.

2. DOE/SF/11439 - 1/1, 1/2, 1/3. Solar Cogeneration Facility, Cimarron River Station, Central Telephone and Utilities - Western Power. Final Report, August 7, 1981.

3. DE-AC0380SF11438, Vol. I, Vol. II. Conceptual Design of a Solar Cogeneration Facility, Industrial Process Heat (Category A). Final Report, Exxon, July 1981.

4. DOE/SF/11437-1, 2. Texasgulf Solar Cogeneration Program. Final Report, June 1981.

5. DE-AC03-81SF-11533. Solar Central Receiver System Integrated with a Cogeneration Facility for Copper Smelting. Final Report, Appendix A through I, August 1981.

6. MDC G9716 Vol I, Vol II (DE-AC03-81SF 11495). Fort Hood Solar Cogeneration Facility Conceptual Design Study. Final Report, August 1981.

7. AESD-TME-3114 Vol I, Vol II (DE-AC03-81SF11494). Robins Air Force Base Solar Cogeneration Facility. Final Report, August 1981.

Reports may be obtained from:
National Technical Information Service
U. S. Department of Commerce
5285 Port Royal Road
Springfield, VA 22161
(703)487-4600
(FTS)937-6011

APPENDIX B. PROJECT ADDRESSES

Listed below are addresses for obtaining additional information on the solar cogeneration projects.

1. Bechtel Group, Inc.
   Attn: Jack R. Darnell
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   San Francisco, CA 94119

2. Black & Veatch Consulting Engineers
   Attn: John E. Harder
   P. O. Box 8405
   Kansas City, MO 64114

3. Exxon Enterprises, Inc.
   Solar Thermal Systems
   Attn: Patrick Joy
   P. O. Box 592
   Florham Park, NJ 07932

4. General Electric Company
   Advanced Energy Programs Department
   Attn: Howard E. Jones
   1 River Road
   Schenectady, NY 12345

5. Gibbs & Hill, Inc.
   Attn: Robert Prieto
   393 Seventh Avenue
   New York, NY 10001

6. McDonnell Douglas Astronautics Co.
   Attn: Robert P. Dawson
   5301 Balsa Avenue
   Huntington Beach, CA 92647

7. Westinghouse Electric Corp.
   Attn: Robert W. Devlin
   P. O. Box 10864
   Pittsburgh, PA 15236

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L. Gutierrez, 8400
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