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AN ANALYSIS OF THE ECONOMICS
OF TYPICAL BUSINESS APPLICATIONS
OF SOLAR ENERGY

NOVEMBER 1981

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EXECUTIVE SUMMARY

- o With the existing 25% tax credit, flat plate solar systems are economically competitive with oil for industrial/agricultural applications in eight of the sixteen cities surveyed. (p.15)
- o Commercial applications of flat plate solar systems are economic in only one of the cities studied with the present 15% credit (p.17) due to the lower tax credit available as well as the requirement for additional storage and only partial year utilization. (p.6)
- o Increasing the tax credits to 40% or 46% makes solar competitive in each application. However, eliminating the credits severely restricts the viability of solar. (p.20)
- o Allowing businesses to deduct their fuel costs on tax returns amounts to a 46% subsidy to the use of conventional fuels (p.19) and is the major hurdle to the widespread penetration of solar in business applications. (p.24)

INTRODUCTION

The purpose of this study is twofold. Primarily, it is intended to provide an economic analysis of flat plate solar collector systems in industrial, commercial, and agricultural business applications. This technology is studied in a number of varied locations throughout the United States. A key element of such an analysis is the federal solar investment tax credit as it was established in the Energy Tax Act of 1978 and was extended and improved upon in the Crude Oil Windfall Profits Tax Act of 1980. These laws set the tax credits for businesses at 15% of the total cost of a solar system (industrial applications also get the standard industrial investment tax credit of 10% - for a total credit of 25%). However, there has been considerable discussion about the possibility of reducing these credits due to the Administration's attempts to reduce the size of the federal budget deficit. In contrast, Congressional proposals have been advanced which would result in an increase in the credits. Thus, in order to assure the usefulness of this study in light of these potential changes the second major aspect of this effort is to examine the economics of solar business applications under different tax credit scenarios.

Attention has been given to examining the cost of these credits to the U.S. Treasury with subsidies provided to other fuels. Market penetration or diffusion of solar business applications in the industrial market has been examined as a byproduct of the Department of Treasury estimates of revenue costs of the credits.

It is anticipated that this study will be used to assist corporate planners as well as the other experts in their evaluation of solar investments as a substitute for other forms of energy in industrial, commercial, and agricultural applications.

Industrial, Agricultural and Commercial Applications of Solar

A look at Exhibit A illustrates United States energy consumption by major end use sector. Fully 36% of our total energy consumption in 1977 was used in the industrial and agricultural sectors of the economy. Commercial energy use is depicted as an additional massive area of energy consumption. Industrial process heat (IPH) accounts for about 18% to 25% of total U.S. energy consumption. A large share (27%) of that total can be achieved with solar technology (up to 550°F). If pre-heating for higher temperature use is included, then potentially 51% of IPH can be served by solar. Exhibit B shows various solar technologies and the temperatures that they are capable of achieving.

Typical solar industrial/agricultural process heat projects, and the temperatures required by solar processes to provide that energy requirement, are shown in Exhibit B. For instance, crop drying requires temperatures in the 100°F-140°F range. Grain drying demands typical temperatures of 120°F-150°F, Livestock shelters require 120°F-140°F. Greenhouses require 100°F-220°F, and food processing temperatures are 120°F-140°F.

Exhibit C shows various solar technologies and the temperatures that they are capable of producing. Finally, Exhibit D shows some of the primary advantages and disadvantages of solar for agricultural and industrial applications.

UNITED STATES 1977 ENERGY CONSUMPTION BY MAJOR END USE SECTOR

Solar Industrial Process Heat Projects

SOLAR COLLECTOR TECHNOLOGY FOR AGRICULTURAL AND INDUSTRIAL PROCESS HEAT

CONCENTRATORS

PARABOLIC DISH
PARABOLIC TROUGH
CYLINDRICAL TROUGH
FRESNEL
CPC TROUGH
EVACUATED TUBE
FLAT PLATE
SHALLOW POND

INDUSTRIAL PROCESS HEAT IS AN EXCELLENT SOLAR APPLICATION

ADVANTAGES

- **YEAR ROUND USE
3 TIMES AS EFFECTIVE
AS HEATING APPLICATIONS**
**MINIMUM STORAGE
ENERGY USED AS PRODUCED**
**LARGE ARRAYS
ECONOMY OF SCALE**
**MAINTENANCE AVAILABLE
PERMITS MORE SOPHISTICATION**
- **NO HEAT ENGINE REQUIRED
HIGHER EFFICIENCY**
**CENTRALIZED PURCHASE AUTHORITY
LOWER SALES COSTS**

DISADVANTAGES

- **HIGHER TEMPERATURES
LOWER EFFICIENCY**
- **INDUSTRIAL ENVIRONMENT
SURFACE CONTAMINATION**
- **UNFAVORABLE ECONOMIC CRITERIA
TAXES, INVESTMENT**

I. METHODOLOGY

A number of methods exist for the design and study of solar energy systems. They range from computer simulations to hand-held programmable calculator applications. This report makes use of the SOLCOST Solar Energy Design Program developed by Martin Marietta for the Department of Energy and maintained by the Solar Energy Research Institute.

The SOLCOST computer program is intended for use by members of the heating, ventilation and cooling (HVAC) industry who are responsible for making decisions on economically justifiable investments in solar energy systems. SOLCOST is an interactive computer program and contains 303 different parameters which allow the user to vary the model to fit his particular requirements for analysis. Several types of solar systems can be evaluated with SOLCOST, including service hot water systems and space heating systems using liquid or air collectors. The specifics of the solar system and its components can be provided by the user or the "built-in" values can be used. Since this analysis is mainly concerned with the economic data, this built-in data was frequently employed. However, several key elements of data must be provided by the user. These include the type of system and collectors, cost of collectors, type and cost of conventional fuel, site location of collectors, and income tax rate. Given these inputs the major outputs of the program consist of (1) prediction of annual fraction of load provided by solar system, (2) optimum collector area, and (3) a detailed cash flow summary for the optimum collector area. For the purposes of this effort, the cash flow summary is the key output.

The major elements of the detailed cash flow summary are the payback and rate of return figures for the optimum collector area. Also provided are solar system cost, annual fraction of load provided by solar, annual energy savings with solar system, net present worth of solar savings, and lifetime cost savings.

Payback and rate of return are two indices that financial planners use to determine the economic benefits of investments. Payback refers to the elapsed time for the cumulative savings to offset the initial investment or down payment. The rate of return on an asset can be defined as the annual return on an investment calculated as a percentage of that investment. The rate of return is calculated on the down payment and not the total investment. Thus, it is extremely sensitive to that input. This study uses a 50% down payment because this is a commonly accepted equity participation rate by industry in these types of investments.

One further term that may need clarification is "net present worth." This is determined by "discounting" or reducing the value of any future savings or costs in order to make them equivalent to current dollars. This adjustment is essential for a valid evaluation of a project's cost effectiveness because, due to inflation and other factors, future dollars are worth less than current dollars. This is especially true if one considers the "opportunity cost of money", which is the rate of return that could be realized if the money were invested in the next best investment rather than the project being considered.

There is significant disagreement as to which discount rate should be used. Electric utilities, for example, use a 2 or 3% discount rate. The federal government often uses a discount rate of 10%. This report makes use of a 15% discount rate, which conventional wisdom suggests is an appropriate rate based on the expectations which a business would have for the alternative investment of its financial resources.

II ASSUMPTIONS

As has been shown, the intent of this paper is to compare the economics of solar flat plate collector systems in business applications (industrial/agricultural, and commercial) in selected areas of the country. Sixteen cities were chosen for their geographic and climatic diversity. They cover regions which have excellent sunshine year-round as well as those which have poor solar insolation.

The business applications were chosen in order to show where solar can best compete among these cities. Industrial and agricultural applications are combined because the types of systems used to provide the energy for these applications are basically the same. The differences between industrial/agricultural and commercial applications are in types of solar systems (hot water vs. space heating), tilt angle of collectors, storage costs, and heating and hot water loads. The details of these differences are provided below.

System Data

Two types of solar systems are used in this analysis, industrial process water heating only (IPH) and combination space heating service hot water systems (heating/HW). The first type of system is used for the industrial/agricultural applications, while the space heating/hot water system is used to simulate commercial applications. A liquid, flat plate collector with two selective covers is used for both types of systems. This was selected because it is generally accepted as the most commonly used system at present.

An installed collector cost of \$46/square foot is considered reasonable for industrial and agricultural applications. The hot water load is assumed to be 30,000 gallons/day at a temperature of 130°F. For the commercial applications, the space heating load is calculated for a 40,000 square foot building (about the size of a football field) and the hot water load is 4.5 million BTU's/day. Storage for hot water is computed at 1.5 gallons/square foot of collector and at \$1.00/gallon. No storage is assumed for space heating, because many applications being sold today do not require or utilize storage. These are also the most economic applications.

Finance and Tax Data

Assumptions concerning the mortgage are determined from a review of existing business loans in several cities. Of course, the particulars of any loan vary with the financial situation of the applicant, but for this study the assumptions are a 10-year loan with 50% down at 15% interest. The economics are much more attractive with a lower down payment but, as will be shown in Section III, a 50% down payment is considered reasonable. The federal income tax rate for a majority of companies is 46% and state rates vary. For purposes of this study, a 50% total income tax rate is used. The discount rate is assumed at 15%. Also, any applicable state income tax credit was added to appropriate federal credits. The straight line, 5-year depreciation method and rate used here simulated the 5-year sum of years digits schedule enacted in the Economic Recovery Tax Act as closely as the SOLCOST program would allow.

Fuel Data

The prices for each fuel vary considerably from city to city. Current prices (October 1981) are used in each case. As for price escalation, any projection of fuel prices over the next 20 years is speculative.

For the purposes of this study, a rate of 16% is assumed for fuel escalation (including inflation) for all types of fuel. Since 1976, world oil prices have risen an average of 22% per year according to a survey by the Washington Post, November 1981. (Some program runs were done assuming deregulation of natural gas. These allowed for a 100% increase in the first year and a 16% rise in the remaining years.)

Exhibit II-1

ASSUMPTIONS

System Data

System type	Process water heating only (IPH) Space heating and hot water (SpHt/HW)
Collector type	Liquid, flat plate, 2 covers, selective
Tilt angle	Latitude (HW), latitude + 15° (SpHt/HW)
Collector module size	30 square feet
Collector cost (installed)	\$46 per square foot
Maintenance cost	2% of initial cost per year
Storage	1.5gals, per sq ft of collector (IPH) none (SpHt/HW)
Storage cost	\$1.00 per gallon (IPH)
Water temperature	130°
Hot water usage	30,000 gallons per day (IPH)
Building gross floor area	40,000 sq ft (SpHt/HW)
Load for water heating	4.5 million BTU's per day (SpHt/HW)

Finance and Tax Data

Term of load	10 years
Loan down payment	50%
Loan interest rate	15%
Term of life cycle cost analysis	20 years
Insurance rate	.5%
Inflation factor for main., insur.	.6%
Income tax rate	50% (federal and state)
Depreciation method	Straight line
Useful life (for depreciation)	5 years
Salvage value	0
Discount rate	15%

Fuel Data

Fuel type	Oil and natural gas
Fuel price	Current price in each city
Fuel escalation rate	16% per year (inflation included)

III ECONOMIC ANALYSIS

As shown above, rate of return and payback are two major indices used by financial planners to determine the economic benefits of an investment. As a result, these are the criteria that are used in this study to compare the economic viability of solar flat plate collector systems in business applications in the selected cities. In interpreting the results of the analysis, it is useful to note that most investments of the type considered here are expected to have a rate of return in the 25-30% range and a payback of 2-4 years in order to be economically viable.

Effects of Key Variables

In conducting the analysis, a number of financial criteria were assumed. While these were explained in detail in Section II, it is useful to briefly demonstrate the effects which two significant assumptions (down payment and reference fuel type) have on the economics before the results are discussed.

In the SOLCOST program, rate of return and payback are extremely sensitive to the down payment of the solar system. In order to determine the effects of this variable, sample runs were conducted for Minneapolis (with electricity as the reference fuel) with down payments of 10%, 30%, 50% and 100%. The results are presented in Table III-1.

Table III-1

Varied levels of down payments (Minneapolis/electricity)		
Down Payment	Rate of return	Payback
10%	277.1%	.3 years
30%	45.6	.8
50%	25.6	2.0
100%	21.2	3.8

As the table shows, a lower down payment yields a higher rate of return and an earlier payback. However, even though the economic viability of solar is dramatically improved with a lower down payment, it was determined that a 50% down payment is typical for these kinds of business investments.

The other key variable that affects this analysis is the type of reference fuel type that solar is compared against. Each of the four major conventional fuel types (oil, natural gas, coal and electricity) were considered for Denver with a 50% down payment. Each fuel had an escalation rate (including inflation) of 16% per year. Natural gas was calculated twice: (1) with only an 16% escalation and (2) with a 100% increase in the first year and 16% there after (to account for deregulation.) The results are shown in Table III-2.

Table III-2

Varied reference fuel types (Denver/50% down)		
Fuel Type	Rate of return	Payback
Oil	30.9%	3.0 years
Natural gas(1)	15.9	4.9
Natural gas(2)	20.1	4.3
Coal	29.6	3.2
Electricity	32.2	2.8

The table shows that the comparison of solar to oil, electricity and coal results in very similar rates of return and payback while comparison to natural gas (even with deregulation) yields considerably lower returns. Thus, it was determined that a selection of a reference fuel type should come from either coal, oil, or electricity. Coal was ruled out due to the heavy restrictions imposed on its use through environmental regulations.

Electricity was not selected because of the considerable fluctuation in cost throughout the country and its impracticality (due to high cost) for use in some of the applications considered here. Oil was considered to be the best reference fuel as a result of its flexibility and its common usage in these applications throughout the country.

Economic Viability of Solar in Selected Cities

After determining the proper assumptions to make in the analysis, it was possible to conduct a series of computer runs to compare the economic viability of solar flat plate collectors for industrial/agricultural and commercial applications in the sixteen cities. All variables remained the same for each type of application except those that reflected the individual nuances of each city (solar insolation, tilt angle of the collector, and fuel cost.) The appropriate federal income tax credit (25% for industrial/agricultural and 15% for commercial) were used. In addition, any applicable state credits were also factored in.

The results for industrial/agricultural process heat applications are shown in Table III-3. This table demonstrates, as would be expected, that the cities in the regions of the country with the highest solar radiation have the best economics for solar. (Los Angeles is considerably better than the rest of the cities for this reason and also because of its 25% state tax credit.) Conversely, the cities with the poorest economics are located in the northern Midwest region and in the Northeast. (The major exception is Milwaukee which has a 10% state tax credit.)

A major result of the analysis can be seen by examining the rates of return. The table shows that half of the optimum systems (selected by the SOLCOST program) are within or above the acceptable range for rate of return. Three cities are higher than 30% and five more are above the hypothetical cutoff of 25% of the remaining eight cities, only four are below 22.7%.

Table III-3

Comparison of Economics for Industrial/Agricultural Applications
(25% of Federal Tax Credit)

City	System Cost	Solar Energy Fraction	Rate of Return (rank)	Payback (rank)
Atlanta	\$472,000	41.2%	26.5 (6)	3.4 years (7)
Boston	355,000	26.4	24.3 (9)	3.6 (9)
Chicago	395,000	31.7	23.0 (11)	3.8 (11)
Cleveland	765,000	48.3	19.4 (16)	4.3 (16)
Denver	301,000	33.8	30.9 (3)	3.0 (3)
Des Moines	274,000	24.9	23.8 (10)	3.7 (10)
Detroit	519,000	36.7	21.0 (14)	4.1 (14)
Fargo	338,000	28.2	25.0 (8)	3.5 (8)
Indianapolis	439,000	33.0	21.8 (13)	4.0 (13)
Los Angeles	304,000	33.2	39.4 (1)	1.4 (1)
Milwaukee	398,000	31.0	25.2 (7)	3.1 (4)
Minneapolis	376,000	29.8	22.7 (12)	3.8 (11)
New York	413,000	30.0	19.9 (15)	4.2 (15)
Phoenix	140,000	36.2	33.1 (2)	2.8 (2)
Tampa	321,000	32.8	27.5 (4)	3.3 (5)
Wichita	373,000	38.5	27.3 (5)	3.3 (5)

As a result, it can be deduced that, (at least in optimal applications) a flat-plate solar system can be somewhat competitive against oil in several areas of the country.

One further point that should be made concerns the size of the solar systems. As stated above, the SOLCOST program computes the calculations for nine different sample systems and selects the system with the highest rate of return for detailed economic analysis. As a rule, the chosen system tended to be one of the smaller ones. As larger systems were considered, the rate of return diminished. As a result, the difference between the highest rate of return and the lowest was frequently as much as 10%. This highlights the fact that solar can compete best in smaller applications where it provides from 15-35% of the total energy load.

The major difference between the commercial applications of a flat plate solar system and the industrial/agricultural applications were in the end use of the energy. Instead of using the energy for heating water to run the process, the energy from the collector is used for space heating and hot water in a commercial application. The results of the analysis, shown in Table III-4, confirm the generally-accepted notion that solar is less economic for these latter business applications. The lower rates of return are a result of this, as well as the fact that commercial applications do not receive the additional 10% federal tax credit available for industrial investments. Thus, it is clear that these applications are only close to being economically viable in the areas of the country with the highest solar radiation.

Effects of Varying Tax Credits on Economics

The previous analyses were conducted using the existing levels of federal income tax credits. However, at present, there is considerable discussion about the possibility of changing the level of those credits.

Table III-4

Comparison of Economics for Commercial Applications
(15% Federal Tax Credit)

City	System Cost	Solar Energy Fraction	Rate of Return (rank)	Payback (rank)
Boston	\$201,000	28.2%	13.7%(6)	11.5years(6)
Chicago	244,000	36.1	14.3(4)	11.2(4)
Cleveland	456,000	46.3	9.5(8)	13.8(8)
Denver	87,000	19.8	21.5(2)	7.4(2)
Detroit	312,000	39.4	12.3(7)	12.2(7)
Los Angeles	47,000	16.0	25.3(1)	5.7(1)
Milwaukee	265,000	34.2	15.2(3)	10.9(3)
Minneapolis	306,000	38.0	14.0(5)	11.3(5)

As a result of the recent attempts by the Reagan administration to reduce the deficit of the federal government, a recommendation has surfaced to consider the elimination of the credits.

Simultaneously, a proposal in the Senate Finance Committee is gaining impetus which might result in the increase of the tax credits for renewable energy. In order to take into account the possibility of these changes, a number of computer runs were conducted to examine their effects.

However, before examining these effects, it is useful to briefly review the incentives that have historically been provided to conventional sources of energy. A 1977 analysis by Battelle Northwest Laboratories is generally considered to be the best illustration of the magnitude of incentives provided to these energy sources over the past sixty years. That study shows that in that time period the following subsidies have been granted: oil-\$101 billion, natural gas-\$17 billion, hydropower-\$15 billion, coal-\$10 billion, electricity-\$57 billion, and nuclear-\$18 billion.

These subsidies cover a broad range of support activities, including the construction of pipelines, depletion allowances, research and development, market development, as well as relief from federal taxation. This last type of subsidy mentioned, federal tax relief, results from allowing businesses to deduct the cost of fuel as a business expense. Thus, any costs incurred from energy expenditures are deducted from the gross income of the business. Since most businesses are taxed at a rate of 46%, this is tantamount to a 46% tax credit for the consumption of conventional fuels. This puts solar and other renewable technologies at a comparative disadvantage, since they receive no similar credit for the amount of energy that is displaced.

The results of varying the level of federal tax credits on industrial/agricultural applications are summarized in Table III-5. As shown previously, the rates of return and payback are within the acceptable range with a 25% tax credit. However, a reduction to 10% by eliminating the additional 15% credit has a dramatic effect on the economic viability of solar in every city. This reduces the number of cities where solar can compete to two (Los Angeles and Phoenix.) Conversely, raising the tax credit levels to 40% or 46% increases the rate of return to such an extent that a flat plate system would be economically competitive with oil in every city covered in the survey. Similar results can be seen in an examination of payback. If a 10% credit is assumed, then only Los Angeles is in the acceptable range; however, with a 40% or 46% credit solar is competitive in every city.

Table III-6 shows the effects of varied tax credits on commercial applications. Since solar can only barely compete in these applications with the existing 15% credit, the reduction to 0% eliminates any likelihood of solar even being seriously considered. However, the increase of the credit to 46% significantly enhances solar's competitiveness and makes it a viable alternative in several of the sample cities.

Table III-5

**EFFECTS OF VARYING BUSINESS INVESTMENT TAX CREDITS
ON RATE OF RETURN AND PAYBACK
(Agricultural/Industrial Process Heat)**

1

LEVEL OF FEDERAL TAX CREDIT

CITY	10% ²		25%		40%		46%	
	3	4	3	4	3	4	3	4
	ROR Payback		ROR Payback		ROR Payback		ROR Payback	
Atlanta	21.2%	6.9	26.5%	3.4	35.7%	1.4	41.1%	0.9
Boston	19.2	9.9	24.3	3.6	33.1	1.5	38.4	1.0
Chicago	18.1	10.4	23.0	3.8	31.6	1.6	36.8	1.0
Cleveland	15.0%	11.7	19.4	4.3	27.3%	1.8	32.3%	1.0
Denver	24.9	4.4	30.9	3.0	40.8	1.3	46.3	0.9
Des Moines	18.8	10.1	23.8	3.7	32.5	1.6	37.7	1.0
Detroit	16.4	11.1	21.0	4.1	29.2	1.7	34.3	1.0
Fargo	19.8	9.1	25.0	3.5	33.9	1.5	39.2	1.0
Indianapolis	17.1	10.8	21.8	4.0	30.1	1.7	35.3	1.0
Los Angeles	30.0	3.1	39.4	1.4	54.5	0.8	62.3	0.7
Milwaukee	19.4	10.1	25.2	3.1	35.7	1.0	42.0	0.9
Minneapolis	17.9	10.5	22.7	3.8	31.2	1.6	36.4	1.0
New York	15.4	11.6	19.9	4.2	27.8	1.8	32.9	1.0
Phoenix	26.8	4.1	33.1	2.8	43.3	1.2	49.0	0.9
Tampa	21.9	4.9	27.5	3.3	36.8	1.4	42.2	0.9
Wichita	21.8	4.9	27.3	3.3	36.6	1.4	42.1	0.9

¹ Any applicable state tax credits are included in computations.

² All industrial investments qualify for an automatic 10% investment credit.

³ Rate of return on net cash flow.

⁴ Payback is number of years for net cash flow to offset a 50% down payment.

Table III-6

EFFECTS OF VARYING BUSINESS INVESTMENT TAX CREDITS
ON RATE OF RETURN AND PAYBACK
(Commercial Space Heat/Hot Water)

City	LEVEL OF FEDERAL TAX CREDIT ¹					
	0%		15%		46%	
	2 ROR	3 Payback	2 ROR	3 Payback	2 ROR	3 Payback
Boston	11.2%	12.7	13.7%	11.5	23.4%	5.0
Chicago	11.8	12.3	14.3	11.2	24.3	4.4
Cleveland	7.4	14.9	9.5	13.8	17.9	10.3
Denver	18.3	9.0	21.5	7.4	34.2	1.6
Detroit	10.0	13.3	12.3	12.2	21.6	6.4
Los Angeles	20.9	7.7	25.3	5.7	45.7	0.8
Milwaukee	12.4	12.1	15.2	10.9	27.1	1.0
Minneapolis	11.5	12.5	14.0	11.3	23.9	4.6

¹ Any applicable state tax credits are included in computations.

² Rate of return on net cash flow.

³ Payback is number of years for net cash flow to offset a 50% down payment.

Market Penetration

Estimating the market penetration or diffusion of industrial, commercial, and agricultural solar applications is an extremely difficult task. However, a study prepared for Lawrence Livermore Laboratory by Urban System Research and Engineering, Inc. entitled "An Analysis of the Impact of Federal Tax Incentives on Market Diffusion For Solar Thermal/WECS Technologies 1980-1990," estimates solar penetration in sixteen southern states for the direct heat market and seven southwestern states for the process steam market. These market penetration results for direct heat were derived for the industrial market in the sixteen southern states where incident solar insolation is highest. Market penetration estimates for process steam were derived for seven southwestern states where direct solar radiation is highest.

The conclusions of the study are detailed below:

If firms contemplating a solar investment require a 30% versus a 20% after-tax internal rate of return, given the same set of tax incentives, this will substantially reduce solar market penetration. However tax incentives insuring a 30% internal rate of return, will accelerate penetration. The study goes on to point out that the profitability and competitiveness of solar equipment are quite sensitive to the level of tax credits available, the amount of leveraging used, and the real rate of inflation in energy prices.

The investment tax credits are seen as a more effective means of promoting market diffusion of solar thermal technologies than accelerated depreciation. The effect of increasing investment tax credits on market penetration is more dramatic in the direct heat than in the process steam market.

Above thirty-five percent, incremental increases in the investment tax credit for solar thermal direct heat equipment are very effective in increasing market penetration.

The estimates of market penetration are based upon the referenced states which encompass roughly one-half of the total national market. Penetration in 1990 is estimated at .56 quadrillion BTU's (annual total market size of output) for solar industrial process steam in the seven southwestern states. The market penetration for solar industrial direct heat in the sixteen referenced states is estimated in 1990 at a potential .53 quadrillion BTU's (annual total market size of output.)

Thus, the study points out, a total annual energy production potential of one quad (quadrillion BTU's) of which solar would contribute approximately one-quarter of this energy required is seen as the solar contribution in 1990 in the industrial process steam and direct heat markets in the mentioned states. No comparable figures are available for the commercial market that entail enough reliability. The above mentioned figures are estimates for parabolic troughs, and evacuated tubes in the process stream market and flat plate collectors and solar salt ponds in the direct heat markets. Although evacuated tubes are employed in direct heat applications, solar salt ponds and flat plate collector systems are the reference system for these estimates due to their lower cost and for simplicity of data presentation.

IV. CONCLUSIONS

The results of the study show that, with the existing 25% tax credits, the use of flat plate solar collectors in industrial/agricultural applications is economically competitive with oil in one-half of the cities studied. Commercial applications with only a 15% tax credit do not fare as well due to the fact that commercial space heating/hot water systems do not benefit from year round utilization and have the requirement for additional storage. The locations which have additional state tax incentives do increase the economic return somewhat.

An increase in the federal tax credits to 40% or 46% dramatically increases the viability of solar. A 46% credit would allow solar to be very attractive in every city surveyed in both industrial/agricultural and commercial applications. Conversely, a reduction of the credits would have a devastating effect. Their elimination causes the system to be non-economic in every city for each type of application.

There are a number of other variations, besides the tax credits, that also have a significant effect upon the rate of return and payback. Lowering the size of the downpayment has a substantial benefit in this regard. A 10% downpayment for industrial applications raises the rate of return from 250 to 300% in most cities. On the other hand, a 100% downpayment lowers the rate of return to 10 to 20%.

Another variable which has substantial effect on the results is the size of the solar system. The SOLCOST program selects the optimum size for each application and makes computations on it; but it appears that larger systems have correspondingly lower rates of return.

Fuel type also has an effect upon the programs. Solar does not compete well with natural gas, even with deregulation.

Electricity, coal and oil are considerably better for solar to be compared with. Since coal and electricity are not widely used as boiler fuel in these types of applications, oil seems to be the most likely target area for solar.

Thus, it seems that the most optimal applications for flat plate solar collectors are: (1.) in locations where oil is being used as the fuel source; (2.) in applications of moderate size; (3.) in areas of the country with high solar radiation (although there are some exceptions); and (4.) where state income tax credits are available.

Recommendations For Further Study

In addition to reducing the depreciation time for solar and other industrial equipment from 10 to 5 years, the Economic Tax Act of 1981 also has created the potential for a new market for solar systems. This is in the area of lease purchases. Under the new law, a prospective buyer of a solar system could make arrangements with a manufacturer (or a third party) to lease the system instead of purchasing it outright. This condition would allow the manufacturer (or third party) to receive the tax credits and reduce the price of the system to the lessee. The main advantage, however, lies in the ability of the lessee to deduct the payments for the system on his income tax return. This amounts to a considerable incentive and would allow solar to compete on an equal basis with other conventional fuels.

It is recommended here that, as soon as the tax regulations for implementing this program are clarified by the IRS, an in depth examination of the potential for leasing solar equipment should be undertaken.