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An Economic Analysis
for the
Hilo Coast Processing Company's
Solar Industrial Process Heat System

MASTER

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Hilo Coast Processing Co.
Pepeekeo, HI

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INTRODUCTION

This analysis has been prepared for the Hilo Coast Processing Company (HCPC) as part of the Phase I design of a solar industrial process heat (SIPH) system for their facility in Pepeekeo, Hawaii. The solar energy system will generate intermediate temperature (420°F) superheated steam that, when fed into the plant, will reduce the need for conventionally generated steam and lead directly to a reduction in fossil fuel consumption at HCPC.

The economic analysis herein is based on the publication UCRL-52814, Economic Analysis of Solar Industrial Process Heat Systems published August 17, 1979 by the Lawrence Livermore Laboratory. Certain input variables to the analysis have been fixed by the Department of Energy (DOE) in an attempt to normalize the analysis for different SIPH projects. While this method may not accurately reflect the economic situation for a particular project (since every firm has different financial characteristics) it does ensure a true "apples to apples" comparison when ranking the economic merits of different SIPH projects.^{1/}

Following the procedures outlined in the above publication, M-Factors (see nomenclature) for a variety of discount rates (i.e.: 10%, 15% and 20%) were developed for the HCPC project. These values were utilized in turn to develop the following economic characteristics:

- internal rate of return assuming the entire component represents an investment by the contractor;
- internal rate of return assuming the solar investment consists only of the equity portion (\$140,000 or 8.2%) of total projected project costs of \$1.74 million.
- the levelized price of the solar thermal process heat energy produced under varying discount rates;
- the levelized price of the alternative conventional energy under varying discount rates;
- expected annual fossil fuel savings; and,
- payback period.

^{1/} In particular, the four "fixed" variables, tax credits (TC), general inflation rate (g), fuel inflation rate (g^1), and replacement of 25% of the system in year 10 $M(t_c)$, do not reflect current economic conditions or expectations at HCPC and the assumed values of these variables markedly change the cost effectiveness of the system.

Nomenclature

$M =$	$\frac{C_s}{I}$ Levelized required revenue per total investment dollar, the M - factor.
$E_s =$	Annualized energy provided (saved) by new system at point of use.
$C_s =$	Levelized required revenue for solar-generated energy or energy conservation.
$I =$	Total initial system component investment.
SOYD:	Sum-of-Years-Digits Depreciation calculation technique.
DP:	Depreciation Period
$\epsilon =$	Solar effectiveness factor (fuel energy saved by new system divided by new energy delivered).
$f =$	Portion of investment financed by loan.
$g =$	General inflation rate.
$g^1 =$	Fuel inflation rate.
$m(t_c) =$	Major component replacement cost in year t_c (as a proportion of I in zero-year dollars).
$N =$	System life.
$OMPI_o =$	Average annual operating, maintenance, property tax and insurance costs (as a proportion of I in zero-year dollars).
$P_{fo} =$	Price of conventional fuel in zero-year.
$S =$	Salvage value of new system (net).
$TC =$	Investment tax credit rate.
$\underline{r} =$	Marginal composite tax rate.
$R =$	Market discount rate.
$R^* =$	Internal rate of return.
DEP:	Present value of depreciation charges (as a fraction of I).

Nomenclature (continued)

DP = Depreciation period.

P_s = Levelized price of solar energy (or energy saved) produced by the prospective project.

ξE_s = Expected annual fossil fuel savings from the solar system.

T_p = Payback period for initial investment.

CRF(R,N) = Capital recovery factor at (R) market discount rate over (N) system life.

LP = Loan period (where LP=N in this analysis).

INTERNAL RATE OF RETURN

The following parameters were inputs to the internal rate of return analysis:

1. SOYD
2. DP = 7 years
3. $E_s = 7.39$ billion Btu (See Table III)
4. $\epsilon = 1.28$ ^{1/}
5. $f = 0$
6. $g = 6\%$
7. $g^1 = 8\%$
8. I = Case I = \$1.741 million
Case II - \$140,000
(See Table II)
9. $M(t_c) = .25$ (10)
10. N = 20 years
11. $OMPI_o = .011$ (Case I) and $.141$ (Case II).
(See Table II)
12. $P_{fo} = \$4.07/\text{million Btu's.}$
13. $S = 0$
14. TC = 20%
15. $\underline{r} = 50\%$
16. R = 10%; 15%; 20%
17. $r = 0$

System capital costs or solar investment are presented in Table I. Variable costs (OMPI) are presented in Table II, and energy information in Table III.

1/ HCPC would utilize number 2 fuel oil and bagasse in lieu of the projected solar thermal system. The fuel oil is currently priced at \$25.22 per barrel (\$4.07 per million Btu's); the present system requires the consumption of 1.28 Btu's to yield 1 Btu of delivered process steam.

Table 1
Projected Initial Capital Costs

<u>Item</u>	<u>Installed Costs</u>
Solar Collectors (42,420 ft ² aperture area)	\$1,081,660
Site Preparation	246,170
Collector Foundations	37,410
Pump House	9,000
Piping	79,350
Insulation	47,440
Steam Generator	46,000
Heat Transfer Fluid Pump	4,250
Feedwater Pump	1,200
Expansion Tank	1,700
Heat transfer Fluid	3,000
Chemical Feed Equipment	1,000
Blowdown Equipment	1,050
System Control Equipment	23,000
Data Acquisition System	81,000
Total Direct Costs	\$1,663,230
Construction Overhead and Expenses	\$57,850
Design and Engineering	20,450
Total Indirect Costs	\$78,300
Contingency	0
Fee	0
Land Acquisition	0
Interest and Escalation	0
Total Costs	\$1,741,530

Table 2

Projected Operating, Maintenance,
Property Tax and Insurance Costs.

<u>Item</u>		
Routine Maintenance		
collector cleaning		\$ 1,750/yr.
mechanical equipment		437
Periodic Maintenance		
collectors (pylon painting and reflective film replacement)		4,437
mechanical equipment (heat exchangers tube bundles)		<u>1,563</u>
Subtotal		\$ 8,187
Operating Costs		
personnel and material		\$ 860
parasitic power		<u>2,220</u>
Subtotal		\$ 3,080
Insurance		\$ 1,000
Property Tax		<u>10,290</u>
Total OMPI		<u>\$21,557/yr.</u>

Table 3
Projected Net Annual Energy

Item

Available Tax Incentives	Fed. - 15% solar credit - 10% invest credit State - 10% solar credit
Total Land Area	2.3 acres (approx)
Number of collector Module	303
Net Area of Single Module	140 ft ²
System Lifetime	20 yrs.
Salvage Value in yr. 20	0
System Energy Storage	0 BTU
Number of Days Plant Can Use	
Solar Generated Steam	305 days/yr.
Unit Price of Fuel Displaced by Solar System	\$4.07/MBTU
Inflation Rate	6%
Fuel Escalation Rate	8%
Energy Breakdown*	
- Gross energy collected	10.47 x 10 ³ MBTU/YR
- Piping Losses	461.8 MBTU/YR
- Start-up and shut-down losses	1164.4 MBTU/YR
- Freeze protection losses	0
- Storage System Losses	0
- Net solar energy delivered to process	8.84 x 10 ³ MBTU/YR
System Parasitic Power Requirements	82.4 MBTU/YR

*Based on 365 operating days per year. Adjust by 305/365 for HCPC operation.

Case I

Under the assumption that the entire projected project cost of \$1.741 million represents an owner's unamortized investment, an internal, after-tax rate of return or R^* was derived graphically utilizing a recast version of equation (9) from UCRL-52814, viz:

$$\frac{M(R^*)}{\mathcal{E}} \cdot \frac{I}{E_s} - P_{fo} \cdot LF(R^*) = 0 \quad (1)$$

$$\frac{M(R^*)}{\mathcal{E}} \cdot \frac{I}{E_s} = P_{fo} \cdot LF(R^*) \quad (2)$$

The value of R^* represents the internal rate of return where the relevant levelized fossil fuel price ($P_{fo} \cdot LF$) equals the levelized price of the solar energy provided by the investment $\frac{MI}{\mathcal{E}E_s}$ or P_s . These values were developed in the following fashion:

Levelized fossil fuel price: $R^* = P_{fo} \cdot Lf(R)$ was plotted (Figure 1) for $R = .10, .15$ and $.20$. Values of the leveling factor $LF(R)$ were developed assuming a constant rate of fuel price escalation (g^1) using equation (7) from UCRL-52814; presented here as equation (3) and (4).

$$Lf = \frac{CRF(R, N)}{CRF(R^{1+g^1}, N)} \quad (3)$$

$$Lf = CRF(R, N) \frac{1 + g^1}{R - g^1} \left[1 - \left(\frac{1 + g^1}{1 + R} \right)^N \right] \quad (4)$$

The value of P_{fo} was derived based on HCPC current number 2 fuel oil cost of \$25.22/barrel.

Levelized solar energy price (P_s): The equation $P_s = \frac{MI}{\mathcal{E}E_s}$ was plotted for $R = .10, .15$, and $.20$. The three values for the required revenues per total investment dollar or M-factor were developed using equation (1) from UCRL-52814:

$$M = \frac{C_s}{I} = \text{OMPI} + \frac{\text{CRF}(R, N)}{1 - r} \left[(1 - f) + f(1 - r) \frac{\text{CRF}(r, LP)}{\text{CRF}(R, LP)} + \right. \\ \left. \frac{f^r}{1 + r} \cdot \frac{\text{CRF}(r, LP) - r}{\text{CRF}(R, LP)} - \frac{TC}{1 + R} - r \cdot \text{DEP} + \left(\frac{1 + g}{1 + R} \right)^{t_c} \right. \\ \left. m(t_c) \cdot (1 - TC - r \cdot \text{DEP}) - \left(\frac{1 + g}{1 + R} \right)^N S \right] \quad (5)$$

Under the Case I assumption that I is the projected project cost of \$1.741 million, including DOE and State of Hawaii funds, plus HCPC cost sharing, a slightly negative R* was derived.

Case II

Under the assumption that the solar investment consists only of the HCPC equity investment (\$140,000), a positive R* of 21 percent was derived and is presented graphically in Figure 1. The entire solar investment level assumed for purposes of Case II analysis consists of equity funds.

The value of ξ , the solar effectiveness factor, was derived from data on the conventional fuel oil energy system to be supplanted by the proposed solar thermal system. Included in the assumptions used for developing values for M is that a major replacement of solar system components is necessary in year 10, comparable to some 25 percent of projected project cost.

The levelized fossil fuel prices (P_{fo} , Lf) and levelized solar energy prices (P_s) for both Cases I and II are presented in Table IV.

Figure I
Internal Rate of Return
Case II

Table 4
Levelized Fossil and Solar Energy Prices*
(Cases I and II)

	<u>P_s</u>	<u>P_{fo}.LF</u>	<u>M</u>
<u>Case I</u>			
R = .10	\$24.97	\$7.94	.136
R = .15	34.33	7.16	.187
R = .20	45.34	6.59	.247
<u>Case II</u>			
R = .10	\$ 5.15	\$7.93	.348
R = .15	5.74	7.16	.388
R = .20	6.40	6.59	.433

*All prices in dollars per million Btu's.

PAYBACK PERIOD

Case I

To permit inclusion of a fuel escalation rate in payback calculation which differs from the general inflation rate, equation (6) was utilized to calculate the payback period for the SIPH project. This equation is variation (T₃) presented in Appendix A ("Determination of Payback Period") of publication UCRL-52814.

$$1 - TC = T_p \cdot \frac{r}{N} + \frac{(1 - r)\epsilon E_s P_{fo}}{I} \sum_{t=1}^{T_p} (1 + g^1)^t - (1 - r) OMPI_o \sum_{t=1}^{T_p} (1 + g)^t \quad (6)$$

Using system values presented earlier, in particular $g = 6\%$, $g^1 = 8\%$, $OMPI_o = .011$, $P_{fo} = \$4.07/\text{million Btu's}$, and $I = \$1.741 \text{ million}$, a lengthy payback period for the proposed project of 19.5 years was derived. A plot of this equation for Case I is presented in Figure II.

Case II

A similar calculation using differing variables applicable to Case II ($OMPI_o = .141$, $I = \$140,000$) yield a much shorter payback period ($T_p = T_n$) of 6.5 years. Figure III presents this calculation graphically.

FOSSIL FUEL SAVINGS

With a value of 9.46 billion Btu's for the variables (ϵE_c), annual projected fossil fuel savings are 9,460 MBtu or 1,526 barrels of oil equivalent (with 6.2 MBtu's per barrel).

Figure II
Payback Analysis
Case I

Figure III
Payback Calculations
Case II