4T

DOE/SF/11436-1(Ex.Summ.)
(DE82005296)

SOLAR CENTRAL RECEIVERS: THE TECHNOLOGY, INDUSTRY, MARKETS, AND ECONOMICS

Executive Summary

September 1, 1981

Work Performed Under Contract No. AC03-81SF11436

Booz, Allen & Hamilton, Inc.
Bethesda, Maryland

U.S. Department of Energy

Solar Energy

DOE/SF/11436-1(Ex.Summ.)
(DE82005296)
Distribution Category UC-62

SOLAR CENTRAL RECEIVERS:

THE TECHNOLOGY, INDUSTRY, MARKETS, AND ECONOMICS

EXECUTIVE SUMMARY

SOLAR ENERGY DIVISION
U.S. DEPARTMENT OF ENERGY

PREPARED BY

BOOZ·ALLEN & HAMILTON INC.
4330 EAST WEST HIGHWAY
BETHESDA, MARYLAND 20814

SEPTEMBER 1, 1981

DOE CONTRACT NO. DE-AC-3-81SF11436

ACKNOWLEDGMENT

Booz, Allen & Hamilton, Energy and Environment Division gratefully acknowledges the assistance of Robert W. Hughey, Director, Solar Energy Division, San Francisco Operations Office, U.S. Department of Energy and of Keith A. Rose, Project Manager, Solar Energy Division, San Francisco Operations Office, U.S. Department of Energy in the conduct of this study and preparation of this report.

TABLE OF CONTENTS

LIST OF EXHIBITS

LIST OF EXHIBITS
(Continued)

EXECUTIVE SUMMARY

During the past decade, the U.S. Department of Energy (DOE), the Electric Power Research Institute (EPRI), and private sector corporations have funded extensive development of solar central receiver (SCR) technology to the pilot plant stage. Technical development activities and preliminary market evaluations suggest three major applications for SCR:

- Industrial process heat (IPH) production
- Electric power generation
- Cogeneration of power and heat.

It is not yet clear how these markets will develop or how the SCR technology currently under development will best match these markets. To help address these uncertainties, this study provides an assessment of solar central receivers, focusing on technology development status, candidate manufacturers and suppliers, markets, and economic factors.

The goal of the DOE Solar Thermal Energy Systems program is to reduce the nation's dependence on scarce and imported fossil fuels by encouraging the development of a viable supply industry offering marketable solar thermal technologies. This program is currently developing four technologies that use concentrating collector concepts: hemispherical bowls, parabolic troughs and dishes, and SCRs.

SCR technology development is being supported by DOE through research and development of components and subsystems and funding of conceptual design studies. The 21 government-sponsored conceptual design studies, listed in Exhibit 1, assess the performance and economics of central receiver systems applied to site-specific utility, industrial, and cogeneration facilities.

Based on the conceptual design studies and this overall assessment, it is clear that the markets for IPH, cogeneration, and utility power generation in the southwest could be addressed by SCR technology.

Even though the market for SCRs has not yet developed, an industry of potential SCR vendors who are continuing SCR technical and market development is evolving to meet the potential demand for SCR equipment and services.

The major conclusion of this study is that there is a near-term utility market that could be supplied by SCR technology which can grow to include significant IPH

EXHIBIT 1

Summary of Solar Central Receiver Conceptual Design Projects

	Project	Prime Contractor(s)	Site Location	SCR Technology
Repowering - Industrial Process Heat	• Exxon Oil Recovery	Martin Mareitta	California	Water/Steam
	• Gulf Mt. Taylor	McDonnell Douglas	New Mexico	Water/Steam
	• Provident Energy Co.	Foster Wheeler	Arizona	Water/Steam
	• Valley Nitrogen	PFR, Inc.	California	Methane/Steam
	• U.S. Gypsum Co.	Boeing	Texas	Air
	• North Coles Levee	Northrup	California	Oil
Repowering - Electric Generation	• El Paso Elec. Co.	El Paso Elec./Westinghouse	Texas	Water/Steam
	• Public Service of Oklahoma	Black & Veatch	Oklahoma	Water/Steam
	• Public Service of New Mexico	Public Service of New Mexico	New Mexico	Water/Steam
	• Arizona Public Service	Arizona Pub. Ser./Martin Marietta	Arizona	Molten Salt
	• Sierra Pacific Power	McDonnell Douglas	Nevada	Molten Salt
	• Southwestern Public Service	General Electric	Texas	Sodium
	• Texas Elec. Services Co.	Rockwell International	Texas	Sodium
	• West Texas Utilities	Rockwell International	Texas	Sodium
Co-Generation	• AMFAC Sugar Co.	Bechtel	Hawaii	Water/Steam
	• Central Telephone & Utilities Western Power	Black & Veatch	Kansas	Water/Steam
	• U.S. Air Force Robins AFB	Westinghouse	Georgia	Water/Steam
	• Phelps Dodge Corp.	Gibbs & Hill	New Mexico	Air
	• Exxon Edison Oil Field	Exxon	California	Molten Salt
	• U.S. Army Ft. Hood	McDonnell Douglas	Texas	Molten Salt
	• Texas Gulf/Comanche Creek	General Electric	Texas	Water/Steam

applications in the 1990's. The implication for the DOE Solar Thermal Energy Systems program is that the acceptance of SCR technology will largely depend on the success of early demonstrations. Encouraged by successful demonstration, the growth of early utility market applications, such as the repowering of existing oil-fired generating stations, can provide the demand which will produce the economies of scale in heliostat production necessary to significantly penetrate IPH markets in the 1990's.

* * * * *

The balance of this Executive Summary presents the major findings and conclusions of this study considering SCR technology, markets, economics, and industry. The next section describes SCR technologies and compares them briefly with other solar thermal technologies.

1. A VARIETY OF SCR SYSTEM CONFIGURATIONS AND SUBSYSTEM OPTIONS HAVE BEEN DEVELOPED TO FIT A WIDE RANGE OF APPLICATIONS

SCR technology, under development in the United States for almost a decade, has progressed to the pilot plant stage. Full size heliostat modules have been built by a number of manufacturers. Other system components have been built and tested, although on a scale smaller than required for an optimum-sized commercial plant.

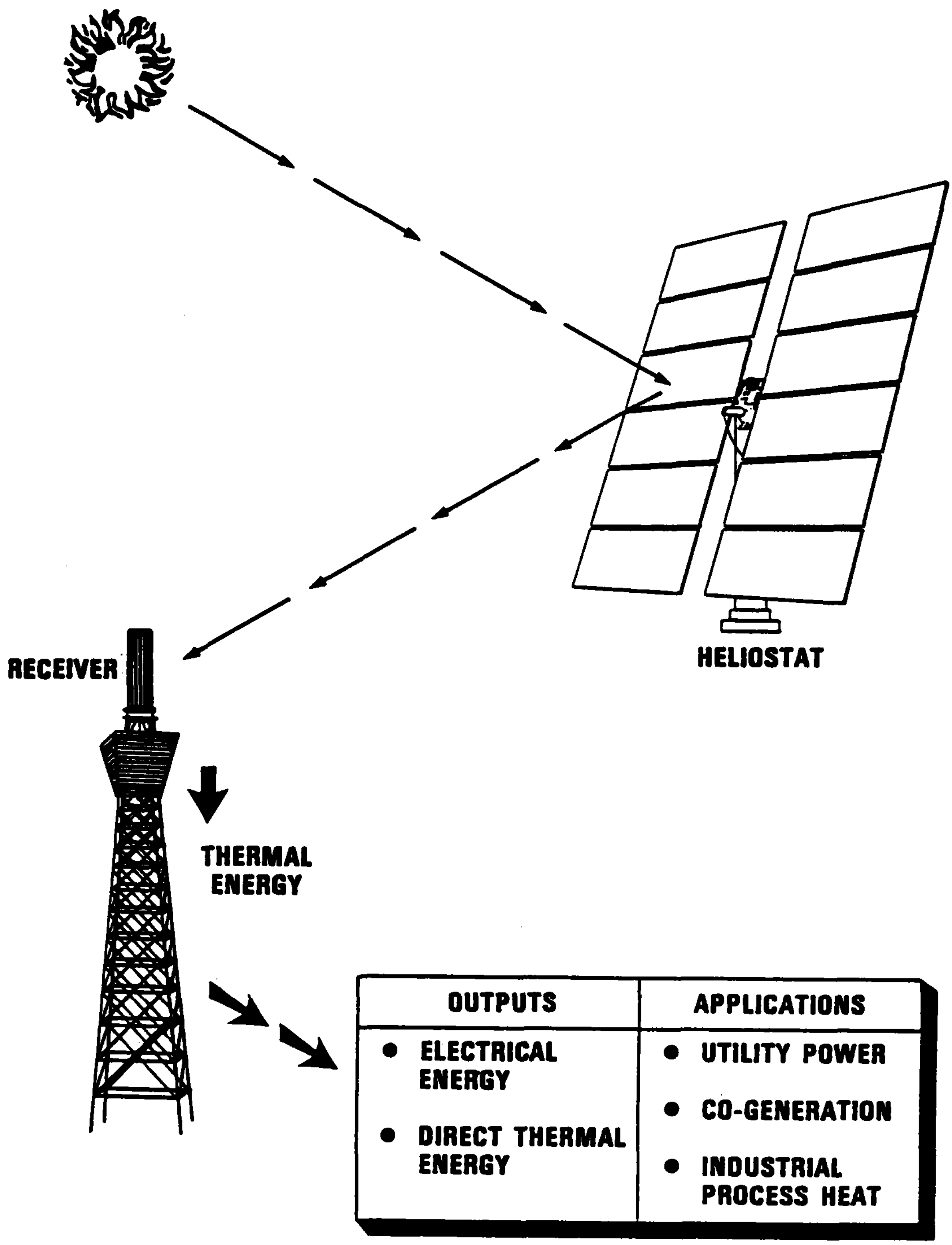
The basic central receiver concept, shown in Exhibit 2, consists of three major components:

- A number of computer guided mirrors--heliostats--that reflect direct solar radiation to a single point
- A receiver located at the heliostat field focal point that absorbs the reflected solar energy
- A thermal transport system that carries the thermal energy from the receiver to the point of use.

The thermal energy in the transport fluid can be used to run a turbine/generator to provide utility power or cogeneration, or to provide heat directly for use in industrial processes.

Peak thermal power output levels for SCR systems range from 1 to about 1,500 MW_t (3.5 to 5100 million Btu/hr). The lower limit corresponds to the point at which the plant size is too small to economically justify building a tower and receiver system. The largest size results from a practical land limitation, loss of reflected solar beam accuracy and image size from remote heliostats, and heliostat field blockage considerations.

EXHIBIT 2
Solar Central Receiver Technology



The primary applications for SCR systems are for electric power generation and direct thermal energy uses. Electric power generation options include:

- Full-scale utility power plants--primarily intermediate load plants with oil or natural gas back-up

- Utility repowering in which the SCR system is retrofit to an existing fossil-fueled power plant

- Electrical cogeneration in which the SCR supplements a conventional heat source to drive a standard cogeneration system.

Direct thermal energy use is primarily for industrial process heat (IPH) applications. SCR system output is compatible with end uses requiring either steam or hot air.

The wide range of potential applications has led to the development of several central receiver system configurations and subsystem options with differing operating characteristics. One key option is the choice of heat transfer fluid.

(1) The Selection of Heat Transfer Fluids Can Determine the Technical Fit With Specific Applications

The major distinguishing characteristic of a SCR system is the type of heat-transport fluid used to deliver the thermal energy from the receiver to its end use or heat-exchange point.

The choice of fluid, or the choice of SCR technology, is dictated by the temperature requirements of the proposed application. In general, for current technologies, the feasible operating temperatures ranges are:

- up to 1000°F for water/steam
- 1500°F to over 2000°F for air
- 500°F to 1050°F for molten salt
- 300°F to 1100°F for liquid sodium
- up to 750°F for silicon-based heat transfer oils.

If, on the basis of operating temperature, more than one heat-transport fluid can be used, then other factors that distinguish among the SCR technologies--such as system performance, size, economics, safety, and familiarity with the fluid technology--become important to the system designer. Some of the major characteristics of the various SCR technologies are presented in Exhibit 3.

EXHIBIT 3
Characteristics of Solar Central Receiver
Technology Options

	SYSTEM CLASSIFICATION				
CHARACTERISTIC	WATER/STEAM	AIR	SALT	SODIUM	OIL
MAXIMUM OPERATING TEMPERATURE (°F)	1000	2000	1050	1100	750
FLUID PROPERTIES	HIGH ENERGY DENSITY*	LOW ENERGY DENSITY*	HIGH ENERGY DENSITY*	MODERATE ENERGY DENSITY*	MODERATE ENERGY DENSITY*
FLUX CAPABILITY	MODERATE	LOW	MODERATE	HIGH	MODERATE
FLUID COST	LOW	LOW	MODERATE $.15/LB	HIGH $.40/LB	HIGH $.35/LB
STORAGE COUPLING EFFICIENCY**	POOR	FAIR	GOOD	GOOD	FAIR
OPERATIONAL CONSIDERATIONS	HIGH PRESSURE	HIGH TEMPERATURE	LOW TEMPERATURE FREEZING	SAFETY	LOW TEMPERATURE FREEZING

* ENERGY DENSITY IS THE PRODUCT OF MASS DENSITY, ρ, AND SPECIFIC HEAT.
** ABILITY TO EFFICIENTLY TRANSFER COLLECTED ENERGY INTO AND OUT OF STORAGE.

- Water/steam systems are characterized by good heat transfer properties at the expense of high operating pressures resulting in smaller receiver and heat-exchanger sizes than for other technologies.

- Air systems have poor heat-transfer properties but are tolerant of high operating temperatures. The low-energy density of air systems results in extremely large heat exchangers to transfer the required amount of heat and low heat-flux capability, which necessitates large, expensive receivers.

- Molten salt systems have excellent heat transfer capabilities, but they must be protected from freezing at ambient temperatures. Salt system heat-transfer characteristics are almost as good as water/steam.

- Sodium systems have high fluid costs and present possible safety hazards if not operated under strictly controlled conditions. Liquid sodium reacts violently with both air and water and must be protected from freezing at ambient temperatures like molten salts.

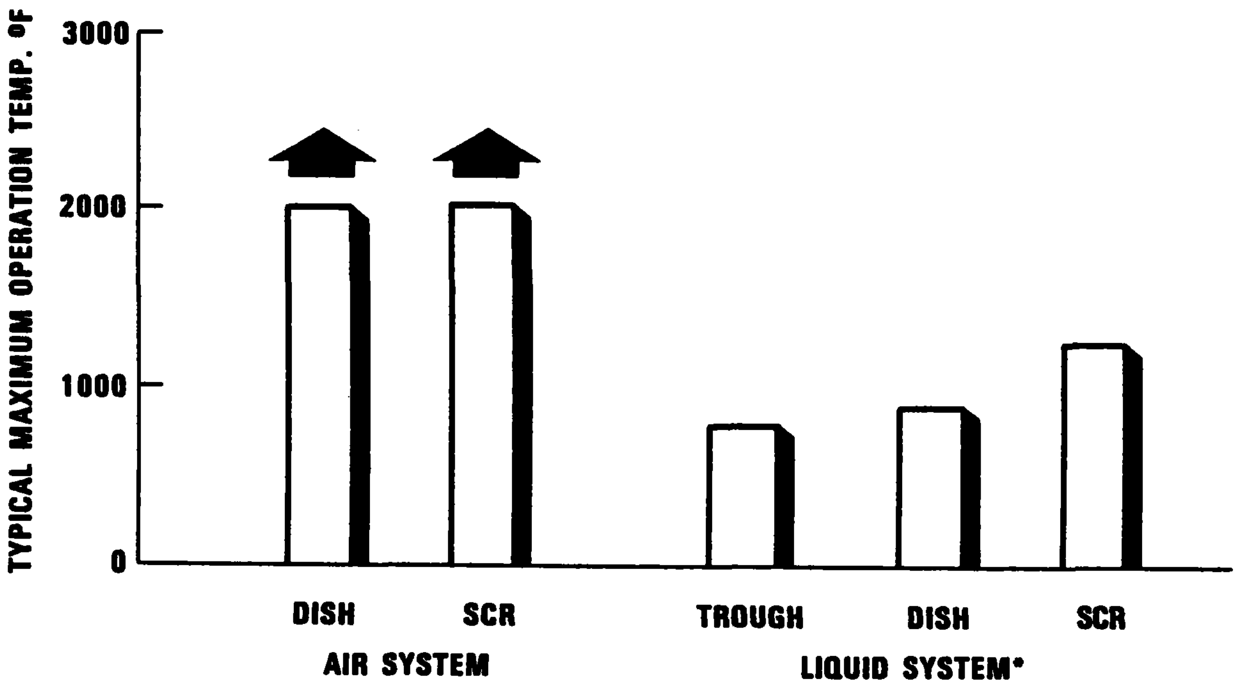
- Oil systems are characterized by low operating temperature capability and relatively high fluid cost. Most heat-transfer oils have a moderate heat-flux capability and must be protected against freezings at temperatures below 100°F.

(2) In General, SCR Systems Can Operate at Higher Temperatures Than Parabolic Trough and Parabolic Dish Solar Thermal Technologies

The designs of each solar thermal system result in certain inherent temperature restrictions and capabilities. Although the technologies are not fully developed, a range of expected maximum temperatures can be projected for each category of solar thermal systems, as shown in Exhibit 4. SCR generally can provide the highest output temperature, using both air and liquid heat-transport fluids.

- With air or gas as the heat transport fluid passing through the receiver, both SCR and dish collector systems can operate at temperatures of 2000°F or higher. SCR operating temperature systems are limited only by the maximum temperature capabilities of the receiver and thermal transport loop materials, while dish systems may also be limited by thermal losses in the transport loop.

EXHIBIT 4
Typical Operating Temperature Ranges for
Solar Thermal Technologies



* FLUIDS INCLUDE WATER/STEAM, OILS, SALTS

- With a liquid heat transfer medium, SCR can operate up to about 1000°F to 1100°F with available hardware technology. This is significantly higher than either dish or trough collectors. The dish collector is probably limited to about 750°F because of transport loop thermal losses. Parabolic trough collectors are limited to a maximum operating temperature of about 550°F by significant operating efficiency losses compared with alternative SCR and dish point focus technologies.

The temperature capabilities and system characteristics of SCR suggest a broader range of potential applications than for dish and trough systems. A matching of the solar thermal technologies and applications is presented in Exhibit 5. SCR technologies provide a good technical fit in the following application areas:

- Utility repowering and central station electric power generation

- IPH applications requiring temperatures above approximately 500°F

* * * * *

Divergence in the capabilities of SCR technical options offers wide spread application, but may also preclude the development of one SCR technology for all markets as discussed in the following section.

2. NO SINGLE SCR TECHNOLOGY HAS EMERGED AS THE BEST TECHNOLOGY FOR ALL APPLICATIONS

Conceptual design studies have been conducted for a variety of technologies in each major application, but no single heat transfer fluid has been identified as the "winner". The DOE Repowering/Industrial Retrofit Program involves central receiver applications at the site of an operating utility power plant or an industrial plant. Under this program, 13 conceptual design studies have been completed for different applications at actual plant sites (Exhibit 6). Seven additional conceptual designs are being developed for cogeneration applications.

- Electric repowering designs have considered water/steam, molten salt, and sodium systems. Two contractors each have designed water/steam and molten salt systems, and three have used sodium.

EXHIBIT 5
Solar Technology/Application Match*

APPLICATION / SOLAR TECHNOLOGY	UTILITY		INDUSTRIAL		COMBINED
			INDUSTRIAL PROCESS HEAT		
	REPOWERING	CENTRAL STATION	MED TEMP <500°F	HIGH TEMP ≥500°F	CO-GENERATION
SOLAR CENTRAL RECEIVER	●	●	◒	●	●
DISH	○	●	◒	◒	◒
TROUGH	○	○	●	○	○

LEGEND

- ● **PROBABLE MATCH OF TECHNOLOGY AND APPLICATION**
- ◒ **POSSIBLE MATCH**
- ○ **UNLIKELY MATCH**

* Assessment based on matching application temperature requirements with solar thermal system temperature capabilities.

EXHIBIT 6

Summary of DOE Solar Central Receiver Conceptual Designs

TECHNOLOGY	NUMBER OF CONCEPTUAL DESIGN STUDIES — APPLICATION		
	REPOWERING	IPH	CO-GENERATION
SODIUM	3		
WATER/STEAM	2	4	4
MOLTEN SALT	2		2
AIR		1	1
OIL		1	
TOTALS	7	6	7

- IPH systems have been predominantly water/steam; however, one oil system and one air system have also been designed.

- Cogeneration systems have also been designed predominantly using water/steam, with molten salt and air system types also included.

(1) <u>For Electric Generation Systems, Studies Have Shown That Molten Salt Will Be the Most Cost-Effective</u>

Exhibit 7 shows busbar electricity costs for water/steam, salt, air, and sodium systems:

- Without thermal storage, molten salt is slightly more cost-effective than other systems.

- The addition of storage further improves the economic advantage of molten salt systems.

- Baseline water/steam and sodium system electricity costs are relatively insensitive to storage. (The advanced water/steam shows cost reduction with increased storage because of the use of a reheat turbine in conjunction with dual stage storage.)

- Systems that use air as the heat transport fluid are not cost-effective for large electric generation units compared with all other technologies.

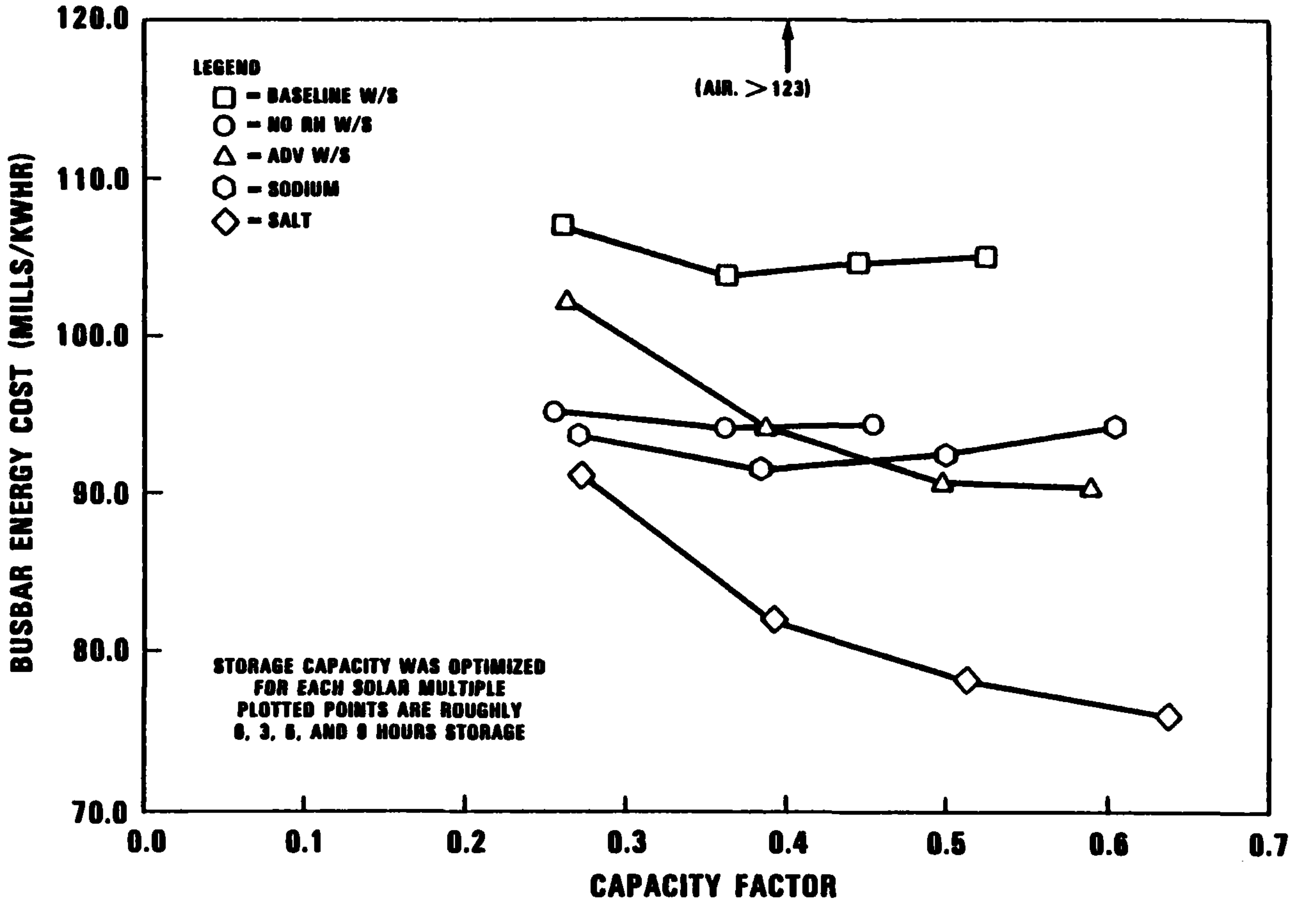
Although the study referenced in Exhibit 7 was based on only a single-system size and on projected costs, the potential economic advantage of molten salt systems for electric power generation is clear.

(2) <u>The Diversity of IPH Requirements Will Probably Lead to the Use of Several Types of SCR Systems</u>

Based on market considerations, most developers feel that the most promising IPH applications for SCR technology involve the supply of process steam or hot air. It remains to be determined which technologies can best satisfy these markets. However, the following general conclusions can be drawn:

- Industrial processes requiring hot air at temperatures of 1500°F and above, such as dryers and kilns, may be most economically addressed with an air receiver as working fluid.

EXHIBIT 7
Solar Central Receiver Busbar Electricity Cost



Source: K. W. Battleson et. al., 1980 Solar Central Receiver Technology Evaluation, SAND80-8235, October 1980.

Note: Based on heliostat costs of $72/M^2

- For industrial processes requiring steam between 500°F and 1000°F, a salt, sodium, water, or oil coupled receiver might be the most cost-effective, depending on the process temperature and storage requirements.

- Continuous process operating requirements, typical of most large energy-consuming industries, result in the need for storage-coupled or fossil-fired hybrid systems.

(3) Most SCR System Types Can Be Used in Cogeneration Applications

The high-temperature capability of molten salt, water/steam, and sodium systems will result in the best cogeneration system performance using steam Rankine technology. Hot air systems might use a topping (Brayton) or bottoming (Rankine) cycle to form a cogeneration system. However, system capital cost and operating reliability may limit the use of combined cycle cogeneration with SCR.

* * * * *

Even though no single technology seems to fit all market applications, there are no critical technical show stoppers to the development of multiple SCR technologies. There is, however, a necessity for continued technical development of both components and systems.

3. THERE ARE NO MAJOR TECHNICAL BARRIERS TO THE IMPLEMENTATION OF SCR TECHNOLOGIES; HOWEVER, SYSTEM INTEGRATION AND OPERATING RELIABILITY REMAIN TO BE PROVEN

The major activities of developers of SCR technologies can be divided into two areas: component development and systems development. Industrial developers, although convinced of the ultimate commercial potential of several types of SCR systems, have concentrated their development activities on areas being stressed by the government's programs.

In the component area, as shown in Exhibit 8, the DOE Barstow Project, which uses a water/steam system, has moved that technology significantly ahead of the others. It currently has progressed to the small-scale system test development stage. Development of other receiver/fluid types, also being supported by the DOE program, are in their first design generation. Small-scale tests have been completed for all of these receivers except sodium. Storage development is receiving less direct attention than most of the other components, with development generally awaiting system tests.

EXHIBIT 8

Development Status of SCR Component Technologies

COMPONENT TECHNOLOGY	APPLIED RESEARCH	PRODUCT DEVELOPMENT AND DEMONSTRATION				COMMERCIAL PRODUCT INTRODUCTION
		FIRST GENERATION DEVELOPMENT	SECOND GENERATION DEVELOPMENT	SMALL SCALE SYSTEM TEST	FULL SCALE SYSTEM TEST	
HELIOSTATS						
GLASS			■	■		
PLASTIC	■	▨				
RECEIVERS						
WATER/STEAM		▨	■	■		
AIR	▨	■				
SALT	■	■				
SODIUM	▨	■				
STORAGE						
OIL	▨	▨		■		
SALT	▨	▨				
CONTROLS				■		
POWER CONVERSION						
STEAM RANKING						▨
BRAYTON	■					

LEGEND:

■ AREA OF MAJOR EFFORT

▨ AREA OF MINOR EFFORT

Source: Booz, Allen and Hamilton Industry Interviews

Also noted in Exhibit 8, the areas of concentration reflect both the readiness of the technology and the nature of the technical barrier being addressed. For example, the difficulties facing developers of plastic heliostats are much more fundamental than those facing developers of glass heliostats. As shown by the area of development activity, plastic heliostat R&D is concentrated in applied materials research, while glass heliostats are in system test and later generation design development.

Industry developers are concentrating their system development efforts on four SCR technologies: water/steam, air, molten salt, and sodium (Exhibit 9). Development efforts by U.S. organizations are approximately the same for each of the four technologies; however, as shown in the exhibit, the focus of the efforts vary by technology. Water/steam systems have moved to the small scale system test phase of development. Since the working fluids and fluid handling systems are well understood for air and sodium systems, development effort is focusing on improving the component technologies for SCR-specific design elements--such as receivers. Although successful short-term component tests have been completed for molten salt systems, a major portion of the development activity for this technology is concentrated in the applied research area, reflecting the readiness of the technology for SCR application. Private sector interest is most evident in the following areas:

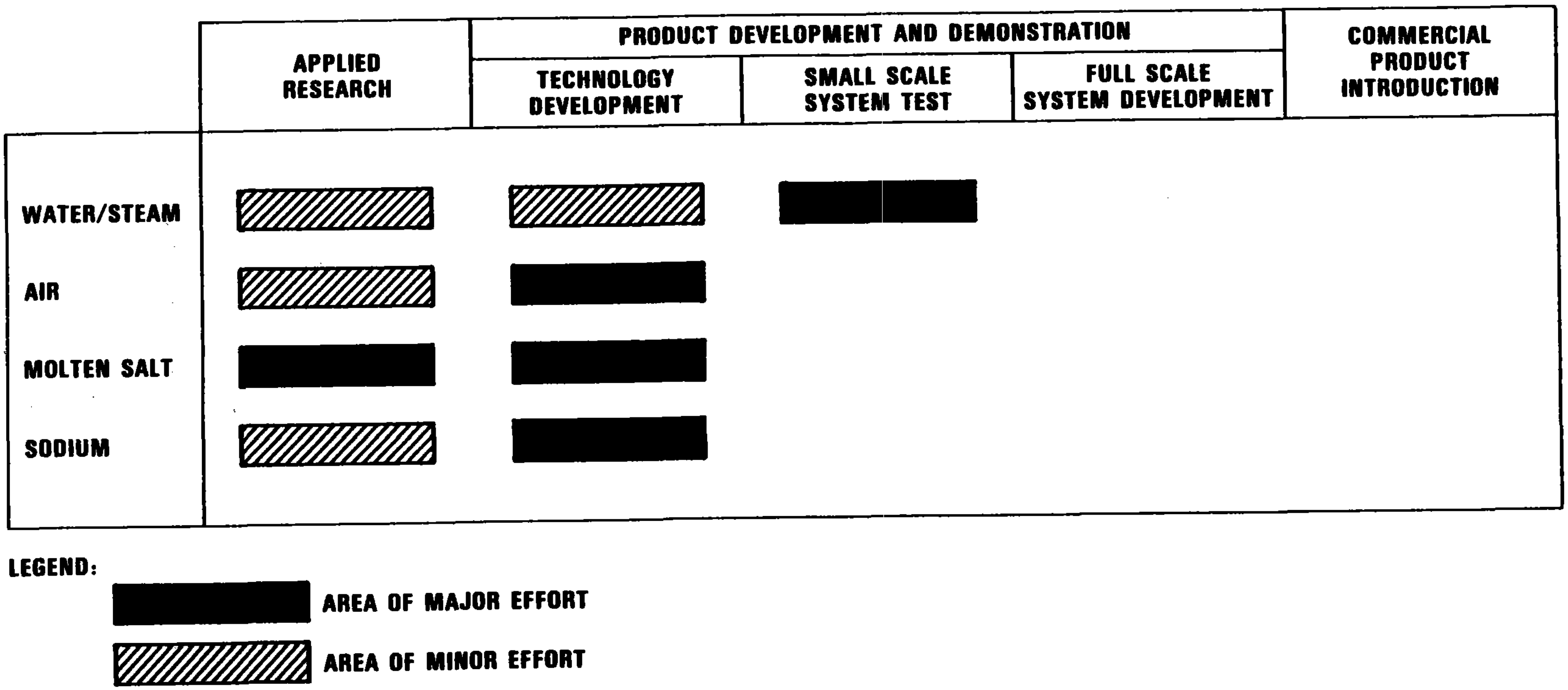
- Substantial industrial effort is evident in heliostat development programs. These programs will result in heliostats that can be used with any of the four SCR technologies. Four major corporations are actively engaged in development programs in this area.
- Manufacturers believe that SCR systems must satisfy the technical requirements of the marketplace as well as represent technologies that are familiar to potential users. For this reason, most companies feel that water/steam systems will be used in early SCR installations.
- Most system developers have focused their efforts on a single technology. This situation has resulted in about equal development activity in each of the four major technologies.

(1) <u>Water/Steam Systems Are Closest to Commercialization</u>

Developers feel that the technology will be adequately demonstrated by the Barstow project. However, some developers and many potential users see a need for a larger size

EXHIBIT 9

Status of Various SCR System Development Programs



Source: Booz, Allen & Hamilton Industry Interviews, June, 1981 or full-scale demonstration system before the technology is fully ready for commercialization.

- The development of water/steam systems has progressed through component testing, and a 10-MWe pilot plant operation will be demonstrated in 1981-1982

- Most technological problems with water/steam systems have been solved, but resistance to thermal cycling receiver fatigue and thermal shock must be demonstrated over at least a 2-year operational period

- Developers believe that water/steam systems will be first in the marketplace and the majority of SCR systems installed over the next 5 to 10 years are expected to be water/steam technology. Half of the DOE-sponsored conceptual design studies selected water/steam systems after evaluations were made with prospective users. Developers feel that because both utilities and industry are familiar with steam as a working fluid, they will more readily accept water/steam systems in the near term.

(2) Air Systems Are in the Technology Development Stage

The major issues related to air system technology are associated with the development of efficient means of transferring heat in the air receiver and distributing high temperature air over relatively large distances. Demonstration of air SCR systems in both IPH and utility applications is required.

- An Electric Power Research Institute (EPRI) development program has proven the technical feasibility of an air receiver operating at high temperatures. Testing of a 1-MW_t air receiver was completed in 1979, with over 100 hours of operation at an outlet temperature of 1500°F.

- Air receiver heat exchange and materials problems that must be solved to take advantage of the inherent higher temperature capability of air systems. High-efficiency heat transfer designs must be developed to provide acceptable receiver costs. Demonstration of complete systems will be required to develop the appropriate control interface between solar and fossil heat sources for hybrid systems

- Development activity is focused on utility power generation systems, although the IPH market may ultimately be more attractive

(3) Molten Salt Systems Have Been Proven to be Technically Feasible Following Successful Component Tests

Molten salt SCR systems have been under development since the mid-1970s. Although component development testing has been successfully completed, several technical issues remain to be resolved. Most of these issues deal with compatibility between the molten salt and containment materials, and the chemical stability of salts over long time periods under conditions imposed by SCR systems. While there is considerable developer interest in molten salt systems, most firms are waiting for some of these basic questions to be answered before actively pursuing molten salt SCR designs.

- Both receiver and molten salt storage tests have been completed for experimental scale units

- Molten salt systems represent a moderate technical risk due primarily to the long-term practicality of using molten salts in an SCR system. Molten salt development programs must not only be aimed at system development and scale-up, but they must also address fundamental materials and chemistry issues as well

- Many developers feel that molten salt systems will be the preferred long-term SCR technology. Molten salt systems are projected to have the best economics for electricity generation when designed as storage-coupled systems. By providing an integrated, cost-effective storage capability, molten salt systems have enough flexibility for application to a wide variety of industrial process situations as well as for electric utility peak displacement.

(4) Although Sodium Is a Developed Technology, Many Issues Remain To Be Resolved Before it Can Be Considered for Most SCR Applications

Developers with experience in the nuclear industry have proposed the use of liquid sodium for SCR systems. In a carefully controlled environment, such as is maintained in a nuclear power plant, sodium systems appear to be acceptable. However, most industrial developers and potential users do not see enough benefits from sodium systems to offset the problems associated with procedures required to deal with the design and operation of these systems.

- Most of the design and characterization data required to implement sodium systems are available since the technology base for sodium systems has been developed in liquid metal fast breeder reactor programs over the past 20 to 25 years.

- Developers have been successful at building laboratory-scale sodium receivers and one is presently being tested at the Central Receiving Test Facility (Albuquerque).

- Although technical issues appear solvable, maintenance and safety issues may delay or preclude use of sodium SCR systems in many applications. Firms interviewed generally expressed a low level of commitment and interest in sodium systems citing potential maintenance and safety problems. The maintenance problems included maintaining cover gas requirements to prevent oxidation and maintaining temperatures above 200 F to prevent freezing. The two primary safety hazards were the formation of potentially explosive hydrogen from reactions with water and the formation of toxic sodium oxide from reactions with air.

* * * * *

Based on interviews with private sector executives and technology leaders, the following consensus emerged:

- Water/steam systems are the closest to acceptance testing and, following pilot plant testing in 1982, are likely to be accepted in the marketplace in the near term.

- Air systems are in the technology development stage, but economic feasibility of these systems is highly uncertain for all applications.

- Molten salt systems have been proven to be technically feasible in component tests

- Sodium systems, while representing a developed technology within the nuclear industry, will have to be proven for SCR applications because of maintenance and safety issues.

The following section considers the geographic segmentation of the addressable market for SCR technology.

4. HIGH INSOLATION LEVELS ENCOURAGE SCR DEPLOYMENT IN THE SOUTHWESTERN U.S.

The average insolation in the U.S. is greatest in sections of the southwest. The insolation levels represented in Exhibit 10 by mean daily direct normal solar radiation affect market acceptance of SCR technology by determining the capital cost and land area requirements for a given energy output level.

A significant number of industrial energy consumers are located in the area of the southwest that has a daily mean direct solar radiation level in excess of 22,000 kilojoules per square meter (6.11 kw-hr/m^2). Some of these industrial plants are energy intensive and may prove to be early adopters of SCR technology.

(1) Capital Costs and Land Area Requirements Are Dependent on the Insolation Level at Specific Sites

The previous section showed that SCR technologies provide a good technical match with all three applications: utility power generation, production of industrial process heat, and cogeneration. In planning for implementation of SCR systems in these applications, two important factors must be considered in addition to system design:

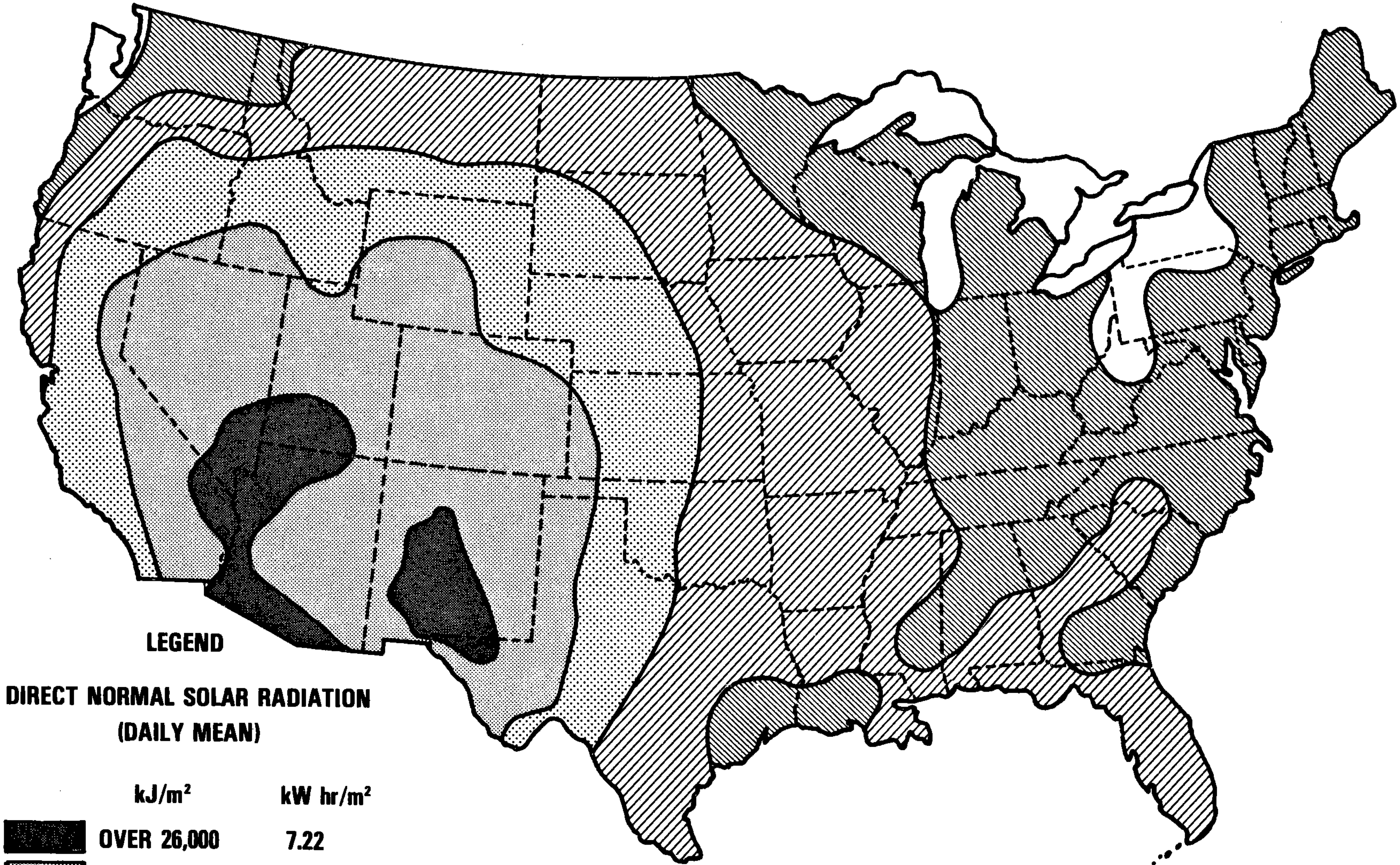
- SCR systems represent a large capital investment.
- SCR systems require the dedication of large land areas.

Both of these factors are related to the available solar resource or to the amount of direct solar radiation at a given site. Higher solar radiation results in fewer heliostats for a given system output requirement, and thus lower system capital cost. Higher solar radiation also results in smaller land area requirements. Exhibit 11 indicates the relationship between direct solar radiation, capital cost of an SCR system, and land area requirements for electric power generation applications. The exhibit is drawn for direct solar radiation values between 5 and 8 kWh/M^2--representative of the major market area for SCR systems. Exhibit 12 shows a similar analysis for a typical IPH system.

Substantial reductions in the cost of installed collector subsystems have been demonstrated as heliostat production has progressed from initial prototype units to pilot plant heliostats. For a range of heliostat installed costs, SCR electric power systems are expected to cost between \$1,400 to \$3,800/kW_e (Exhibit 11). If the DOE heliostat cost target of about \$100/M^2 is met, these systems are projected to cost between \$1,400 to \$1,800/kW_e, with the lower costs associated with high insolation areas.

EXHIBIT 10

U.S. Direct Normal Solar Radiation



LEGEND

DIRECT NORMAL SOLAR RADIATION (DAILY MEAN)

	kJ/m²	kW hr/m²
(dark)	OVER 26,000	7.22
(dense dots)	22,000-26,000	6.11-7.22
(light dots)	18,000-22,000	5.00-6.11
(wide hatching)	14,000-18,000	3.89-5.00
(dense hatching)	10,000-14,000	2.78-3.89
(blank)	UNDER 10,000	2.78

Solar Energy available to Tracking Concentrators Data collected by the DOE National Insolation Resource Assessment Program Solar Energy Research Institute, Lead Center

EXHIBIT 11
Typical Capital Cost and Land Requirements for Electric Power Generation SCR Systems

Notes:

- Molten Salt System
- Capacity Factor 0.40

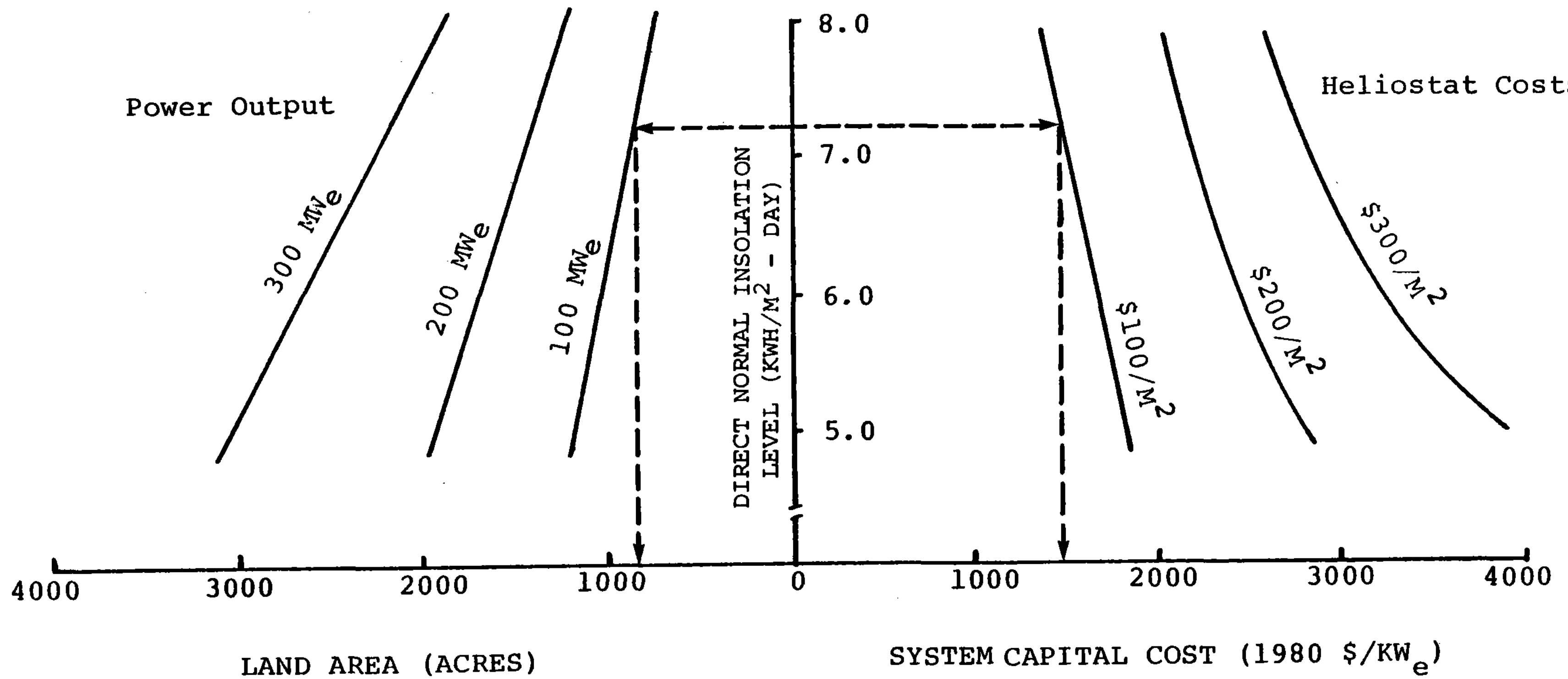
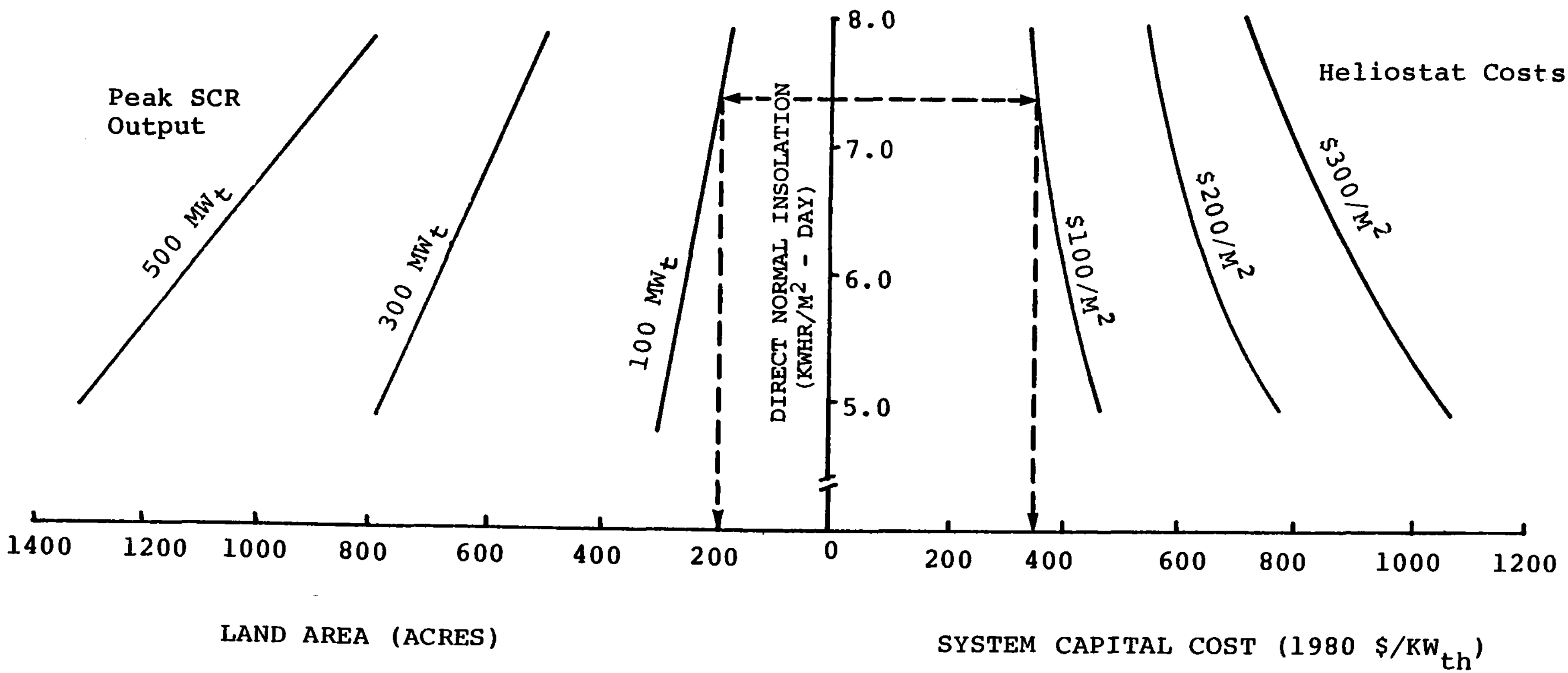


EXHIBIT 12

Typical Capital Cost and Land Requirements for IPH SCR Systems

Notes:

- Molten Salt System
- Capacity Factor =0.40



Under the same range of heliostat cost estimates, IPH SCR systems capital costs are expected to range from $350 to $1,100/kW$_t$. As shown in Exhibit 12, system capital costs for $100/M^2 heliostats are estimated to be between $350 and $460/kW$_t$ for a range of locations.

In general, SCR systems for primary electric generation will require over 1,000 acres of land each, but typical IPH systems will be 1/10 that size or smaller.

The amount of land required for each unit of heat produced is affected by many factors, such as local insolation level and SCR working fluid. Based on typical field densities of 20 to 25 percent in the regions of highest solar insolation in the United States, the land requirement is about 1.8 acres/MW$_t$ (peak).

A 300-MW$_e$ electric power plant operating at about 1000^{o}F will require between 2,000 and 3,000 acres of land (3.1 to 4.7 square miles). In addition, a 100-MW$_t$ (340 x 10^6 Btu/hr) SCR IPH system supplying 900^{o}F to 1000^{o}F heat will require about 175 to 275 acres of land area.

(2) <u>The Potential IPH Market In the Southwest Is Large Enough to Interest SCR Equipment Suppliers</u>

There are over thirty thousand industrial facilities in the nine state* region of the Southwest. Nearly four thousand of these facilities are production plants for the twenty greatest industrial consumers of energy in the U.S.:

- Crude petroleum producers
- Natural gas liquids producers
- Soft drink bottlers
- Copper refiners and smelters
- Alkali and chlorine manufacturers
- Fluid milk producers
- Industrial organic chemicals producers
- Potash, soda, and borate producers
- Phosphate fertilizer manufacturers
- Ammonia producers
- Steel mills
- Textile mills
- Paper mills
- Beet sugar manufacturers
- Petroleum refiners
- Cement producers
- Sulfer producers
- Meat packers
- Saw mills
- Aluminum refiners and smelters

* Area includes Arizona, California, Colorado, Kansas, Nevada, New Mexico, Oklahoma, Texas, and Utah.

Insolation varies widely over the nine state region (Exhibit 10). Sections of California, Nevada, Utah, Arizona, and New Mexico receive more than twice the mean daily direct solar radiation than portions of eastern Texas. Since SCR technology is most likely to be adopted where it will have the maximum advantage over conventional energy sources, it is likely that early adopters will be located in the areas of greatest insolation.

Out of the four thousand facilities of major energy consuming industries in the southwest, more than one hundred are located in the areas with insolation greater than 7.22 kilowatt hours per square meter, shown as the darkest area on Exhibit 10. However, more than eleven hundred facilities are located in an area with an insolation level of 6.11 kilowatt hours per square meter.

As indicated in Exhibit 13, these facilities represent a broad spectrum of the twenty largest energy consumers. There are at least ten plants in the area of highest insolation representing:

- Soft drink bottlers and canners
- Meat packers
- Saw mills
- Fluid milk producers

In the geographic market segment with insolation exceeding 6.11 kilowatt hours per square meter there are at least ten operating facilities in thirteen of the twenty largest energy consuming industries.

* * * * *

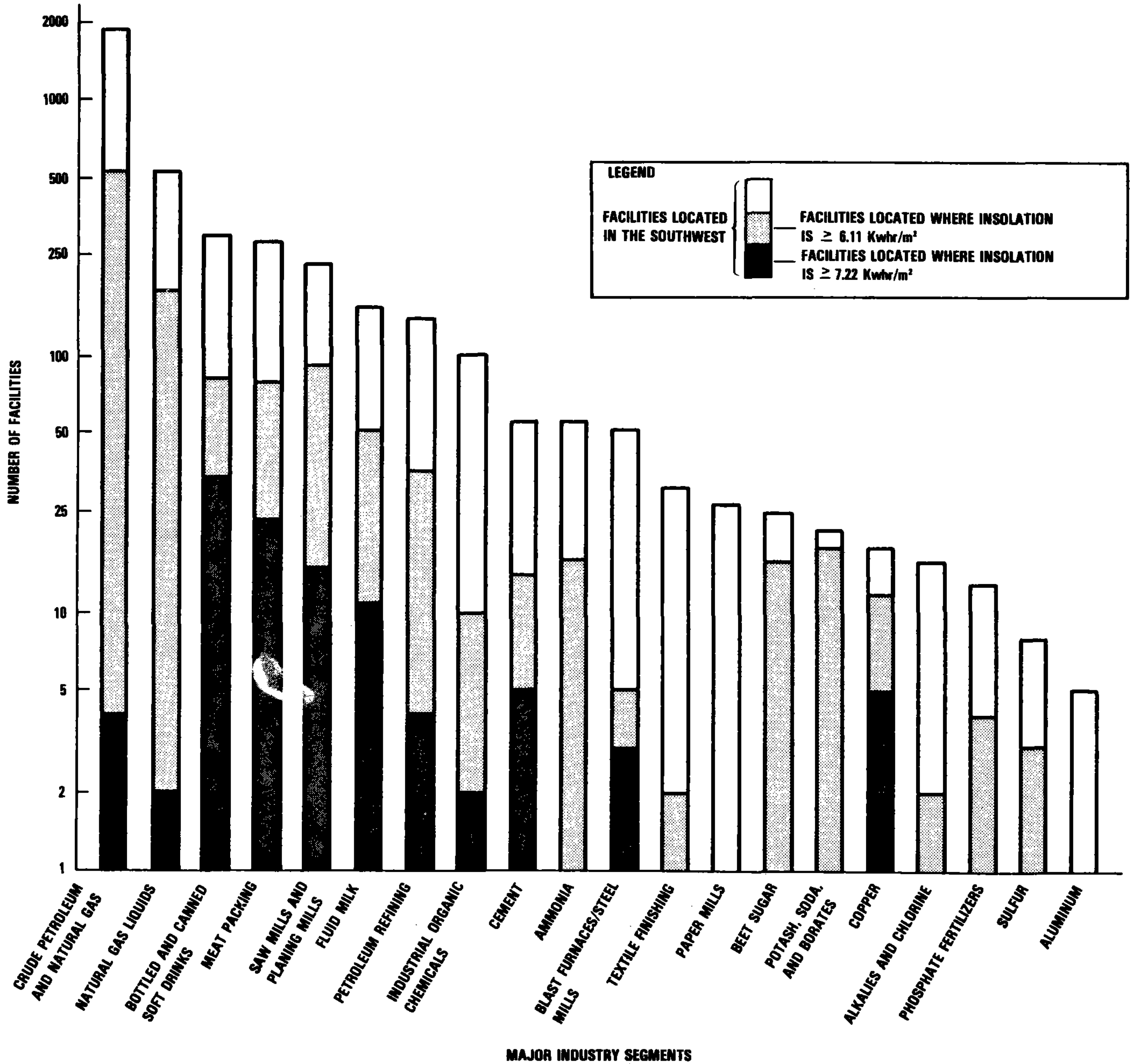
This geographic segmentation of possible target markets by insolation levels indicates a broad range of industry candidates and number of possible earlier adopters. The development of these markets is however largely dependent on other factors such as the economics of competitive energy sources.

5. ECONOMICS AND MARKET FACTORS WILL GENERATE A CLIMATE FAVORABLE TO ADOPTION OF SCR TECHNOLOGY IN THE MID-1990's

SCR economics and market factors suggest an SCR technology adoption path similar to that displayed in Exhibit 14. In the near to mid-term (up to mid 1990's), the high capital costs of SCR systems in most applications cannot be offset by lower operating costs. Market penetration is limited and largely confined to specialized utility needs--peaking power generation and repowering of oil-fired baseload plants.

EXHIBIT 13

Distribution of Key Industrial Energy Consumers by Insolation Level at Plant Location



However, beyond the mid 1990's, SCR capital costs can be substantially reduced by volume production of heliostats; lower purchase cost can expand the addressable market and lead to a self-sustained SCR industry. While the necessary heliostat output levels can be achieved through penetration of the utility market, carefully targeted government programs can serve to stimulate utility and industrial acceptance of SCR and nurture the developer's technology. Innovative third-party financing arrangements can hasten industrial market penetration by overcoming the capital cost hurdle.

(1) The Differences in the Investment Criteria Indicate That the Utility Market is Likely to Adopt SCR Technology Earlier Than the Industrial Market

The investment criteria used by industrial customers differ from that of electric utilities. Generally, industrial users seek high returns measured against the cost of the initial outlay, while utilities seek low life cycle costs. For both groups, the size of the initial outlay is important, but the valuation of the continuing outlays--operating costs--is markedly different.

This divergence is due to the different operating constraints facing each customer group and the management level at which the investment decision is made. The major sources of difference between the two groups are time horizons, process needs, and competitive risks (Exhibit 15). Industrial organizations tend to have short planning horizons because they need to respond quickly to shifts in market demands created by the competitive thrusts of other firms. Performance results also tend to be measured in the short term, either quarterly or annually.

Utilities, in contrast, operate under longer time horizons. The typical planning horizon is 15 to 20 years for capacity additions. Generating equipment has longer planned service life--30 to 40 years--and the design and construction time for major baseload additions range from 5 to 12 years. While a utility supplies electricity continuously, individual generating units may operate only during peak demand periods of a few hours.

The origination point for investment decisions also differs between the two groups. For a process modification or materials sourcing change, industrial plant managers typically originate the decision, which may require confirmation from a higher level. Capital spending by a utility, on the other hand, tends to originate at corporate headquarters, which has a broader picture of market needs and the ability to satisfy those needs.

EXHIBIT 14
Market Adoption Time Path for SCR Technology

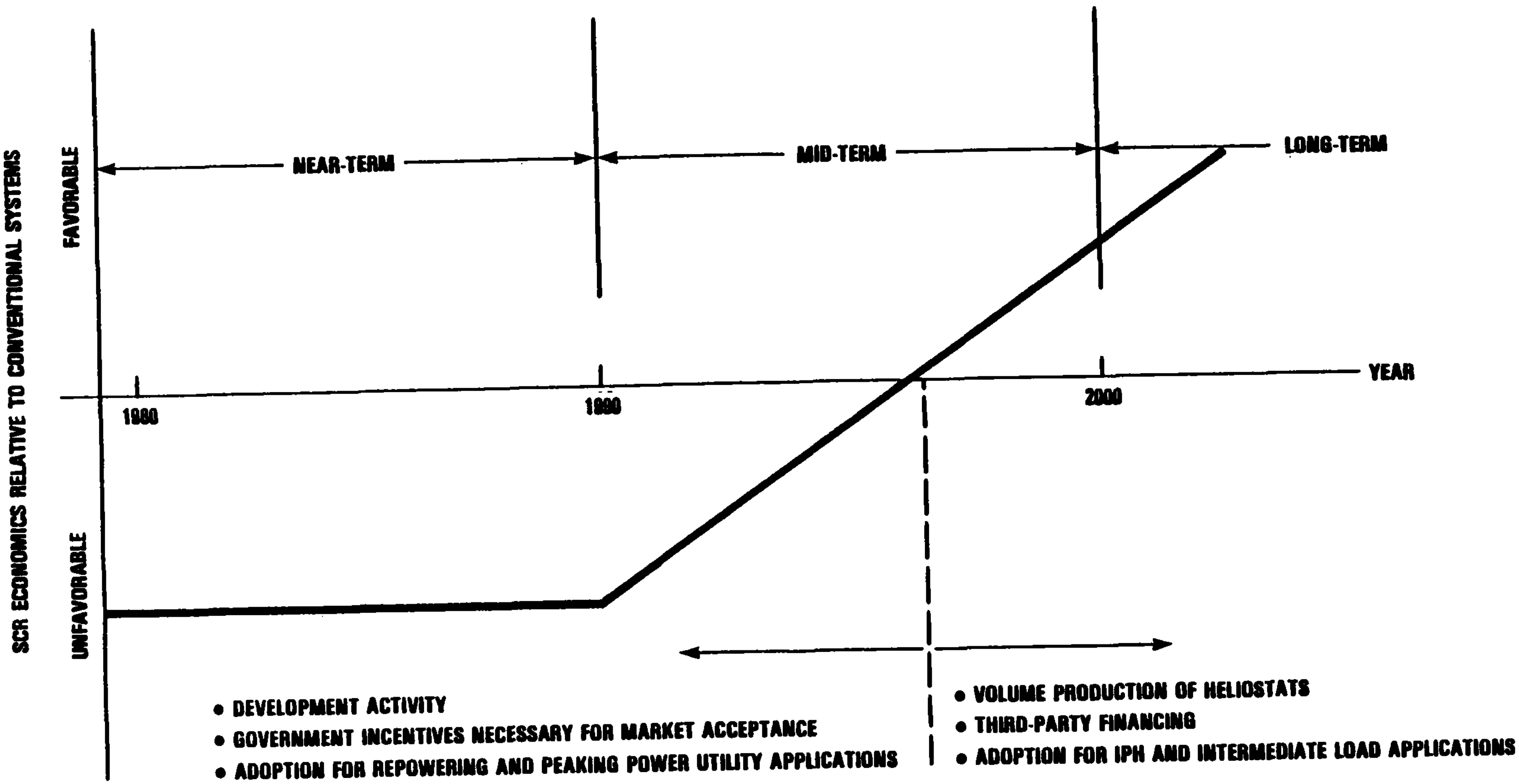


EXHIBIT 15

Investment Criteria and Minimum Returns Set By Selected Industries

COMPANY	COMMENT
Ammonia Manufacturer	Internal hurdle rate of 26%
Chemical Manufacturer	Payback period, averaging three years but varies by project
Chemical Manufacturer	Payback period; generally three years but could be as little as one year if a radical process change considered or unstable product market conditions existed
Paper Manufacturer	Discounted cash flow method; discount rate used is 25-30%
Food Processor	Discounted cash flow method; discount rate of 25%
Food Processor	Payback period; maximum of two years
Steel Manufacturer	Method and minimum return not specified; only minimal investment activity, due to severe capital shortage.

SOURCE: Booz, Allen & Hamilton Interviews.

An emerging technology such as SCR faces markedly different customer preferences between these two user categories. Industrial users seek proven equipment that is available for installation. Untried or innovative production techniques may be shunned because the plant manager fears disruption of plant operations, which can hurt his career. With their longer planning and operating time horizons, utilities are more inclined to investigate technologies which are not yet commercially available, and possibly commit the time needed to more fully develop the technology. Particularly as other power generation options are foreclosed due to rising costs and regulatory restrictions, utilities may be more ready to adopt innovative generation technologies.

To penetrate the IPH market, SCR developers must be sensitive to both the financial and non-financial criteria imposed by industrial energy users. The energy saving characteristics, together with operating dependability and integration with existing process equipment, will need to be well demonstrated in order to overcome purchaser risk aversion.

- In assessing investments, industrial customers are willing to accept longer payback periods, or lower rates of return, for projects offering energy savings. Within the context of their investment decisionmaking a number of companies interviewed in mid-1981 described a relaxation of their selection criteria when evaluating projects that could result in energy savings.

  While this investment policy is not universal, it does reflect a growing sophistication on the part of industrial firms in their evaluation of investment options. To the extent that preference is given to investments which offer energy savings, a favorable investment climate is created for SCR.

- In addition to financial criteria, a capital investment must also meet the technical requirements and purchase preferences of the decisionmakers. Preferences often cannot be quantified and may prove to be the most difficult screening hurdle. For example, purchasers preferences that can determine investment selection include:

  - Reluctance to be the "first purchaser" of a new technology

  - Preference for "off-the-shelf" equipment

  - Preference to purchase energy, rather than generate

- Electric utilities, while sensitive to capital costs, screen investments on the basis of operating characteristics that are different from the industrial sector. As the first step in their selection of generation capacity additions, utilities assess the need for the investment and seek a low-cost system. Moreover, given the long service lives of generating equipment, utilities also incorporate the operating cost characteristics of the proposed capacity addition by determining levelized busbar cost of electricity. In addition, utilities exercise discretion in their investment selection process by including factors such as:

  - Cost of unplanned forced outages due to unreliable generating equipment or insecure fuel supplies

  - Cost of prolonged construction periods, which can inflate facility costs by 50 to 60 percent

  - Cost of regulatory delay in approving new facilities for operation and inclusion in the rate base

  - Future fuel costs and escalation rates

  - Cost of inaccurate electricity demand projections, which could lead to underused capacity or the need to purchase power from other sources.

  When such cost uncertainties are considered, a generating system which, at first glance appears more expensive than another, may in fact be chosen.

- In addition to meeting internal criteria, utility capital investments must meet criteria imposed by regulatory bodies. State Public Utility Commissions (PUCs), through their rate-setting authority, have exerted the most direct influence on utility capital budgeting decisions.

  In the area of emerging technologies, PUC ratemaking authority has tended to discourage utility investments. In many jurisdictions, regulators are perceived as ready to pass on any savings arising from risky technologies to the ratepayers, while forcing utility shareholders to absorb losses should the investment prove unsuccessful. Utility executives have cited this risk/reward imbalance as a deterrent to their supporting emerging technologies.

Federal policies and programs have a mixed effect; in some instances serving to broaden investment options while in others tending to constrict the choices.

- The Federal Powerplant and Industrial Fuel Use Act (PIFUA) serves to prohibit construction of new baseload natural gas and oil-fired power plants after 1985.
- Environmental regulations have raised the cost of fossil-fired plants by requiring installation of costly pollution-control equipment or burning of low-sulfur fuels.
- Expensive safety and complex siting and licensing requirements have discouraged investment in nuclear power plants through increasing capital costs and delaying construction times.
- Federal cost-sharing of R&D, feasibility studies and construction costs have tended to make investment in nontraditional generating technologies more affordable for utilities.

(2) <u>In The Near Term, SCR Economic Characteristics Are A Limiting Factor To Its Market Acceptance</u>

The general consensus, based on supplier interviews and the literature, is that SCR holds a decided operating cost advantage over conventional systems. However the high-capital costs of SCR systems currently out weigh this operating advantage and constitute the most immediate barrier to market acceptance. SCR's high initial cost can be ameliorated:

. Operating hours can be extended through the addition of storage, capitalizing on the operating cost advantage.

. Cost reductions are achievable through large-scale production of heliostats, reducing total system costs.

- A program of financial assistance to encourage early adoption of SCR technology can be instituted, mitigating financing costs.

The data contained in DOE-sponsored feasibility studies and other public sources was used in this analysis to determine the costs of "typical" SCR systems in comparison to competing conventional systems.

- Near-term SCR systems have capital costs substantially higher than those for conventional systems. For industrial customers, SCR capital costs constitute an addition to the cost of a conventional boiler or furnace systems. A conventional system is needed to supply energy for those periods, such as at night, when SCR would be inoperable. This added capital cost can be substantial. At near-term heliostate costs of $\$230/m^2$, SCR systems increase furnace costs by 5 to 8 times that of conventional furnaces and steam boiler costs by 7 to 30 times.

  In utility applications the capital cost of an SCR system is also projected to be higher than that of conventional equipment until significant heliostat cost reductions are achieved. For smaller scale SCR systems used to generate peaking electricity, the capital cost can be 10 times higher than that for peaking turbines.

  Meaningful cost comparisons are difficult because a major portion of SCR system costs, e.g., heliostats costs, is indefinite at this time. For the Barstow pilot plant, using noncommercial-scale manufacturing techniques, heliostat costs were approximately $500 per square meter. As SCR technology reaches the point of commercial introduction, more efficient manufacturing techniques can be used that will reduce heliostat costs. Nonetheless, early systems are likely to have installed costs substantially greater than conventional systems, which could make purchasers reluctant to commit to SCR systems.

- The economic advantage of SCR systems lies in lower operating costs available through fuel displacement, but this cost saving is insufficient to compete with conventional systems. The SCR payback period--the evaluation yardstick cited by several industrial interviewees--exceeds the industrial requirement of 3 years. At likely fuel escalation rates of 2 to 5 percent in real terms (8 to 13 percent with an underlying inflation rate of 6 to 8 percent), SCR systems repay their initial costs in 5 to 11 years at pretax savings.

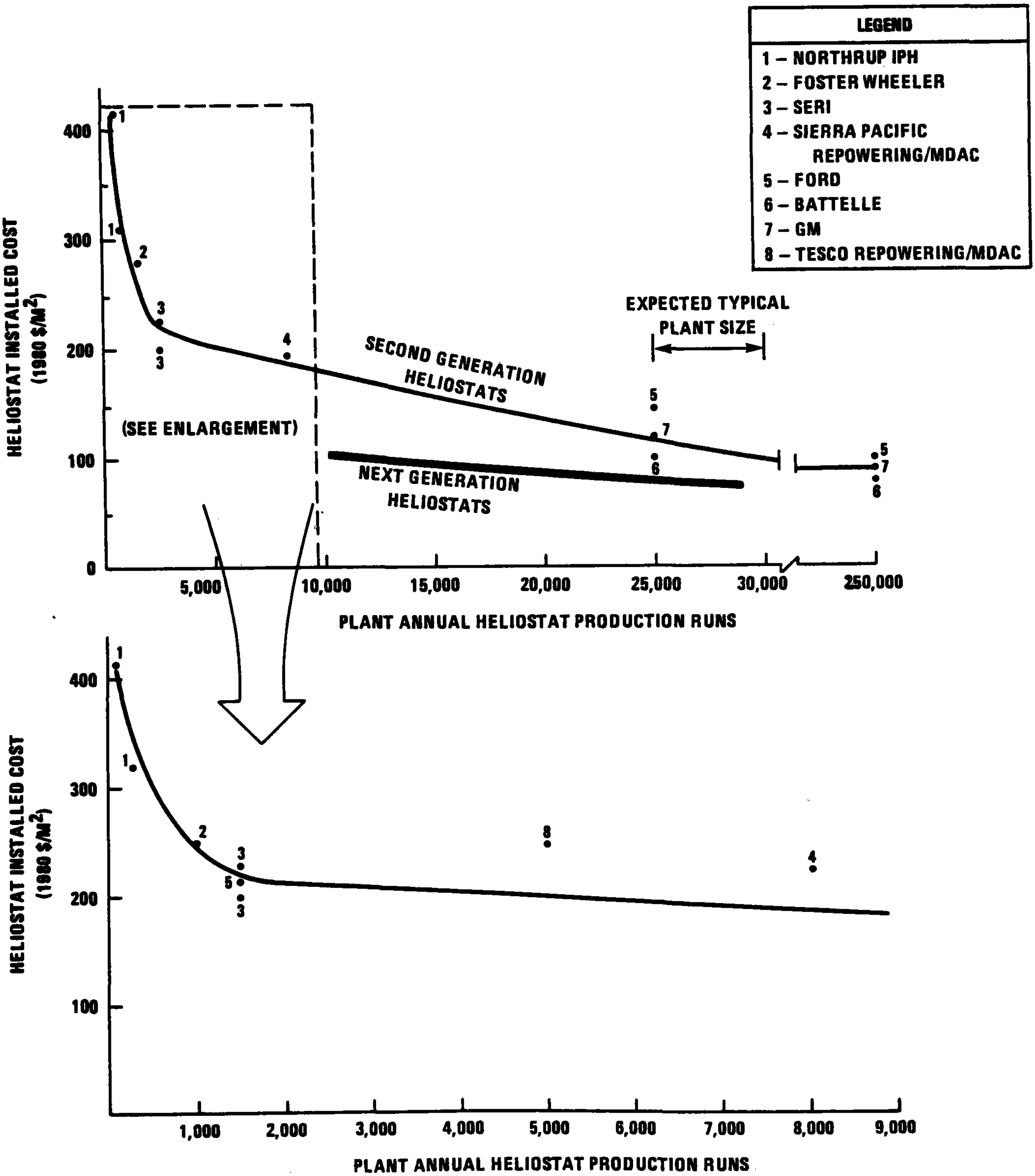
For utility applications, SCR systems have a significant advantage because fuel costs account for 60 to 75 percent of the cost of electricity generated by conventional systems. For baseload generation systems, SCR levelized busbar costs are found to be substantially higher than coal and nuclear baseload, while more competitive with baseload oil-fired units. To enhance SCR economic attractiveness, some combination of lower capital costs and extended hours of operation is necessary so that the operating efficiency--and lower operating costs--can induce purchase in a freely competitive market.

- Adding storage capacity capitalizes on SCRs' operating cost advantage, but does not represent an optimal near-term solution. Because SCR operating costs are markedly lower than those of conventional systems, one means of overcoming the high initial cost hurdle is to extend SCR operating hours beyond the hours of available sunlight. However, oversizing the SCR system and storing the excess energy for later use does not improve SCRs' competitive posture, unless this storage can displace expensive oil- and gas-fired peak load capacity.

  Providing 3 hours of storage increases SCR system costs by 35 percent, and 18 hours of storage raises SCR system costs by 150 percent. At near term heliostat costs of $\$230/m^2$, the levelized busbar costs for SCR systems with 18 hours of storage are still greater than conventional oil fired base load generation.

- Reducing heliostat costs, which is achievable at relatively low-production levels, constitutes a better near-term means of minimizing SCR system costs. At near-term cost projection of $\$230/M^2$, heliostat costs represent more than one-half of SCR installed costs for a variety of SCR system sizes, configurations, and applications. Heliostat production can be standardized, permitting assembly-line production methods that can lower production costs. As SCR market niches develop, the sheer number of heliostats needed to fulfill market requirements offers "learning curve" cost savings through extended production runs as indicated in Exhibit 16.

EXHIBIT 16
Expected Heliostat Costs Under Different Manufacturing Plant Production Levels



At manufacturing plant output levels equivalent to one 10 MW_e SCR plant per year heliostat costs are between \$200 and \$230/m^2. It is this cost level that has been described as "near-term." If a manufacturing plant can be sized at 25,000 to 50,000 heliostats/year (equivalent to 300 to 650 MW_e, without storage), heliostats can be produced at \$100 to \$150/m^2.

Further cost improvement in heliostats requires development of a "next generation" design, using lighter weight materials. However, additional material testing and development work are needed on "next generation" heliostats, making it unlikely that such designs will be ready for demonstration before 1985.

(3) <u>In The Near Term To Midterm, Utility Applications Represent The Best Match With SCR Economic Characteristics</u>

On the basis of SCR economics, acceptance of SCR technology in the near term to midterm--1985-1995 timeframe--is most likely to occur in the utility market. Early SCR production volumes (100 to 250 MW_e/year) would equate to heliostat costs of \$200 to \$230/m^2 and open two specific market niches:

- Peaking-power generation
- Repowering of oil-fired baseload capacity.

The coincidence of peak demand in these markets with SCRs' operating cycle provides maximization of SCRs' operating cost advantage over fossil-fired peak generation. SCRs' generating costs are similarly competitive with oil-fired baseload electricity.

Penetration of the utility market will encourage higher volume production of heliostats, which in turn can result in dramatic reductions in SCR capital costs. As heliostat costs are lowered, a sustainable SCR manufacturing industry will develop with the benefit of additional SCR market opportunities, including competition with coal-fired intermediate baseload capacity and IPH applications.

- <u>SCR systems can meet the purchase criteria and operating cost requirements of utility applications</u>. According to utility executives interviewed, an SCR system could compete in the utility market if it resulted in electricity costs within 10 to 15 percent of the cost of conventionally generated electricity. On the basis of levelized busbar cost analysis, there are two market niches:

- Peaking-power generation: As indicated in Exhibit 17, using near-term heliostat costs of $230/m^2$, SCR plants are competitive with distillate-fired gas turbines using fuel costs which prevail in California and most southwestern states. SCR plants would be competitive against natural gas-fired turbines in California but not in Texas or Oklahoma where gas costs are extremely low.

- Repowering oil-fired intermediate load and baseload capacity: Oil-fired capacity having higher fuel costs than other fossil-fired or nuclear capacity has busbar costs against which SCR plants can sucessfully compete in the near-term to midterm in all regions except Texas and Oklahoma (Exhibit 18).

- SCR operating cycles represent a good technical fit with utility generation needs. On a daily basis, power peaks in Southwestern utility systems occur in the early morning and mid to late afternoon, and in the West and Southwest utilities tend to be summer peaking.

  To extend operations, and thus penetrate the intermediate load and oil-fired repowering niche, only modest amounts of thermal storage are needed; 3 hours of storage capacity yields busbar costs roughly comparable to those at 18 hours.

  As storage systems are further developed, the operating limitations of SCR systems will be minimized. This in turn opens the longer term possibility of SCR systems successfully competing against other baseload generating systems--notably coal-fired.

- The utility market represents the best near-term opportunity to develop a viable SCR technology industry. Utility sales can be large enough to stimulate investment in heliostat manufacturing of a sufficient production level to build a viable manufacturing infrastructure. The resulting cost reductions, in turn, can "boot strap" the industry into new market penetration by SCR

EXHIBIT 17

Electricity Costs From Conventional and SCR Peaking Plants

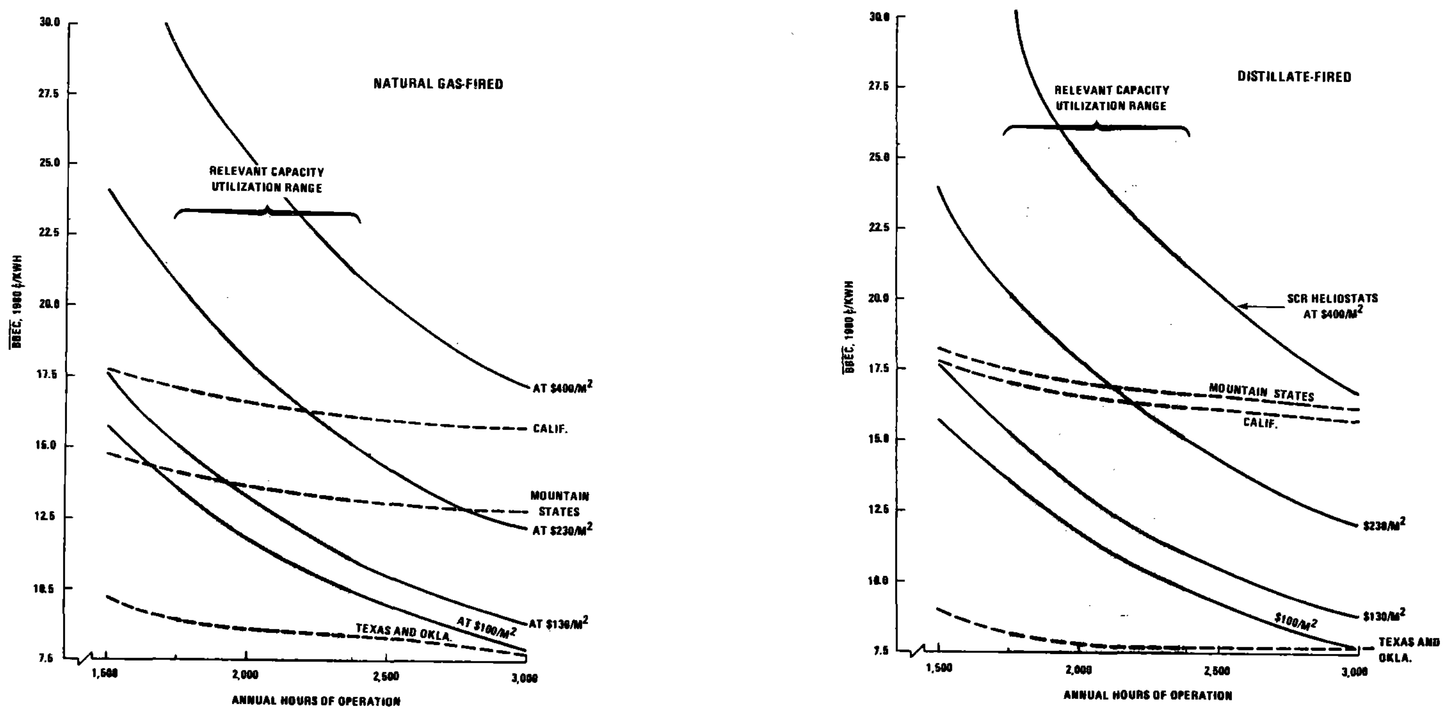
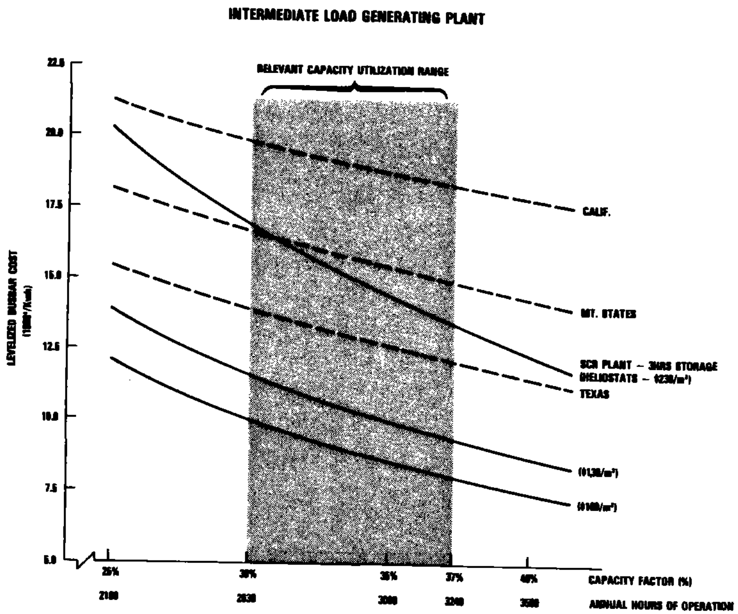
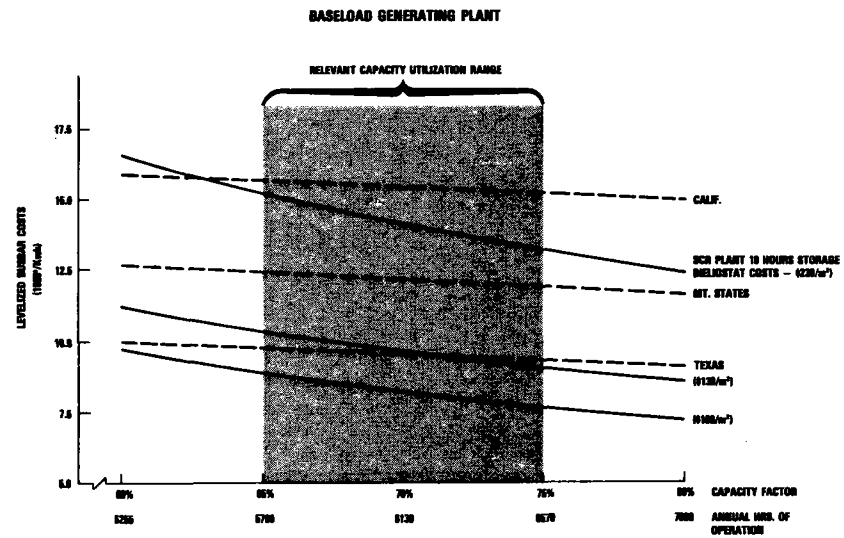


EXHIBIT 18

Electricity Costs from Oil-Fired Conventional and SCR Intermediate and Baseload Plants





systems--utility baseload and IPH applications. Moreover, modest penetration of this market yields substantial heliostat cost reductions (Exhibit 19).

Looking solely at repowering opportunities and seeking to displace 0.5 quad of oil and gas by solar, SCR costs can decline sharply within 3 years of market acceptance (Cases I and II). At a more moderate penetration rate (0.25 percent of oil and gas-fired capacity, doubling each year to a maximum of 5 percent displacement annually), SCR costs can approach midterm heliostat levels within 4 years (Case III).

(4) To Penetrate the IPH Market, SCR Systems Will Need to Overcome the Impediment of Its High Capital Cost.

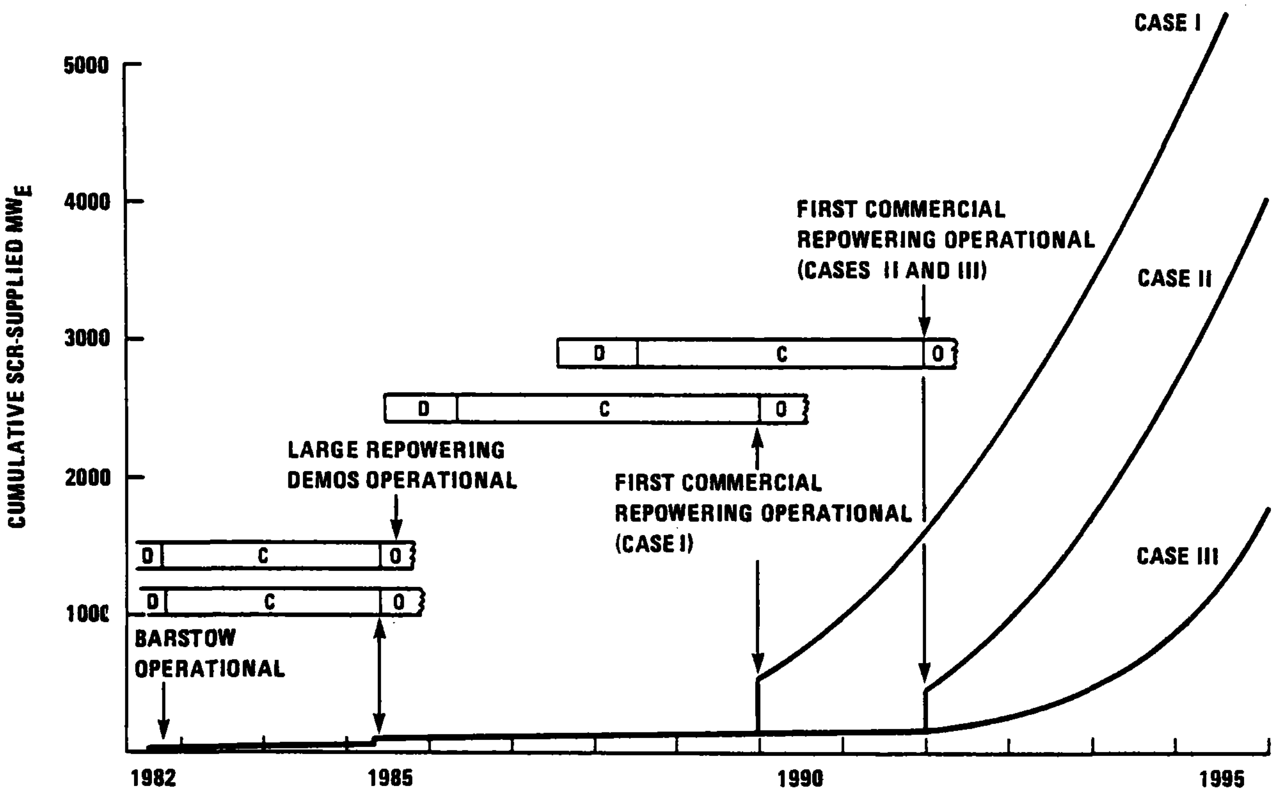
The requirement of a large initial capital investment is the most significant barrier to the adoption of SCR technology in the industrial process heat market, but other conditions faced by potential industrial users in specific applications may preclude the use of SCR's. For example, if land is not available at a specific site or if SCR technology cannot meet the duty cycle requirements of a particular process, then the technology will not be considered. This analysis provides an indication of possible early adopters assuming that necessary conditions of siting and process requirements can be met.

Industrial firms which were interviewed expressed some willingness to relax their investment screening criteria when buying equipment which would reduce their energy consumption, in return for assured, continuing cost savings. Although SCR systems offer the prospect of such savings, industrial firms may hesitate to make an SCR purchase because fuel savings are simply too low at near-term SCR cost levels.

Broad penetration of the the IPH market requires lower SCR capital costs and reducing heliostat costs constitute the best opportunity for capital cost reductions.

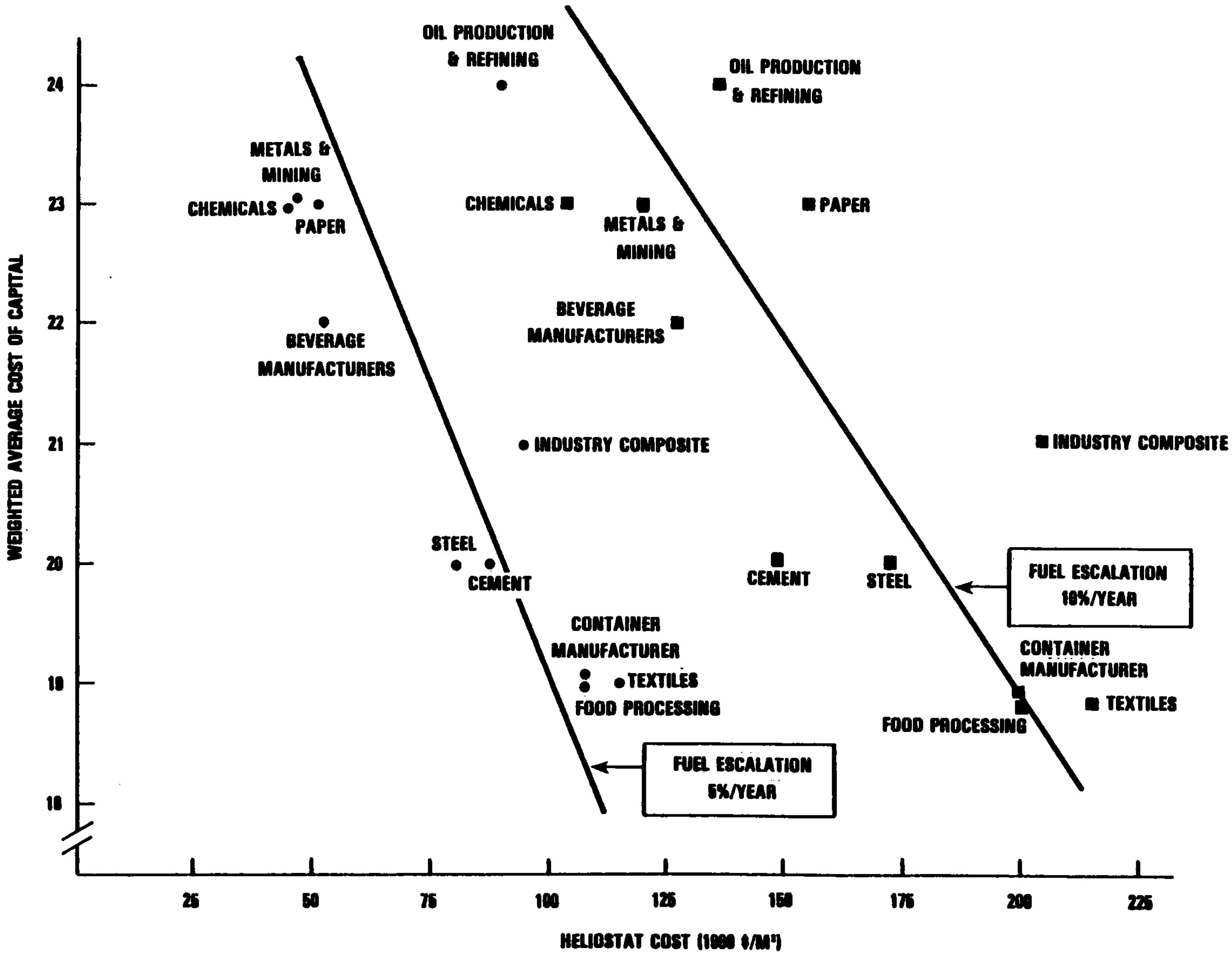
- The higher return on investment levels set by industrial firms require very low heliostat costs to make SCR systems economically attractive. Industrial firms tend to set higher required return on their capital investments than utilities. Using effective cost of capital for industry groups in the Southwest, the fuel savings

EXHIBIT 19
Effect of Potential SCR Utility Market Penetration Rates on Heliostat Costs



		1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
CASE 1	HELIOSTATS (000/YR)	8	8	–	–	34	68	101	135	136	178	220	262
	HELIOSTAT COST ($/M²)	220	220	–	–	123	108	103	101	101	101	101	101
CASE II	HELIOSTATS (000/YR)	8	8	–	–	–	–	25	76	101	152	203	266
	HELIOSTAT COST ($/M²)	220	220	–	–	–	–	132	108	103	103	103	103
CASE III	HELIOSTATS (000/YR)	8	8	–	–	–	–	5	10	20	40	80	90
	HELIOSTAT COST ($/M²)	220	220	–	–	–	–	220	180	140	120	105	105

EXHIBIT 20
Heliostat Cost Levels Required to Satisfy Minimum Investment Return Rates by Industry Category



Source: Booz, Allen & Hamilton

from a representative SCR system can be computed over a probable range of fuel escalation rates, assuming residual oil as the displaced fuel. Mapping the corresponding capital investment level, discounted by the minimum acceptable ROI, against the effective cost of capital for industry groups (Exhibit 20) points out key features of the IPH market:

- At near-term heliostat cost levels (\$200-\$230/ m^2), SCR systems could prove attractive to the food processing, textiles and container manufacturing industries if oil costs rise 10 percent annually.

- As heliostat costs approach mid- to long-term price levels (\$100-\$130/m^2), SCR plants are viable for nearly all industrial users, at the high and low end of the high fuel escalation rate range.

- SCR systems are generally more price competitive--and hence attractive--in industries with low required returns.

• SCR market opportunities could also develop in industries with high energy costs as a fraction of total product cost or low profit margins. In both instances, energy cost savings registered on the "bottom line" of the income statement is a strong inducement for an SCR plant investment.

Using the energy costs and profit margins for industrial groups in the Southwest (Exhibit 21), the effect of a 20 percent reduction in energy costs points to several potential SCR market niches:

- Cement manufacturers, whose profit margins could be improved by 85 percent

- Container manufacturers, which would enjoy a 75 percent increase in profitability

- Steelmakers, whose profitability could climb by 50 percent. However, the severe capital constraint and high degree of fuel by-product reuse clouds this market prospect.

Potential target markets which are attractive on the basis of required heliostat cost levels--the food processing industry and textile manufacturers--

EXHIBIT 21
Impact of Energy Cost Savings On
Industrial After-Tax Profit Margins

	ENERGY COSTS AS A PERCENT OF SALES	1980 NIAT* AS A PERCENT OF SALES	NIAT WITH A 20% SAVINGS IN ENERGY COSTS
FOOD PROCESSING	2%	4%	4.3%
BEVERAGE	12	6	8.4
CEMENT	24	11	20.3
CHEMICALS	14	7	9.8
CONTAINER MFG.	14	4	7.0
STEEL	7	3	4.5
METALS & MINING	N.A.	N.A.	N.A.
OIL PRODUCTION/ REFINING	3	7	7.5
PAPER	8	6	7.5
TEXTILES	3	3	3.6

*Net income after taxes

N.A. - Not Available

Source: American Society of Manufacturers; Value Line Investor Service; Booz, Allen & Hamilton Inc.

were found to be less attractive using this profitability criteria. This analysis confirms that the oil industry will be difficult to penetrate; this industry requires relatively inexpensive SCR systems and also shows the least improvement in profitability from an energy cost reduction.

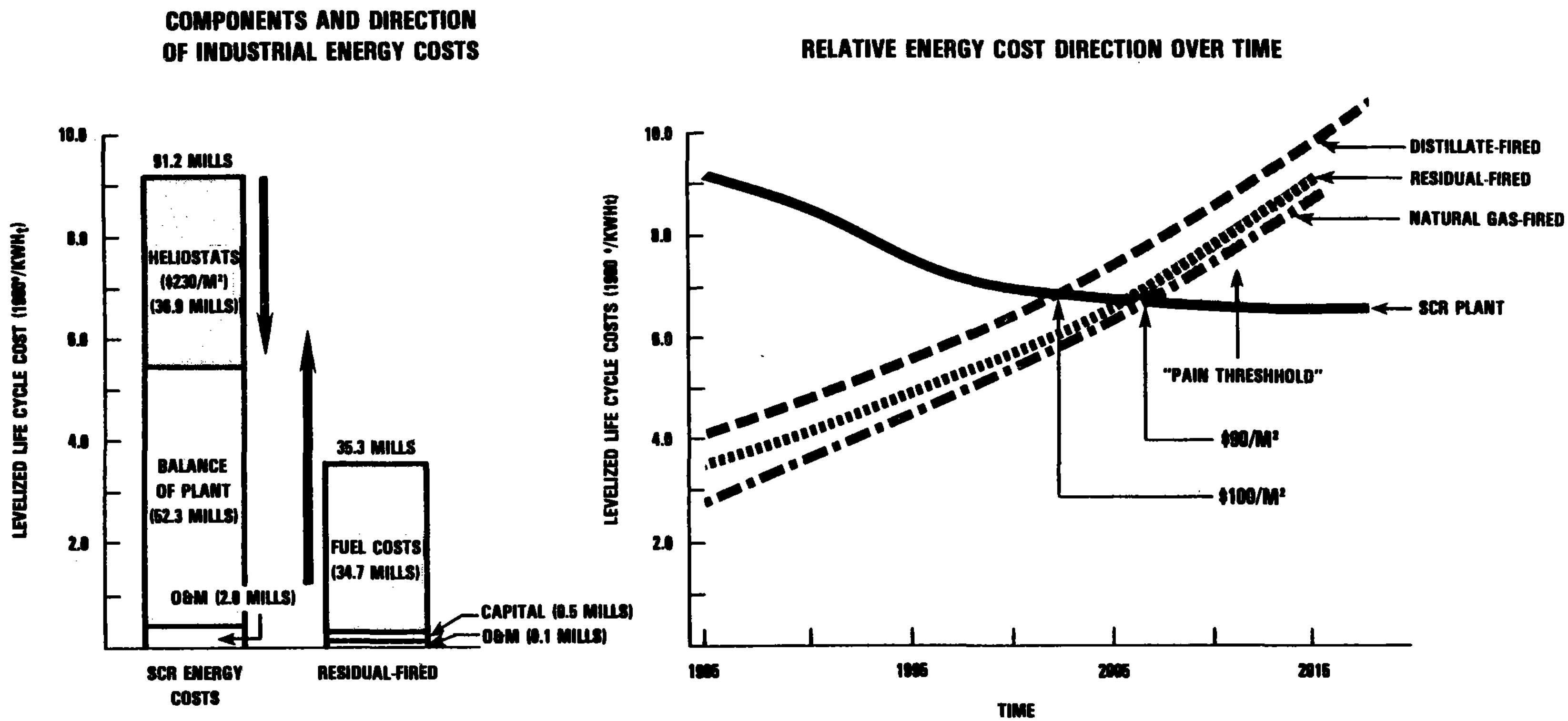
- Imaginative financing--particularly leveraged leasing--can help overcome industrial buyer resistance to SCR Systems. On the basis of SCR economics, the industrial market--with a few exceptions--does not hold the promise of early adoption of this technology.

A major barrier to SCR use in IPH markets is its high capital cost. However, capital cost reductions are possible and will, in fact, occur as SCR penetrates the utility market, achieving high volume, low-cost heliostat production. At the same time, the fossil fuel costs are likely to rise. The likely outcome of these cost component dynamics is that SCR systems will eventually achieve a cost advantage over conventional systems. The timing of this SCR cost advantage is well into the future, when looking at IPH costs for a typical (composite) industrial firm (Exhibit 22). Even then, the switch to SCR system will not be instantaneous; a demonstrable margin of advantage--or a "pain threshold"--must be shown to overcome buyer reluctance or ingrained purchase patterns.

Innovative financing of SCR systems provide a means of accelerating the adoption process. One potential mode of private sector innovative financing is a leveraged leasing arrangement. Independent investors supply the funds (their own equity plus loans which constitute the "leveraging") to purchase an SCR facility. The facility, in turn, is either leased to the industrial customer at a known price or the plant output (energy) is sold to the user. This arrangement satisfies a number of objectives of the venture participants.

- Being a power purchaser, not an equipment purchaser, the industrial user need not impose unfavorable investment criteria on the SCR system.

EXHIBIT 22
Dynamics of Industrial Life-Cycle Energy Costs



- The arrangement appeals to the lessors, who obtain assured markets for the plant output and have assured cash flows (low risk) and the tax benefits which shield their other income

- SCR vendors secure earlier market development, with attendant equipment sales and cash flows.

The leveraged leasing arrangement was specifically mentioned by several SCR-equipment suppliers as a viable near-term marketing approach. This financing means has, in fact, been successfully used by two vendors of competing solar systems--dish and trough manufacturers.

* * * * *

The competitive economics of SCR technology and its adoption rate in the market place can be improved with the implementation of specific Federal programs as pointed out in the next section.

6. PROPERLY TARGETED FEDERAL GOVERNMENT PROGRAMS CAN IMPROVE THE MARKET PROSPECTS FOR SCR AND HASTEN MARKET ADOPTION

The Federal government has the option of differing degrees of involvement, ranging from no participation at all (including total funding shut off for R&D) to direct subsidy of SCR purchases. To the extent the Federal government seeks to support solar tech- nology development activities, the most efficient allocation of scarce Federal resources would be one which accomplishes that aim at least cost.

(1) Federal Financial Assistance Can Reduce The High Capital Costs Associated With Near- and Mid-Term SCR Installations, and Thus Broaden the Potential SCR Market

An incentives program directed toward reducing the capital (initial purchase) cost of an SCR system would offer the following benefits:

- Overcoming purchaser reluctance to bear the full risk and cost of an emerging technology

- Hastening the adoption process, and thus securing more rapid SCR cost reductions achievable by volume production and installation

- Enlarging the potential market applications for SCR systems.

While there is a wide variety of potential economic incentives (Exhibit 23), only a small set of these can have a significant economic impact on the "rational" decision-maker:

- Direct cash subsidies
- Low-interest loans
- Investment tax credits
- Accelerated depreciation.

The incentives required to reduce SCR costs to parity with conventional energy systems for utility coal-fired baseload and industrial or gas-fired boiler applications are shown in Exhibit 24. Three important points identified in the field interviews were verified by this analysis:

- In the utility sector, a higher level of incentives is needed to stimulate SCR investment by investor-owned than publicly-owned utilities, since investor-owned utilities have higher revenue requirements, reflecting their higher cost of capital and tax burden (Exhibits 24 and 25).

- For utility baseload generating purposes, relatively modest incentives are needed to reduce mid- and long-term heliostat costs to competitive levels. For example, at heliostat costs of $\$130/m^2$, SCR can be competitive with investor owned coal-fired plants, if the depreciation period is shortened to 10 years.

- In the industrial sector, tax preferences need to be substantial to overcome higher SCR costs.

In the industrial sector, SCR systems become competitive with gas- and resid-fired conventional boilers when heliostats cost $\$100/m^2$ or less. However, SCR could become cost competitive at heliostat cost of $\$200/m^2$ through institution of an investment tax credit of 50% the plant capital cost (Exhibit 26).

(2) To Be Cost-Efficient, A Federal Incentives Program Must Reconcile Cost Minimization With User Financial Conditions And Preferences

An effective incentive program is one which entails the least cost on the part of the Federal government while providing maximum benefit--either the greatest cost reduction or widest recipient acceptance and utilization.

EXHIBIT 23
Economic Incentives for Emerging Technology Development and Adoption

1. DIRECT FINANCIAL INCENTIVES:
   - Direct cash subsidy to
     - Purchaser
     - Manufacturer
   - Cash rebates
2. TAX INCENTIVES
   - Income tax deductions
   - Income tax credits
   - Sales tax exemption
   - Property tax exemption
   - Accelerated depreciation for tax purposes
   - Capital gains applicability to system sales
3. FAVORABLE LOAN TERMS
   - Loan guarantees
   - Low-interest loans
     - Granted through Federal agencies (SBS, HUD, REA, DOE)
     - Interest subsidy on loans made through private lenders
4. RD&D SUPPORT
   - Product and component improvement
   - Site and market surveys
   - Performance and safety standards
   - Education and training grants
   - Information disemination
5. GOVERNMENT PROCUREMENT
   - Demonstration program
   - DOD installation
6. INSURANCE GUARANTEES
   - Government-backed insurance pool
   - Government-issued insurance
7. GOVERNMENT EQUITY INVESTMENT IN MANUFACTURING FACILITIES
8. DISINCENTIVES TO CONVENTIONAL ENERGY FORMS
   - Regulation of consumption volumes, fuel end-uses
   - Use and consumption taxes
   - Strengthened environment regulation
9. REGULATORY ACTIONS

EXHIBIT 24

Government Incentives Needed to Make SCR Cost-Competitive with Investor-Owned Utility Coal-Fired Plants

Coal-Fired Unit Levelized Busbar Cost (1980 ¢/KWh)		Effective Heliostat Cost (1980 $/m^2)
68.5¢ - 71.5¢	Equals	$52 - $58/m^2

INCENTIVE TYPE	INCENTIVE SIZE AND COST		
	Heliostat Cost $230/m^2	Heliostat Cost $130/m^2	Heliostat Cost $100/m^2
• Direct Cash Subsidy			
- % of capital cost	56.5 - 54.4%	36.3 - 33.2%	26.0 - 22.3%
- Cost ($ mill.)	$211.1-203.3	$92.5 - 84.7	$57.1 - 49.2
• Low-Interest Loans			
- Required reduction in capital-related revenue requirements	57 - 54%	36 - 33%	26 - 23%
- Interest rate (loan amount for full plant cost)	4%	8%	9.75%
• Investment Tax Credit			
- Credit amount	60%	40%	30%
• Accelerated Depreciation			
- Tax life (years)	< 1 yr.	10 yr.	15 yr.

EXHIBIT 25

Government Incentives Needed to Make SCR Cost-Competitive With Publicly-Owned Utility Coal-Fired Plants

Coal-Fired Unit Levelized Busbar Cost (1980 ¢/KWh)		Effective Heliostat Cost (1980 $/m²)
61.7 - 64.7¢	Equals	$66 - $75/m²

INCENTIVE TYPE	INCENTIVE SIZE AND COST		
	Heliostat Cost $230/m²	Heliostat Cost $130/m²	Heliostat Cost $100/m²
• Direct Cash Subsidy			
- % of capital cost	52 - 49%	29 - 26%	18 - 14%
- Cost ($ mill.)	$193.8 - 184.0	$75.3 - 65.5	$39.8 - 29.9
• Low-Interest Loan			
- Required reduction in capital-related revenue requirements	52 - 49%	29 - 26%	18 - 14%
- Interest rate (loan amount for full plant cost)	4.75%	8.0%	9.75%

EXHIBIT 26

Government Incentives Needed to Make SCR Plants Cost-Competitive With Industrial Boilers

		1990	1995
	INCENTIVE TYPE	Heliostat Cost $200/m^2$	Heliostat Cost $130/m^2$
LEVELIZED LIFE-CYCLE COST CRITERIA	• Direct Cash Subsidy		
	- Subsidy size (% of capital cost)	54.1%	47.0%
	- Subsidy cost ($ mill.)	$6.1	$4.6
	• Low-Interest Loan		
	- Reduction in levelized fixed charge rate	54.1%	47.0%
	- Loan Rate (loan amount for full cost of plant)	8.7%	10.3%
	• Investment Tax Credit		
	- Credit amount	52%	46%
	• Accelerated Depreciation		
	- Tax life (years)	< 1 year	< 1 year
PAYBACK PERIOD CRITERIA	• Direct Cash Subsidy ($ mill.)		
	- 3-year payback	$8.8	$6.9
	- 5-year payback	$5.8	$4.4

NOTE: Assumes residual-fired boilers. To make SCR competitive with gas-fired boilers in 1990, incentives would be slightly larger.

The cost to the government for the relevant incentive categories is compared over a range of incentive values in Exhibit 27. The cost to government for all incentive categories rises as function of the size or value of the incentive extended. However, the effective cost-- or the cost per 1 percent saving to the purchaser--may in fact remain constant or decline as the incentive value increases. When seeking the "least cost" solution, the required value of the incentive must be compared to this effective cost. For an investor-owned utility, for example:

- If heliostats cost $230/m^2$, the least cost incentive is a 60 percent investment tax credit.
- At a heliostat cost of $130/m^2$, the least cost incentive is accelerated depreciation over a 10-year, rather than 20-year, period.
- At a heliostat cost of $100/m^2$, low interest loans (10 percent for the full plant cost) represent the least cost solution.

An incentive which is optimal from the government stand point--that of least effective cost--may not in fact be desirable or even usable from the SCR purchaser standpoint. Based on our interviews, the following preferences emerged:

- Subsidies can stimulate both industrial and utility investment in SCR; however, these should be structured in such a way that government involvement as an equity participant, is held to a minimum
- Low-interest loans, to the extent they create an undesirable debt/equity ratio on the company's balance sheet, are a less effective means of direct financial assistance since they substitute financial risk for business risk
- Tax relief measures favor industrial users and third-party lenders (e.g., leveraged leasing arrangements) and are preferred since they are less subject to the vicissitudes of the appropriations process.

Existing Federal and state policies, by directing energy consumption patterns, may also serve to stimulate SCR deployment. Two such Federal laws, passed in 1978 as

EXHIBIT 27

Cost to the Government of Utility Financial Incentives for SCR Plant Purchase*

• DIRECT CASH SUBSIDY:

Subsidy Size (% of Capital Cost)	Reduction in Capital-Related Revenue Requirements	Government Cost	Cost/1% Reduction
10%	8.6%	11.6%	1.16
20	17.2	23.3	1.16
30	25.9	34.7	1.16
40	34.5	46.4	1.16
50	43.1	58.0	1.16

• LOW INTEREST LOAN (100% Principal Amount):

Loan Interest Rate	Reduction in Capital-Related Revenue Requirements	Government Cost	Cost/1% Reduction
10%	22.8%	5.2%	0.2%
8	33.6	24.2	0.7
6	44.3	43.1	1.0
4	55.1	62.1	1.1
2	65.8	81.0	1.2

• INVESTMENT TAX CREDIT:

ITC Amount	Reduction in Capital-Related Revenue Requirements	Government Cost	Cost/1% Reduction
10%*	-	9.09%	-
20	11.2%	18.18	1.62%
30	22.4	27.27	1.22
40	33.6	36.36	1.18
50	44.7	45.45	1.02
60	55.9	54.55	.98

• ACCELERATED DEPRECIATION**:

Taxable Life	Reduction in Capital-Related Revenue Requirements	Government Cost	Cost/1% Reduction
20 Years*	-	6.31%	-
15 "	25%	9.91	0.40%
10 "	35%	14.32	0.41
5 "	45%	19.78	0.44
Fully Expensed in Year 1	55%	24.26	0.44

* Base Case

** Sum-of-the-Years Digits

Note: Discount rate assumed for the government is 0.1.

part of President Carter's energy legislation package, hold this potential:

- Powerplant and Industrial Fuel Use Act (PIFUA): PIFUA is largely responsible for utility interest in SCR for repowering applications, although its provisions are equally applicable to industrial energy users. The fuel use exemption, available to a user which arranges for a qualifying fuel or technology to be used at distant--and possibly non-affiliated--site can encourage interest in SCR technology by potential customers whose site constraints would otherwise make SCR impractical and unattractive.

- Public Utility Regulatory Policy Act (PURPA): The major thrust of this law is to encourage non-utility electricity generation and to stimulate electricity conservation. The net effect of the law is to encourage user power generation--which is offered through SCR technology.

(3) Federal Policies And Programs Should Be Directed At Encouraging Development of A Private Sector SCR Industry

In addition to economic incentives, a variety of institutional issues must be addressed:

- The SCR demonstration program should be continued, in order to allay purchasers' technical concerns. Emphasis should be placed on confirming SCR performance on a scale and under conditions consistent with utility operations.

- The utility regulatory climate, if not favorable, should at least be neutral towards SCR adoption; currently,

  - R&D expenditures may be disallowed or reduced

  - Expenses during protracted construction are often not in the rate base

  - Construction of least cost generation systems is often required.

- Program funds should be directed into the private sector in an unbiased manner

  - Funding through the national labs may not be the most effective means of SCR development

- Evenhanded loans and tax relief measures are preferrable to order guarantees.

- Program direction should be predictable and sustained and insulated--to the extent practical--from political risk; for example:

  - Provision of tax relief financial incentives, which are less prone to later Congressional reduction or elimination

  - Clear enunciation, and subsequent follow-through, of demonstration projects and construction design funding--both scheduling and priority

* * * * *

A cohesive Federal program--including financial incentives for SCR purchase--can serve to advance the date of free market competition and thus retain SCR developer interest and create a sustainable SCR industry.

7. PRIVATE SECTOR PARTICIPANTS IN THE SCR R&D PROGRAM HAVE THE CAPABILITIES TO SUPPORT THE IMPLEMENTATION OF SCR SYSTEMS

Successful development implementation of an emerging technology, such as SCR, requires several technical, corporate, and financial capabilities. Companies participating in SCR development show strength in each of these areas. In addition, the industry has been acquiring key technical expertise, primarily as a result of government-funded programs, in the design of SCR systems.

A viable solar central receiver (SCR) supply industry does not yet exist, primarily because the markets that the industry will serve are not yet formed. However, the DOE and EPRI funded programs have attracted a group of private sector developers from which a viable supply industry can evolve.

(1) Corporate Participants in SCR Development Have Substantial Experience in Related Technologies and Potential Markets

SCR technology is being developed by a diverse group of companies with broadly different business backgrounds falling into three generic categories:

- Technology-based developers diversifying into new product lines through technology innovation

- Market-based developers diversifying product lines to serve current markets

- Customer-side developers encouraging SCR development for their own use through research.

Customer-side developers, utilities and industrial energy consumers, will do more to shape the market for SCR technology as early adopters than as potential suppliers, in the near-term.

Aerospace companies are technology-based SCR developers. Their primary historic business background is the development and manufacture of sophisticated aerospace technology products. Recently, aerospace companies have diversified into nonaerospace areas, such as energy engineering and transportation, by building upon their technical expertise.

Architect and engineering (A&E) firms are marketbased SCR developers. These firms generally perform the engineering evaluation, design and integration function in the construction of new industrial and utility plants. A&E firms are primarily involved with the implementation of emerging and established technologies for the utility and industry markets they currently serve.

Conventional Energy Equipment Vendors may be either market or technology based developers. These vendors are a diverse group that are generally involved with the development, implementation, and manufacturing of conventional and innovative energy supply and control systems and subsystems.

(2) The SCR Industry Is Applying Experience Gained in the Development Implementation of New Technologies to Areas That Reflect Their Business Background

The previous experience and expertise of the SCR industry provides the basis for their participation in the various technology segments of SCR development. A summary of the activities of corporate developers, Exhibit 28, points out an overlapping pattern of activity for the nine SCR technology areas that is strongly related to the business backgrounds of the developers. In general each company is proceeding cautiously and is participating only in the SCR technology areas in which they possess demonstrated technical competence or excellence.

- Aerospace companies are addressing nonconventional hardware such as heliostats, receivers, and thermal storage; instruments and controls; and advanced systems integration

- A&E firms are in general, focusing on the tower and balance of system and on systems integration

EXHIBIT 28

Overview of Business Backgrounds and Technology Areas

Business Background	Heliostat	Tower	Receiver	Working Fluid	Thermal Storage	Electric Generation	Instruments & Controls	Balance System	Systems Integration
Aerospace Companies	• Boeing • Martin Marietta • McDonnell Douglas		• Martin-Marietta • McDonnell Douglas • Rockwell	• Martin-Marietta • McDonnell Douglas • Rockwell	• Martin Marietta • Rockwell		• Martin Marietta • McDonnell Douglas		• Boeing • Martin Marietta • McDonnell Douglas • Rockwell
A & E Firms		• Badger • Gibbs & Hill • Kaiser • Stearns-Roger	• Bechtel	• Badger	• Badger • Gibbs & Hill	• Bechtel • Gibbs & Hill	• Stone & Webster	• Badger • Bechtel • Black & Veatch • Gibbs & Hill • Stone & Webster • Stearns-Roger • Brown-Root	• Bechtel • Black & Veatch • Gibbs & Hill
Equipment and Service Vendors	• ARCO	• PFR Engr.	• ARCO • Foster Wheeler • G. E. • PFR Engr. • Babcock & Wilcox	• ARCO • Foster Wheeler • G. E. • PFR Engr. • Westing-house • Babcock & Wilcox • Combustion Engineering	• Foster Wheeler • Babcock & Wilcox • Combustion Engineering	• G. E. • Westing-house	• ARCO • G. E. • PFR Engr. • Westing-house	• ARCO • Foster Wheeler	• ARCO • G. E. • PFR Engr. • Westing-house

- Conventional energy equipment companies have diverse technical backgrounds and are involved in all nine technology areas, with major emphasis on integration and development of the receiver, and working fluid, as well as the instruments, and controls.

(3) SCR Developers Have Adopted Traditional Market-Entry Strategies and are Establishing Formal Competitive Positions based on them

Exhibit 29 describes four traditional market-entry strategies that have been used by new technology development companies in other business areas and indicates which are being adopted by SCR developers.

- First-to-market strategy is based on a strong R&D program, technical leadership, and risk-taking.
- Follow-the-leader strategy is based on strong development resources and an ability to react quickly to changing competition and market growth.
- Applications engineering strategy is based on discovering different product needs in the mature marketplace and making engineering modifications to fit those needs.
- Last-to-market strategy is based on superior production efficiency, cost control, and mass marketing.

Aerospace companies, adopting a first-to-market strategy, are attempting to make a market for SCR in IPH, cogeneration, and utility applications. Conventional energy technology vendors are taking either an aggressive and competitive second-to-market approach keeping in the forefront of technology development and waiting for the market to develop or a last-to-market approach hoping to step in late with superior manufacturing experience. Some A&Es have an application engineering strategy, adapting current power generation plant designs to use SCR technology.

SCR developers are formulating competitive strategies that are related to their market-entry strategies. Like entry strategies, the competitive strategies reflect the companies' perceptions of the needs of the marketplace and

EXHIBIT 29
Major Market-Entry Strategies by Application

FIRST-TO-MARKET STRATEGY	FOLLOW-THE-LEADER STRATEGY	APPLICATION ENGINEERING STRATEGY	LAST-TO-MARKET (OR "ME TOO") STRATEGY
STRATEGY IS BASED ON STRONG R&D PROGRAM, TECHNICAL LEADERSHIP AND RISK TAKING	STRATEGY IS BASED ON STRONG DEVELOPMENT RESOURCES AND ABILITY TO REACT QUICKLY	STRATEGY IS BASED ON PRODUCT MODIFICATIONS TO MEET NEEDS OF PARTICULAR CUSTOMERS IN A MATURE MARKET	STRATEGY IS BASED ON SUPERIOR PRODUCTION EFFICIENCY AND COST CONTROL
• RESEARCH INTENSIVE • PROXIMITY TO STATE-OF-THE-ART • HIGH R&D INVESTMENT • TOP TECHNICAL STAFF • HIGH RISK INVESTMENTS • MANAGEMENT PROBLEMS – PRODUCT IMPROVEMENT VS. MARKET ENTRY – MARKET RESEARCH – MANAGE RISKS – ABSORB FAILURES	• DEVELOPMENT INTENSIVE • MODERATE COMPETENCE ACROSS MANY TECHNOLOGIES • SUPERIOR COMPETITIVE INTELLIGENCE • QUICK RESPONSE TO CHANGING MARKETS • MANAGEMENT PROBLEMS: – BALANCE TECHNICAL, MARKETING AND MANUFACTURING – TIME MARKET ENTRIES	• NO RESEARCH • LITTLE DEVELOPMENT • KEY IS PRODUCT REFINEMENT • TECHNICALLY-PERCEPTIVE SALES STAFF • GOOD PRODUCT LINE CONTROL • MANAGEMENT PROBLEMS: – DIFFERENTIATE PRODUCTS – SEGMENT MARKETS	• NO R&D • STRONG MANUFACTURING • DOMINATING PRODUCTS • STRONG PRICE AND DELIVERY PERFORMANCE • LOW OVERHEAD • HARD SELL FOR HIGH VOLUME • MANAGEMENT PROBLEMS: – PRODUCT DESIGN – COST CONTROL

MARKET APPLICATION					
	IPH	2 Aerospace Cos.	2 Conventional Energy Equipment Vendors	1 A&E	1 Conventional Energy Equipment Vendor
	COGENERATION	4 Aerospace Cos.	1 Conventional Energy Equipment Vendor	2 A&E	1 Conventional Energy Equipment Vendor
	UTILITIES	4 Aerospace Cos.	1 Conventional Energy Equipment Vendor	2 A&E	1 Vendor Equipment Vendor

the companies' capabilities. In addition, the competitive strategies indicate the perceived strengths of the other industry participants.

- Product differentiation strategies--currently the most prevalent--are based on industrywide product uniqueness derived from technical superiority, vendor brand name, unique design features, and prior experience

- Industrywide low-cost leadership, based on low-cost materials and designs that are cheaper to manufacture are being adopted where test, demonstration, or applicable previous experience permits

- Two different market niche strategies currently being used are to sell IPH receivers and to do custom design systems integration with any hardware.

A number of key competitive issues for the SCR marketplace were identified in the interviews focusing on three components of the SCR technology market entry and competitive strategies.

- System integration: The integration of the SCR technology and the end-use application will be a highly competitive area, requiring technical and multifaceted skills.

- Heliostats: This is the largest single-cost item in the SCR technical system. The development of a significant competitive advantage in heliostats could result in a strong overall competitive advantage.

- Receiver and working fluids: This is not as critical to the plant cost as the heliostats, but a high reliability and efficiency product will be required by the users. The competitive issues in this area will be similar to the competitive issues for high-temperature heaters and boilers which are currently used in industry and utilities.

(4) The SCR Industry Views The Market as in the Formative Stages--With Size and Timing Uncertain And Foreign Competition a Near-Term Threat

The companies involved in SCR development exhibit widely different perceptions and a great deal of uncertainty in estimates of the timing and the size of SCR markets. These perceptions appear to have a major impact on the expectations of each of the developers and on the cohesiveness and momentum of the development process.

- There is general disagreement within the industry as to when the period of introduction will begin and how long it will last. Perceptions of the year of commercial introduction range from 1983 to 1990 and the period of introduction is estimated to take 2 to 3 years.

- Similarly, the industry's estimates of the potential market for the year 2000, vary from "negligible" to 3 quads, but most developers envision less than 1 quad. The uncertainty of these estimates was attributed by industry executives to two key factors--in the near-term, changing government role and, in the long-term, conventional energy price uncertainty.

Foreign competition is perceived by the developers as a threat to the U.S. SCR markets. Foreign SCR technologies are considered by U.S. developers to be currently less developed than U.S. technology, they are developing rapidly may influence near-term and midterm markets.

The foreign SCR developers are perceived as having highly aggressive marketing skills that could permit them to significantly penetrate U.S. markets as they further develop their technology. U.S. developers pointed to the number and status of foreign demonstration projects and recent large flat plate sales in the international market as an indication of future competition.

Several U.S. developers said that they would feel the vulnerable to foreign competition if the U.S. government-sponsored demonstration programs were removed in the near-term. This would significantly reduce the U.S. technology development process and allow the foreign competitors to over- take the U.S. industry.

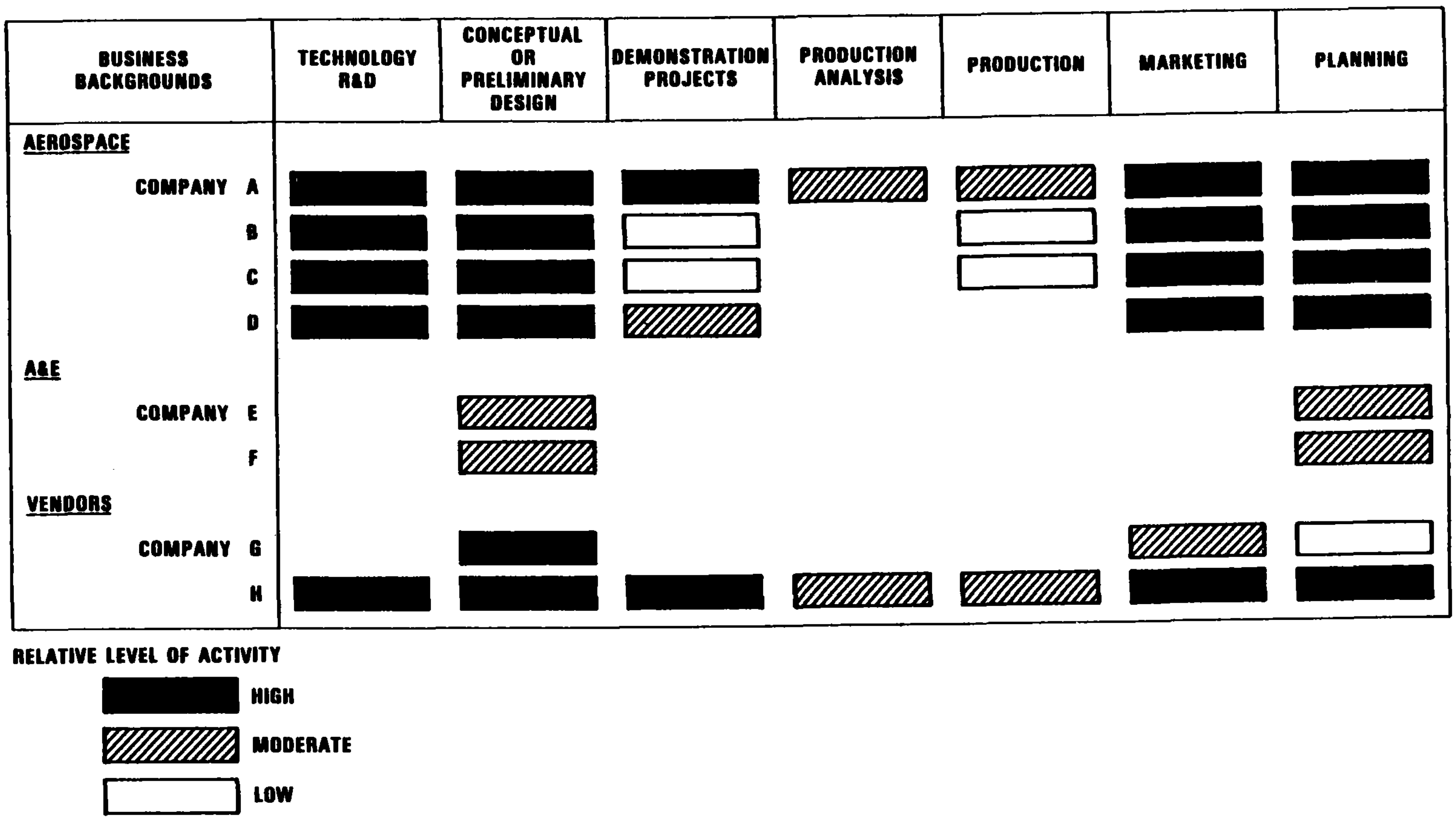
(5) <u>Current Business Activity Is Multifaceted and Generally Reflects the Government-Sponsored Programs</u>

The development companies have applied their funds to a wide range of activities, as summarized in Exhibit 30:

- <u>R&D</u>: These activities are continuing but are under evaluation because of uncertain funding.

- <u>Conceptual design</u>: This activity from the government-sponsored conceptual designs is the only funded activity and is expected to decline rapidly as the designs are completed.

EXHIBIT 30
Current Commercialization Activities



Source: Booz, Allen & Hamilton Industry Interviews, mid-1981.

- Marketing: This activity is receiving considerable emphasis in the hopes of closing a near-term deal.

- Planning: Anticipation of changing government support and general uncertainty regarding market timing and size are causing critical evaluation of business plans and activities.

- Demonstration project activities: These are centered around two ongoing projects and one anticipated project.

- Production analysis: This effort is ongoing mainly to support the demonstration projects; however, this is a longer term, low-level activity for nondemonstration participants.

The annual sales figures for eight key participants in SCR development indicate that two companies have captured a major portion of the nearly $50 million in annual sales. Approximately 98 percent of the sales have been from government programs. The remaining 2 percent have come from EPRI programs and have been captured exclusively by one company. In addition to government and EPRI sales, companies are investing their own funds in SCR programs.

* * * * *

The SCR industry possesses a wide range of capabilities to implement SCR technology based upon prior business experience and government funded project experience. However, the industry is in the formative stages and considerable uncertainty exists among the companies as to market timing, market size, and the effects of foreign competition. Since the markets that the industry will serve are not yet formed, the industry is heavily dependent upon government support for the near term. Participation in government sponsored demonstration programs is considered essential by most of industry for near-term viability.

☆U.S. GOVERNMENT PRINTING OFFICE: 1981-740-145/2754