THE IMPACT ON PHOTOVOLTAIC WORTH OF UTILITY RATE AND REFORM AND OF SPECIFIC MARKET, FINANCIAL, AND POLICY VARIABLES

A Commercial/Industrial/Institutional Sector Analysis

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Abstract

This work provides an assessment of the economic outlook for photovoltaic systems in the commercial, industrial and institutional sectors in the year 1986. We first summarize the expected cost and performance goals for photovoltaic technology, and then estimate aspects of the market and financial environment pertinent to assessment of a PV investment beginning in that year. Our analysis covers three geographic regions of the U.S., characterized by Boston, Madison, and Phoenix, and examines PV economic performance when operating against five different means for establishing utility backup rates. In addition, we assess the potential of a photovoltaic array to reduce a firm's monthly capacity charge.

Our results break down as follows. For our initial analysis, utilizing a base case set of financial parameters, we find that a peak-shaving credit (reduction in monthly capacity charge) attributed to a photovoltaic array can be significant, but not so much as to prove photovoltaics economic in the commercial sector in 1986. The institutional sector will find photovoltaics profitable if they discount at rates reflective of the returns on long-term government bonds. In our extended analysis, we perform sensitivity studies and examine the impact of combinations of government incentives. We find that photovoltaics will just turn economic in 1986 for the commercial/industrial sector given an optimistic set of incentive policies. We finalize our analysis with an important list of caveats to our conclusions.

ACKNOWLEDGEMENTS

We would like to acknowledge the generous cooperation of three electric utilities for their giving of time and resource in supplying M.I.T. with customer load profile data. The utilities and their representatives include Roger Currier of the New England Electric System, Jim Watkins and Marilyn George of the Salt River Project, and Mike Anderson, Ron Frank, and John Walker of Wisconsin Power and Light.

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I. Introduction

The United States Department of Energy is currently engaged in an effort to make photovoltaic energy conversion systems competitive with conventional means of obtaining electricity as early as the mid-1980's. This work examines the investment worth of photovoltaic systems for the commercial, industrial, and institutional sectors utilizing 1986 projected costs and technology. Previous studies have determined that, due primarily to the investment finance environment, photovoltaic technology will likely be accepted in order of 1) residential, 2) institutional, commercial and industrial, and 3) utility applications. The cost goals established for 1986 technology are expected to prove photovoltaic systems competitive in certain segments of the residential sector by that year. The work included in this paper demonstrates that under most market/finance scenarios for the commercial, industrial and institutional sectors*, photovoltaic system costs will need to be

*From here on, "commercial" will be taken to mean commercial and industrial while "institutional" will mean just that. "Firms" will be taken to mean all three.

considerably lower in 1986 than the DOE goal in order to be competitive with utility supplied electricity.

This paper makes use of the OESYS model, later described, designed for policy analysis of non-conventional energy applications. Previous papers by the authors demonstrate the use of this model for other applications. [See (1), (2), (3), (4)].

I.1 Scope and Objectives

This paper first establishes a base-case set of economic assumptions that describe the financial behavior observed for firms in the United States. We then establish for each of three locations in the U.S. (Boston, Madison, and Phoenix), five separate utility rate structures based upon alternative means of costing electricity production. Our physical model performs an hour by hour matching of photovoltaic output with a firm's electrical demand, with the utility as both a backup source and a purchaser of excess photovoltaic-derived electricity. No on-site storage means was modeled in this analysis. The firm's electrical demand is taken from customer load profiles obtained directly from electric utilities in each of the three geographic locales. The photovoltaic model utilized meteorological data for precisely the same years as the load data* and thus an hour by hour matching of load (often weather-dependent) with photovoltaic output was possible. This latter feature is crucial to our assessment of the credit allowed to photovoltaic arrays for reducing a firms peak demand (and, hence,

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*This is true for all cases except one-half year (the 1979 portion) of the Boston runs. Here, no MET data were available and a 1978 weather year was filled in.

capacity charge) each month. An assessment of the peak-shaving characteristics of a photovoltaic array is included as part of the base-case analysis.

Our base-case study concludes that photovoltaics will require some special forms of incentives to be competitive in 1986. For this reason, we undertake an extended analysis to determine those market/finance parameters to which PV project financing is most sensitive. These parameters include the firm's expected rate of return, the proportion of debt to equity financing, interest costs, the firm's tax rate, the escalation rate of electricity prices, the inflation rate, the price of oil, allowed investment tax credits, and depreciation allowances. This analysis is concluded with a search for specific government policies under which firms would likely invest in photovoltaics by 1986.

I.2 Analysis Methodology

PHYSICAL MODEL

Both physical/operational and economic performance modeling were carried out on the Optimal Energy Systems Simulator (OESYS).* OESYS performs hour-by-hour energy transfer accounting between pre-defined generation and load profiles, and can handle both conventional and nonconventional utility rate-setting practices. The program structure is depicted in Figure 1-1. OESYS is documented, and currently in the public domain. [See (4)].

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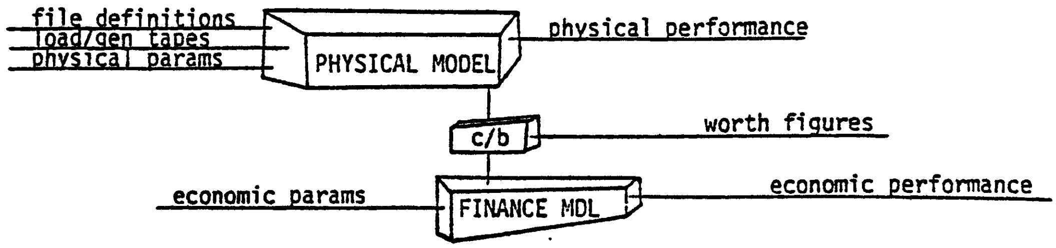
*Developed by T.L. Dinwoodie of the MIT Energy Laboratory.



OESYS Schematic

Figure 1-1

The Finance Method

The commercial/industrial/institutional finance model utilized by OESYS was designed to simulate the significant components of cash flow resulting from a firm's investment. The methodology is modeled after Meyers (5) and is depicted in figure 1-2. Here, the discount factors include a risk free (interest rate) component and that component which reflects the average riskiness of a firm's investments. The discount rate is then obtained by a weighted average, given by

$$DR = (DEBT) \times r_b + (1 - DEBT) \times r_e \quad . \tag{1-1}$$

where,

DR = weighted average discount rate

DEBT = debt to total value ratio

r_b = interest rate on bonds

r_e = rate of return on equity.

It is seen that all tax and finance flows related to debt-financing are discounted at the lower, risk-free rate, while costs and benefits related directly to the project are discounted at the higher rate.

Also in figure 1-2, the known and unknown portions of the initial capital investment are separated in order that the breakeven capital cost of the unknown portion, I^u, can be readily computed. In order to compute the system breakeven capital cost (BECC), the capital investment variable is solved for and hence only the first three terms on the right side of the equation were utilized. [See reference (1)]. The system BECC did assume knowledge of the operating and maintenance costs (hence, truly a breakeven capital cost), which showed up each year as a subtraction from that year's benefits. The photovoltaic (module) BECC assumed knowledge of all operation and maintenance costs, plus balance of system costs (structures, wiring, invertor, etc.). The latter became the I^k portion in the formulation of figure 1-2. Finally, all costs are assumed when computing net benefits (or profit), internal rate of return, and levelized energy cost figures, and hence the first three terms on the right side in figure 1-2 are ignored.

II. Modeling Conditions

II.1 System Costs Description

In each of the analysis where a known capital costs portion was assumed, those costs were set at the 1986 DOE target figure and then varied to reflect a lower and upper bound condition. Thus, all figures in this report labeled "medium" costs reflect the 1986 cost goal. The DOE cost goal for the photovoltaic module component is \$.70/Wp, set for the end of 1986. This analysis examined a January 1, 1986 construction start year with a one-year construction lag and should, therefore,

Figure 1-2

COMMERCIAL/INDUSTRIAL/INSTITUTIONAL FINANCE METHOD

$$\sum_{t=1}^{L} \frac{(1 - CT) \cdot (Y^t \cdot B_t - OP_t) \cdot \alpha^t}{(1 + r_i)^t \cdot \alpha^t} = \beta^{t_o} \cdot I^u \cdot (1 - ITC - DEBT)$$

$$+ \sum_{t=1}^{L} \frac{(1 - CT) \cdot r_b \cdot DEBT \cdot I^u \cdot \beta^{t_o} - CT \cdot D_t^u \cdot I^u \cdot \beta^{t_o}}{(1 + r_f)^t \cdot \alpha^t}$$

$$+ \frac{DEBT \cdot I^u \cdot \beta^{t_o}}{(1 + r_f)^L \alpha^L}$$

$$+ B^{t_o} \cdot I^k \cdot (-1 + ITC + DEBT)$$

$$+ \sum_{t=1}^{L} \frac{(1 - CT) \cdot r_b \cdot DEBT \cdot I^k \cdot \beta^{t_o} - CT \cdot D_t^k \cdot \beta^{t_o}}{(1 + r_f)^t \cdot \alpha^t}$$

$$+ \frac{DEBT \cdot I^k \cdot \beta^{t_o}}{(1 + r_f)^L \alpha^L}$$

where:

L = life of the project

α^t = general price inflator in year t computed with respect to the base year, i.e.,

$$\alpha^t = \prod_{j=t_b}^{t} (1 + \alpha_j)$$

α_j = general price inflator in year j

t_b = base year

β^{t_o} = escalation in capital costs in year t_o with respect to the base year, i.e.,

$$\beta^{t_o} = \prod_{j=t_b}^{t_o} (1 + \beta_j)$$

t_o = year of investment

β_j = escalation in capital costs in year j

γ^t = real price escalator applied to project benefits computed from the base year to the year of investment, i.e.,

$$\gamma^t = \prod_{j=t_b}^{t} (1 + \gamma_j)$$

γ_j = real price escalator applied to benefits in year j

B_t = energy savings in year t

CT = corporate tax rate

DEBT = the ratio of the firm's debt to debt plus equity

D_t^k = depreciation fraction in year t computed for the known portion of capital investment

D_t^u = depreciation in year t computed for the unknown portion of capital investment

I^k = known portion of the initial investment

I^u = unknown portion of the initial investment

ITC = investment tax credit

OP_t = operation and maintenance costs in year t

r_b = nominal bond interest rate computed as

$$r_b = -1 + \sqrt[L]{\prod_{t=1}^{L} (1 + r_f)(1 + \alpha_t)}$$

r_f = real risk-free rate of return

r_i = real rate of return which reflects the riskiness of the investment class.

take the cost goal for midyear, or June 1986. However, it was decided to utilize the \$.70/Wp figure in order to remain consistent with virtually all similar studies.

The assumed balance of system costs are expected costs for 1986 technology and are broken down as shown in figure 2-1. These costs are region-dependent due to the effect of wind loading on the structural requirement. The lower and upper bound cost estimates were made by multiplying the photovolataic module figure by 0.5 and 1.5 and the balance of system figure by 0.8 and 1.2.

FIGURE 2-1

BALANCE OF SYSTEM SUMMARY (1980 $)

Construction Year BOS Costs

	Phoenix	Madison	Boston
Structure Costs (1)	$45.37/$m_2$	55.75	65.97
Lighting Protection (2)	$ 6.00/m_2	6.00	6.00
Field Wiring (2)	$ 6.00/m_2	6.00	6.00
Warranty (non-government mandated) (3)	$ 5.00/m_2	5.00	5.00
Power Conditioning (4)	$15.00/$m_2$	15.00	15.00
TOTAL*	$77.37/$m_2$	87.75	97.97

Annual BOS Costs

	Phoenix	Madison	Boston
Insurance (5)	$5.00/$m_2$	5.00	5.00
Maintenance (6)	$1.50/$m_2$	1.50	1.50

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(1) Avg. Site Prep.
Surveying and Location Marking
Earthwork for Foundations
Supply and Fabrication of Materials
Installation of Support Structures
Field Construction Costs
SAND79-7002
Bechtel Nat'l. Inc., Nov. 1979
Sandia Vol's I, II

(2) Post, 14.N (Sandia)
JPL/Gatlinburg Proceedings
May, 1979
Conf-79-595

(3) Calculated to be 5¢/Wp
in construction year;
Cox, C.H., et. al., MIT/LL
Jan., 1980

(4) Based on $.15/Wp 1986
Price Goals. Includes power inverter, max power tracker, automatic start/shut, and controls

(5) Telephone conversation with Local Insurance Agent. Price includes cost of additional insurance to cover fire, lightning, windstorms, etc.

(6) Based on Mead, Nebraska Experiment

*These figures require à 15% distribution and 15% contractor markup markup

II.2 Utility Rate Structures

A variety of utility rates were estimated based on EPRI synthetic utility characteristics for each of the three regions considered*, and are depicted in figure 2-2. The set of rates labeled "embedded" are merely estimated from current rate-setting practices, allowing the utility to cover its taxes, recover its fuel and operating costs and to receive a fair and reasonable rate on its undepreciated capital stock. Rates labeled "marginal" are estimated by setting the cost of fuel to its 1980 level (although an escalation rate is applied each year thereafter) while computing a demand charge based upon the replacement value of the utility's operating capital. Both flat (constant) and time-varying (time of day) rates were estimated and are displayed. For the time of day rates, an energy charge is determined based upon the average plant fuel consumption during each time-of-day period. The fuel and operating revenues are then held constant while a 3:1 and 6:1 peak to base rate differential is computed. The latter rates are designed solely to answer the question of whether the return to photovoltaic investments will improve with a wider price differential. They are not the result of utilizing a consistent methodology.

In this analysis, capacity rates are charged against the industrial plant's peak 15-minute consumption during the peaking periods in each month. Although this is the conventional means of calculating capacity charge, experiments are currently underway which, for example, calculate capacity charges based on a firm's demand at the time of system peak. In this analysis, however, the credit allowed to the PV array was calculated

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*These rates result from use of ERATES, The Electricity Rate Setting Model, developed by Alan J. Cox of the M.I.T. Energy Laboratory.

FIGURE 2-2

UTILITY RATE STRUCTURES

Phoenix

		Energy	Capacity	Buyback
FLAT EMBEDDED		30.4 m/kwh	$3.27/kW/mo	.85
FLAT MARGINAL		30.4 m/kwh	$7.67/kW/mo	.85
TOD EMBEDDED	Peak	31.3 m/kwh	$3.27/kW/mo	
	Base	29.5 m/kwh		
TOD EMBEDDED (3:1)	Peak	44.77	$3.27/kW/mo	.85
	Base	14.9227		
TOD EMBEDDED (6:1)	Peak	50.872	$3.27/kW/mo	.85
	Base	8.4785		

Peak period: 4/1 to 10/31 11:00 a.m. to 8:00 p.m.
Monday-Friday

Boston

		Energy	Capacity	Buyback
FLAT EMBEDDED		35.4 m/kwh	$5.12/kW/mo	.85
FLAT MARGINAL		35.4 m/kwh	$7.87/kW/mo	.85
TOD EMBEDDED	Peak	37.1 m/kwh	$5.12/kW/mo	.85
	Base	35.3 m/kwh		
TOD EMBEDDED (3:1)	Peak	98.209	$5.12/kW/mo	.85
	Base	32.735		
TOD EMBEDDED (6:1)	Peak	178.46	$5.12/kW/mo	.85
	Base	29.74		

Peak Period: 1:00 p.m. - 3:00 p.m.
Monday-Friday All Year

Madison

		Energy	Capacity	Buyback
FLAT EMBEDDED		35.4 m/kwh	$5.12/kW/mo	.85
FLAT MARGINAL		35.4 m/kwh	$7.87/kW/mo	.85
TOD EMBEDDED	Peak	37.1 m/kwh	$5.12/kW/mo	.85
	Base	35.3 m/kwh		
TOD EMBEDDED (3:1)	Peak	98.209	$5.12/kW/mo	.85
	Base	32.735		
TOD EMBEDDED (6:1)	Peak	178.46	$5.12/kW/mo	.85
	Base	29.74		

Peak Period: 1:00 p.m. - 3:00 p.m.
Monday-Friday All Year

FIGURE 2-3

BASE CASE FINANCIAL PARAMETERS

	Commercial/Industrial	Institutional A	Institutional B
Discount Rate (real, after tax)	5.7%	10%	2%
Corp. Tax	.46	0.	
Bond Interest Rate (real)	3%	2%	
Debt/Value Ratio	.4	1.0	
Depreciation	Sum of the Years	Sum of the Years	
Investment Tax Credit on PV Array	10%	0%	
Investment Tax Credit on BOS	10%	0%	
Construction Start	1986	1986	
System Life	20 years	20 years	
Electricity Price Inflator	5%/year in 1980 and declining linearly to 0% in 2010		

simply by taking the difference between the total (non-PV) peak load each month and the net peak load (actual peak load seen by the utility after PV generation is added) in that same month.

II.3 Finance Parameters

A summary of parameters used for the base-case financial analysis is presented in figure 2-3. All figures shown here, with the exception of the system life, were later varied in the sensitivity studies. Two separate discount rates were utilized in the institutional analysis. The higher (10 percent real, after tax) rate is an estimate of the real opportunity cost of public funds, as reported by Hanke and Anwyll (3). As such, it is representative of a rate used for social project appraisal. The lower (2 percent) rate is representative of financial yields on long-term government securities. This rate is more representative of the market rate at which private institutional analysis is likely to actually take place. Of course, ideally, there should be no difference between the commercial and institutional discount rates, but this is not so due primarily to effects stemming from introduction of the tax wedge. The assumed private sector opportunity cost of capital of 5.7 percent is an average real rate of return on private investments, after taxes.*

II.4 SIC Description

Hourly kilowatt-hour load profile curves were obtained for each commercial, industrial, and institutional firm used in this analysis. Firms were selected to represent a cross-section of activities indigenous

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*U.S. Office of Management and Budget, 1972, as reported in (3).

FIGURE 2-4

DESCRIPTION OF FIRMS

(all asterisk firms were subjected to institutional methods of finance)

MADISON

FIRM	SIC	AVG LOAD (kwh/h)	PEAK LOAD (kwh/h)	DATE OF YEAR PEAK	DAY HOUR OF YEAR PEAK
Grocery Store	5411	367	536	7/12	16:00
School*	8211	71	330	11/23	11:00
Manufacturing	3500	269	601	6/21	14:00
Hospital*	8062	143	257	8/16	9:00
Department Store	5311	182	457	7/20	21:00
Waste Water Treatment Plant*	4952	320	457	12/22	11:00

BOSTON

	SIC	AVG LOAD (kwh/h)	PEAK LOAD (kwh/h)	DATE OF YEAR PEAK	DAY HOUR OF YEAR PEAK
Grocery Store	5411	400	730	8/10	20:00
School*	8211	311	772	5/10	10:00
Manufacturing	3500	784	1357	4/26	12:00
Hospital*	8062	1198	3506	10/3	8:00
Department Store	5311	427	1083	9/21	20:00
Paper Mill	2621	5040	8370	2/12	16:00

PHOENIX

	SIC	AVG LOAD (kwh/h)	PEAK LOAD (kwh/h)	DATE OF YEAR PEAK	DAY HOUR OF YEAR PEAK
Grocery Store	5411	8	24	10/6	12:00
School*	8211	27	140	1/5	11:00
Manufacturing	3500	62	125	7/6	15:00
Gas/Service Station	5540	10	31	1/12	19:00
Savings Bank	6020	54	67	7/10	18:00
Public Administration*	9100	24	32	8/21	21:00

to each of the Phoenix, Boston, and Madison locales. A listing of each firm's basic profile characteristics is presented in figure 2-4. Special note should be taken of the hour of the day in which the peak load occurs for each firm. The hour shown was found to be roughly characteristic of the firm's load profile throughout the year and correlates well with the effectiveness of credits allowed to the PV array for displacing peak demand. This issue is further explored in the next section. It must be emphasized that the load profiles used contain historical data figures. Hence, this study suffers from the assumption that there will be no shifts in demand patterns due to such technologies as load management.

For purposes of comparison of load profiles across the regions modeled, three similar firms were selected for each city. These include a grocery store, a school, and some form of manufacturing plant. A hospital and a department store were also types of firms common to Boston and Madison.

III. Preliminary User Worth Study

III.1 Caveats on Performance Evaluation

The objective of the base case analysis was to determine whether those prices required to make photovoltaic systems economic fell below the DOE cost goals for a conservative set of financial assumptions. To satisfy this objective, we computed the system and module breakeven capital costs for the various firms under each set of utility rate assumptions. It turns out that, when estimating these figures, it is sufficient to model an undersized array (an array with peak output sized considerably lower than the firm's average demand) to determine the maximum break-even figures allowable. This fact is explained with the assistance of curve A in figure 3-1a. Here we modeled the grocery store in Madison for the allowed system costs when the utility computed a flat electrical rate based on marginal costing methods, and no credit was allowed the PV array for peak shaving. Since the output of the array is linearly related to its size, the system breakeven capital cost (an average figure) is constant until the array output begins to exceed the firm's demand. At this point, the benefits to excess PV generation are some fraction (the utility buy-back rate) of the value assessed when satisfying load directly. The PV module breakeven costs show the same relationship with array size, as depicted in figure 3-1b. This occurs for the large applications characteristic of commercial firms since the balance of system costs (all but the PV module) will scale linearly with array size (since fixed costs are negligible).

As a result, we have chosen for the base case analysis to examine the financial prospects for undersized arrays for each firm. When no value is ascribed to PV load matching (zero capacity credit allowed to the PV array) the PV and system breakeven figures for an undersized array will be correlated solely to the local solar insolation and local utility rate setting strategies. This is true since all PV output is valued automatically at 100 percent of the utility sell rate (since it will always go to load) and therefore a firm's profile characteristics will show no effect on the worth of the PV system.

On the other hand, the benefits attributed to the peak shaving aspects of photovoltaic generation are directly related to a firm's individual load profile. A comparison of the system and module breakeven figures when such a credit is allowed versus the previous case is a

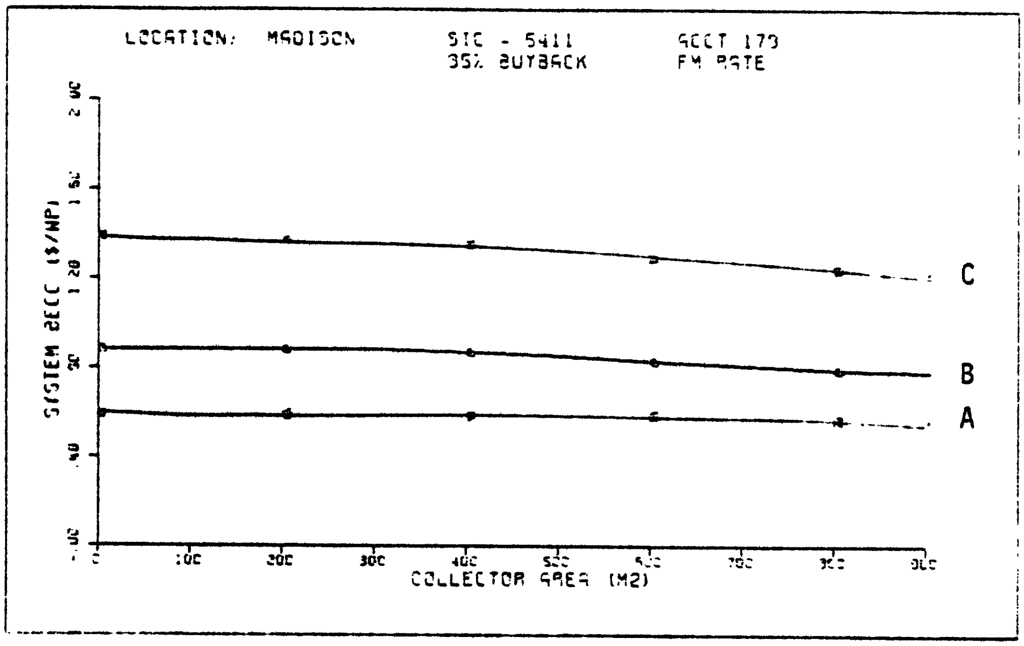

Figure 3-1a
System Breakeven Capital Cost for a Madison Grocery Store

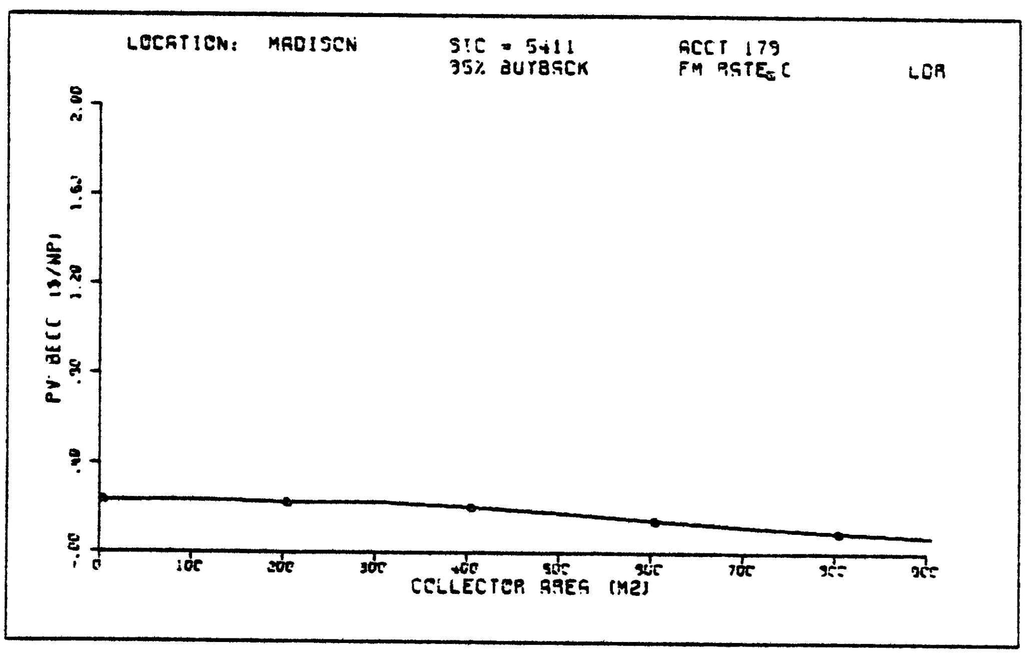

Figure 3-1b
PV Breakeven Capital Cost for a Madison Grocery Store

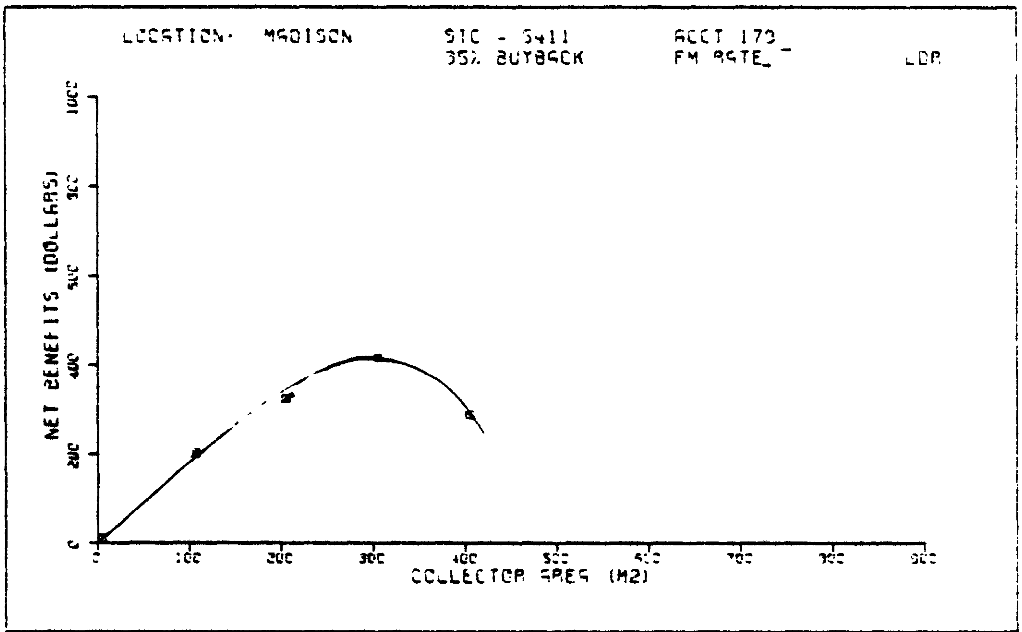

Figure 3-2

Net Benefits vs. Array Size for a Madison Grocery Store

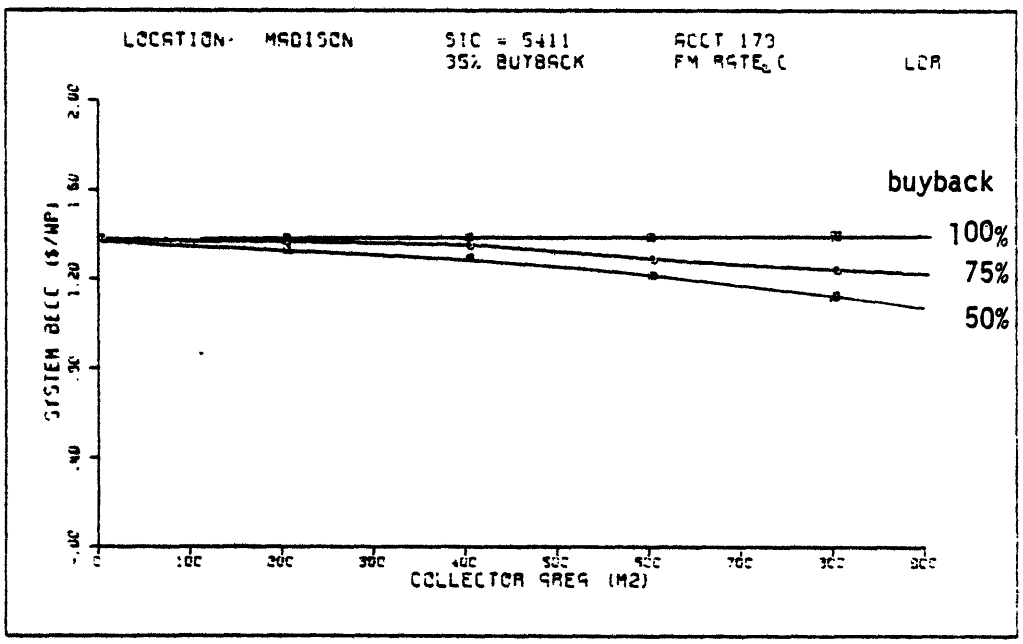

Figure 3-3

Effect of Utility Buyback Rate on System Breakeven Capital Cost direct measure of the impact of PV load matching on investment worth.* Comparison of figures A and B in figure 3-1a relates this result. Here we have calculated the difference between total peak load seen each month without the array and the net peak load seen after the array output is subtracted from the normal load curve. This difference is then multiplied by the capacity charge ($/kw/month) and credited to the photovoltaic array.

Since none of the conditions modeled for curves A and B of figure 3-1 resulted in breakeven cost figures above the 1986 targets, a condition was modeled using a lowered expected rate of return in order that, at least for the lower set of cost asumptions, positive net benefits would accrue to the array. This condition results in the C curve in figure 3-1 and the resulting net benefits curve is shown in figure 3-2. In this curve a peak results since the benefits figure is not normalized to the size of the array and since decreasing benefits accrue (for less than 100 percent buyback) per kilowatt-hour produced once the array is sufficiently large to generate in excess of the firm's demand. Finally, figure 3-3 illustrates the effect of utility buyback rate upon the maximum allowable costs. It is seen here that an undersized array is insensitive to this market parameter as well.

III.2 Base Case Analysis With An Assessment of A Peak-Shaving Credit

The preceding discussion illustrated why, when seeking the highest possible breakeven costs for a given firm, it is sufficient to model an

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*This assumes that no other effort is made to modify the firm's load. See the discussion of section V.

undersized array. We have also shown why an estimate of the capacity credit is important for our purposes, and how that credit is strictly firm-dependent. Figure 3-4 presents the maximum breakeven capital cost figures resulting from an undersized array in each region when operating against each utility rate structure discussed in section II.2. The first three columns of figure 3-4a present the results utilizing commercial/industrial financial parameters while the final three columns present the institutional analysis at the social-valued discount rate representative of the opportunity cost of public funds, described in section II.3. Figure 3-4b presents the results after setting the discount rate to the lower (2 percent) rate, more nearly representative of the decision rate used by institutional firms.

It is shown that the institutional means of financing, where no taxes are levied and the low discount rate is applied, proves more favorable to a photovoltaic investment than does the commercial method. It is also shown that time-of-day rates improve the economic outlook for PV in both Boston and Madison, but harms photovoltaic economics in Phoenix. A review of the rate structures of figure 2-2 reveal that these results owe to the short differential pricing period, extending only from April through October. The lower base rate applies in all other months. The Boston and Madison base rates are only marginally lower than the computed flat rates, and thus, even the short peak-price period shown offers an improvement in photovoltaic worth. Comparing results across geographic regions, we see that the higher Phoenix insolation contributes strongly to the attractivenes of PV in that region as insolation effects override the lower flat rate applied in this location.

FIGURE 3-4a

BASE CASE FINANCIAL ANALYSIS

MAXIMUM BREAKEVEN CAPITAL COSTS WITH NO PEAK-SHAVING CREDIT (1980 DOLLARS)

System BECC/ PV BECC	PV Cost*	Commercial/Industrial: Boston	Commercial/Industrial: Madison	Commercial/Industrial: Phoenix	Institutional- A: Boston	Institutional- A: Madison	Institutional- A: Phoenix
Flat Embedded	L	.63/-.40	.61/-.31	.80/0	.48/-.58	.43/-.49	.45/-.36
	M	.60/-.68	.58/-.56	.78/-.23	.42/-.86	.41/-.74	.43/-.58
	H	.57/-.97	.55/-.82	.75/-.46	.40/-1.13	.39/-.98	.41/-.80
Flat Marginal	L	.63/-.40	.61/-.31	.80/0	.44/-.58	.43/-.49	.45/-.36
	M	.60/-.68	.58/-.56	.78/-.23	.42/-.86	.41/-.74	.43/-.58
	H	.57/-.97	.55/-.82	.75/-.46	.40/-1.13	.39/-.98	.41/-.80
TOD Embedded	L	.63/-.39	.62/-.30	.79/-.02	.45/-.58	.43/-.48	.44/-.37
	M	.60/-.68	.59/-.56	.76/-.25	.43/-.86	.41/-.73	.42/-.59
	H	.58/-.96	.56/-.82	.74/-.48	.41/-1.13	.40/-.98	.40/-.81
TOD Embedded (3:1)	L	.82/-.21	.81/-.11	.56/-.25	.57/-.45	.57/-.35	.31/-.50
	M	.79/-.49	.78/-.37	.53/-.48	.55/-.73	.55/-.60	.29/-.72
	H	.76/-.78	.75/-.62	.50/-.71	.53/-1.00	.53/-.85	.27/-.95
TOD Embedded (6:1)	L	1.07/.04	1.07/.15	.46/-.35	.75/-.28	.75/-.17	.22/-.61
	M	1.04/-.24	1.04/-.11	.43/-.58	.73/-.55	.73/-.42	.20/-.78
	H	1.01/-.53	1.01/-.36	.40/-.81	.71/-.83	.71/-.67	.18/-.94

*PV Cost Legend: L = low, M = DOE objective, H = high

FIGURE 3-4b

BASE CASE FINANCIAL ANALYSIS

MAXIMUM BREAKEVEN CAPITAL COSTS WITH PEAK SHAVING CREDIT (1980$)

INSTITUTIONAL CASE B

System BECC / PV BECC	PV COST*	BOSTON	MADISON	PHOENIX
Flat Embedded	L	.96/-.06	.94/.02	.98/.17
	M	.92/-.36	.90/-.25	.94/-.07
	H	.88/-.66	.86/-.52	.90/-.32
Flat Marginal	L	.96/-.06	.94/.02	.98/.17
	M	.92/-.36	.90/-.25	.94/-.07
	H	.88/-.66	.86/-.52	.90/-.32
TOD Embedded	L	.97/-.05	.94/.03	.96/ .15
	M	.93/-.35	.90/-.24	.92/-.09
	H	.89/-.65	.86/-.51	.88/-.33
Tod Embedded (3:1)	L	1.24/.22	1.23/.31	.67/-.14
	M	1.20/-.08	1.19/.04	.63/-.33
	H	1.16/-.37	1.15/-.22	.59/-.62
TOD Embedded (6:1)	L	1.62/.59	1.62/.70	.53/-.28
	M	1.58/.30	1.58/.43	.49/-.53
	H	1.54/0.	1.54/.16	.45/-.77

*PV Cost Legend: L = low, M = DOE objective, H = high

**Institutional financial parameters were used.

FIGURE 3-5
BASE CASE FINANCIAL ANALYSIS
MAXIMUM BREAKEVEN CAPITAL COSTS WITH PEAK SHAVING CREDIT
BOSTON

System BECC/ PV BECC	PV COST*	GROCERY STORE SIC = 5411	SCHOOL ** 8211	MANUFACTURING 3500	HOSPITAL ** 8062	DEPARTMENT STORE 5311	PAPER MILL 2621
Flat Embedded	L	.63/-.39	1.49/.47	.96/-.06	1.51/.49	.63/-.40	.96/-.16
	M	.60/-.68	1.43/.17	.93/-.35	1.47/.19	.60/-.68	.83/-.45
	H	.57/-.97	1.41/-.13	.90/-.64	1.43/-.11	.57/-.97	.80/-.73
Flat Marginal	L	.63/-.29	1.79/.76	1.14/.11	1.81/.79	.63/-.40	.99/-.04
	M	.60/-.68	1.75/.47	1.11/-.17	1.77/.49	.60/-.68	.96/-.32
	H	.57/-.97	1.71/.17	1.08/-.46	1.73/.19	.57/-.97	.93/-.61
TOD Embedded	L	.63/-.39	1.50/.48	.96/-.06	1.52/.49	.63/-.39	
	M	.61/-.68	1.46/.18	.93/-.35	1.47/.19	.60/-.68	.87/-.16
	H	.58/-.96	1.42/-.12	.90/-.63			.81/-.73
TOD Embedded (3:1)	L	.82/-.21	1.77/.75	1.15/.12	1.79/.76	.82/-.21	1.05/.03
	M	.79/-.49	1.73/.45	1.12/-.16	1.75/.47	.79/-.49	1.02/-.26
	H	.76/-.78	1.69/.15	1.09/-.45	1.70/.17	.76/-.78	.99/-.54
TOD Embedded (6:1)	L	1.07/.04	2.14/1.12	1.40/.37	2.16/1.13	1.07/.04	1.30/.28
	M	1.04/-.24	2.10/.82	1.37/.09	2.12/.84	1.04/-.24	1.27/-.01
	H	1.01/-.53	2.06/.52	1.34/-.20	2.07/.54	1.01/-.53	1.24/-.29

*PV Cost Legend: L = low, M = DOE objective, H = high
**Institutional financial parameters were used.

FIGURE 3-6
BASE CASE FINANCIAL ANALYSIS
MAXIMUM BREAKEVEN CAPITAL COSTS WITH PEAK SHAVING CREDIT
MADISON

System BECC PV BECC	PV COST*	GROCERY STORE SIC = 5411	SCHOOL ** 8211	MANUFACTURING 3500	HOSPITAL ** 8062	DEPARTMENT STORE 5311	WASTE WATER TREATMENT** 4952
Flat Embedded	L	.80/-.12	1.47/.55	.98/.06	1.26/.34	.63/-.29	1.22/.31
	M	.77/-.38	1.43/.28	.95/-.20	1.22/.07	.60/-.55	1.18/.03
	H	.74/-.63	1.39/.01	.92/-.46	1.18/-.20	.57/-.80	1.14/-.24
Flat Marginal	L	.90/-.02	1.77/.85	1.18/.26	1.44/.52	.64/-.28	1.39/.47
	M	.87/-.27	1.73/.58	1.15/0.00	1.40/.25	.61/-.53	1.35/.20
	H	.84/-.53	1.69/.31	1.12/-.26	1.36/-.02	.58/-.79	1.31/-.07
TOD Embedded	L	.80/-.11	1.48/.56	.98/.07	1.27/.35	.63/-.28	1.23/.31
	M	.78/-.37	1.44/.29	.95/-.19	1.23/.08	.61/-.54	1.19/.04
	H	.75/-.63	1.40/.02	.93/-.45	1.19/-.19	.58/-.80	1.15/-.23
Tod Embedded (3:1)	L	.99/.07	1.76/.84	1.17/.25	1.54/.62	.82/-.10	1.51/.59
	M	.96/-.18	1.71/.57	1.14/-0.00	1.50/.35	.79/-.35	1.47/.32
	H	.93/-.44	1.67/.30	1.11/-.26	1.46/.08	.77/-.61	1.43/.05
TOD Embedded (6:1)	L	1.24/.33	2.13/1.21	1.43/.51	1.92/1.00	1.08/.16	1.89/.97
	M	1.22/.07	2.09/.94	1.40/.25	1.87/.73	1.05/-.10	1.84/.70
	H	1.19/-.19	2.05/.67	1.37/-.01	1.83/.46	1.02/-.36	1.83/.46

*PV Cost Legend: L = low, M = DOE objective, H = high
**Institutional financial parameters were used.

FIGURE 3-7
BASE CASE FINANCIAL ANALYSIS
MAXIMUM BREAKEVEN CAPITAL COSTS WITH PEAK SHAVING CREDIT
PHOENIX

System BECC / PV BECC	PV COST*	GROCERY STORE SIC = 5411	SCHOOL ** 8211	MANUFACTURING 3500	GAS SERVICE STATION 5540	SAVINGS BANK 6020	PUBLIC ADMINISTRATION** 9100
Flat Embedded	L	.95/.14	1.14/.33	.95/.14	.79/-.02	.86/.08	1.00/.19
	M	.93/-.09	1.10/.09	.93/-.09	.76/-.25	.86/-.15	.96/-.05
	H	.90/-.32	1.06/.15	.90/-.32	.73/-.48	.83/-.38	.92/-.29
Flat Marginal	L	1.18/.37	1.59/.78	1.16/.35	.79/-.02	.99/.18	1.10/.30
	M	1.15/.14	1.55/.54	1.13/.12	.76/-.25	.96/-.05	1.06/.05
	H	1.12/-.09	1.51/.30	1.10/-.11	.73/-.48	.94/-.28	1.02/-.19
TOD Embedded	L	.94/.13	1.13/.32	.94/.13	.77/-.04	.87/.06	.86/.05
	M	.91/-.10	1.09/.08	.91/-.10	.75/-.27	.84/-.17	.82/-.19
	H	.88/-.33	1.05/-.17	.88/-.33	.72/-.50	.81/-.40	.78/-.43
Tod Embedded (3:1)	L	.72/-.09	.86/.05	.71/-.10	.54/-.27	.63/-.18	.69/-.12
	M	.69/-.32	.82/-.19	.68/-.33	.51/-.50	.60/-.41	.65/-.36
	H	.66/-.55	.78/-.44	.65/-.56	.48/-.73	.57/-.64	.61/-.60
TOD Embedded (6:1)	L	.62/-.19	.74/-.07	.61/-.20	.44/-.37	.52/-.28	.56/-.24
	M	.59/-.42	.70/-.31	.58/-.43	.41/-.60	.50/-.51	.52/-.49
	H	.56/-.65	.66/-.55	.55/-.66	.38/-.83	.47/-.74	.48/-.73

*PV Cost Legend: L = low, M = DOE objective, H = high
**Institutional financial parameters were used.

FIGURE 3-8
PEAK SHAVING EACH MONTH AS A FRACTION OF OUTPUT CAPACITY OF AN UNDERSIZED PHOTOVOLTAIC ARRAY* (kWh/h peak shaved/peak kWh/h capacity of array)

	MADISON						BOSTON**						PHOENIX					
	Grocery Store 5411	School 8211	Manufacturing 3500	Hospital 8062	Department Store 5311	Waste Water Treatment 4952	Grocery Store	School	Manufacturing	Hospital	Department Store	Paper Mill	Grocery Store	School	Manufacturing	Gas Service Station	Savings Bank	Public Administration
JAN	.552	.785	.254	.310	0	.423	0	.376	.663	.124	0	.272	.534	.413	.185	.012	.013	0
FEB	.462	.680	.652	.253	0	.796	.018	.584	.895	.800	0	0	.303	.298	.033	0	.330	0
MAR	.009	.950	.686	.649	0	.393	0	.588	.639	.768	0	.083	.303	.411	.153	.005	.149	0
APR	.212	.095	.417	.330	0	.593	0	.107	.833	.765	0	.062	.200	.704	.422	0	.313	0
MAY	.347	.545	.562	.535	0	.400	0	.797	.218	.696	0	.322	.440	.463	.175	0	.416	.023
JUNE	.354	.547	.602	.273	.134	.003	0	.304	.237	.781	0	.371	.100	.545	.336	0	.341	.266
JULY	.287	.494	.615	.318	0	.001	0	.388	.574	.540	.004	.575	.151	.666	.387	0	.048	.069
AUG	.084	.282	.336	.289	0	.133	0	.609	.506	.574	0	.738	.153	.500	.289	0	.328	0
SEPT	.168	.540	.116	.150	0	0	0	.628	.377	.506	0	.091	.560	.484	.320	0	0	.026
OCT	.029	.214	.849	.278	.200	.242	0	.726	.274	.115	0	.505	.416	.516	.430	0	0	.048
NOV	.247	.692	.769	.153	0	.097	0	.358	.097	.338	0	.105	.382	.211	.680	0	.064	.817
DEC	.219	.171	.081	.085	0	.237	0	.530	0	.104	0	.074	.322	.382	.240	0	.011	.084

*By "undersized" is meant that the peak output capacity of the array is below the average demand of the firm.

**January-July load profile figures for all Boston accounts were matched to a different weather-year.

Figures 3-5 through 3-7 illustrate how photovoltaic worth is enhanced due solely to the reduction in the firm's monthly capacity charge. In each of these figures, the institutional organizations were modeled using the case B discount rate, or that (lower) rate representative of the long-run returns on government securities. Figure 3-8 then characterizes, for each firm and month of operation, the total kilowatt-hours per hour displaced by the array on peak. These sum to the total yearly peak-shaving credit. It is seen that some applications, notably schools, show a large advantage resulting from PV load-matching. Hospitals, and grocery stores have good potential, but the magnitude of that potential is strictly firm dependent. Department stores which are open during the evening hours generally have their peaks during these hours and, hence, show little or no peak-shaving advantage. Importantly, we see that some applications allow PV system and module costs above the 1986 DOE objective. This is true for institutional agencies with moderate to high load matching potential, and which discount future costs and benefits at the low-risk rates.

III.3 Base Case Conclusions

The values in figures 3-4 through 3-8 allow the following set of conclusions regarding the investment worth of photovoltaics in 1986:

- Investment prospects for the institutional sector are favorable to the commercial sector when low discount rates are applied reflecting the interest rates allowed on long-term government bonds. When higher discount rates are applied, reflecting the opportunity cost of public funds, the economics of photovoltaics look much less favorable in this sector. (This assumes that zero tax rates and all debt financing is the norm in the institutional sector.)

- o Time-of-day rates can enhance photovoltaic worth substantially, but can also do it harm, depending upon the length of the time-of-day season, size of the peak to base differential, and the operating hours for peak rates.

- o Firms which exhibit moderate to high levels of load matching with PV array output may find the value of a PV system considerably enhanced if a credit is applied for capacity charge savings.

- o Institutional firms with the described set of financing criteria and with moderate to high levels of peak load-matching may find it profitable in 1986 to invest in photovoltaic systems when operating against specific utility rate-setting strategies. For example, schools in both the Boston and Madison areas would be wise to consider investment when a capacity charge is computed based on the replacement value of a utility's capital stock or while operating against time-of-day rate structures.

IV. Searching for a Likely Investment Scenario

In this section we examine the sensitivity of several figures of merit to variations in specific market and financial parameters. These figures result from various treatments of the net benefits figure of our cost/benefit analysis, and includes profit (net benefits), internal rate of return, and levelized energy costs and benefits, in addition to the system and module breakeven cost figures already shown. Throughout this analysis, we exhibit results using low, medium, and high cost projections as defined in setion II.1. The firm which we use in this example, unless otherwise stated, is a Madison commercial establishment with moderate peak-shaving potential. Specifically, we make use of the Madison grocery store characteristics as described in figures 2-4 and 3-8, ad we assume the array is optimally sized to 300 m^2 as suggested by figure 3-2.

Finally, all analysis were set against the flat marginal utility rate structure as described in figure 2-2, unless stated otherwise

IV.1 Single Parameter Sensitivity Analysis

The Expected Rate of Return

The real, after tax discount rate was varied between three and eleven percent for the Madison commercial application and the results are tabulated in figure 4-1. The risk-free discount factor (the bond interest rate) was held constant at 3 percent while the weighted average discount rate varied, forcing the required return on equity to change according to

$$DR = (DE) * (R_b) + (1 - DE) * R_e \tag{1-1}$$

where

DR = weighted average discount rate

DE = the firm's debt plus equity ratio

R_b = bond interest rate

R_e = expected return on equity

As expected, the lower discount rates prove the investment most profitable. That weighted average discount rate at which the firm will breakeven is given by the internal rate of return (computed independently of the discount rate shown in the left-most column). The project modeled here will receive a 0.7% return (real, after tax) when costs are set to the 1986 DOE goal.

Interest Ratio and the Rate of Debt to Equity Financing

Figure 4-2 presents the results of varying the ratio of debt to debt equity financing when the cost of loans varies and when the firm maintains a constant (weighted average) rate of return of 7.5 percent (see equation 1-1). In this figure, the familar breakeven capital cost

FIGURE 4-1

SENSITIVITY TO A FIRM'S EXPECTED RATE OF RETURN*

MADISON COMMERCIAL LOCATION WITH AN OPTIMALLY SIZED ARRAY (1980 DOLLARS)

Weighted Average Discount Rate	Return on Equity	PV Cost	Net Benefits (Dollars)	Internal Rate of Return (Weighted)	Levelized Energy Cost (mills)	Levelized Energy Benefit (mills)	System BECC ($/$W_p$)	PV Module BECC ($/$W_p$)
.03	.03	L	413	.03	39	40	1.41	.49
		M	- 9929	.007	55	40	1.36	0.22
		H	-20272	-.007	71	40	1.32	-.05
.05	.063	L	- 5251	.03	44	34	1.01	.09
		M	-15432	.007	64	34	.98	-.17
		H	-25613	-.007	83	34	.94	-.43
.07	.097	L	- 8881	.03	51	31	.75	-.17
		M	-18957	.007	74	31	.73	-.42
		H	-29033	-.007	96	31	.70	-.67
.09	.13	L	-11305	.03	58	28	.58	-.34
		M	-21310	.007	85	28	.56	-.59
		H	-31316	-.007	111	28	.54	-.83
.11	.163	L	-12976	.03	66	26	.46	-.46
		M	-22931	.007	97	26	.45	-.70
		H	-32887	-.007	128	26	.43	-.94

*Debt to Value Ratio: .4, Inflation after 1985: 5%/year, Bond Interest Rate: 3%

**Weighted Average Discount Rate = (DE)*(R_b) + (1-DE)*(R_e) where; DE = the firms debt to value ratio, R_b = required return on debt (bond interest rate), R_e = expected return on equity

FIGURE 4-2

SENSITIVITY TO THE INTEREST RATE AND THE RATIO OF DEBT TO EQUITY FINANCING*

MADISON COMMERCIAL LOCATION (1980 DOLLARS)

Debt to Debt Plus Equity	R_{br}**	R_{bn}	R_{er}	R_{en}	Net Benefits (dollars)	Internal Rate of Return	Levelized Energy Cost (mills)	Levelized Energy Benefits (mills)
0.0 (all equity)	0.0	.05	.075	.129	-22872	-0.22	92	38
	.03	.081	.075	.129	-25069	-0.26	98	38
	.06	.113	.075	.129	-26361	-.03	101	38
.2	.0	.05	.094	.148	-21354	-.011	83	33
	.03	.081	.086	.141	-22128	-.008	87	35
	.06	.113	.079	.133	-22384	-.004	90	37
.4	0	.05	.094	.181	-20274	-.002	74	26
	.03	.081	.105	.160	-19638	.007	76	30
	.06	.113	.085	.139	-18637	-.018	79	35
.6	0	.05	.187	.247	-19688	.002	63	17
	.03	.081	.42	.2	-17875	.02	65	23
	.06	.113	.097	.152	-15390	.038	68	32
.8	0	.05	.375	.438	-19413	.004	53	07
	.03	.081	.255	.318	-17224	.028	54	12
	.06	.113	.135	.132	-13563	.052	56	24

*Assumed that a 7.5% Weighted Average Discount Rate was maintained.

**R_{br} = real bond interest rate, R_{bn} = nominal bond interest rate, R_{er} = expected rate of return on equity, R_{en} = expected nominal rate of return on equity.

FIGURE 4-3
SENSITIVITY TO MARGINAL TAX RATE
MADISON COMMERCIAL LOCATION

Tax Rate*	Taxable Income	PV Cost**	Net Benefits	Rate of Return	Levelized Energy Cost (mills)	Levelized Energy Benefits (mills)	System BECC ($/Wp)	PV BECC ($/Wp)
17%	0-25k	L	-10690	.031	72	51	.89	-.03
		M	-26466	.008	104	51	.86	-.28
		H	-42242	-.007	136	51	.84	-.54
20%	20-25k	L	-10278	.031	70	49	.89	-.03
		M	-25471	.008	100	49	.87	-.28
		H	-40663	-.007	131	49	.84	-.54
30%	50-75k	L	- 8904	-.03	61	43	.90	-.02
		M	-22153	.007	87	43	.87	-.28
		H	-35402	-.007	114	43	.84	-.54
40%	75-100k	L	- 7530	.03	52	37	.90	-.02
		M	-18836	.007	75	37	.87	-.27
		H	-30141	-.007	97	37	.85	-.53
46%	100k	L	- 6706	.03	46	33	.90	-.01
		M	-16845	.007	67	33	.88	-.27
		H	-26984	-.007	87	33	.85	-.53

*Internal Revenue Code, Section II

**PV Cost Legend: L = low, M = DOE Objective, H = high

columns are deleted due to abnormal values resulting from precision error by the computer. The net benefits column provides and interesting basis for comparison. We find that net benefits increase with increasing ratio of debt financing and that this effect is most dramatic at high interest rates. High interest rates are favored by high debt financing, due to the tax advantages of borrowing. Those investments that are highly equity financed favor low interest rates.

Marginal Tax Rate

For this study, we sought the impact upon investment worth of varying the firm's marginal tax bracket. Results of the analysis are depicted in figure 4-3. Each row indicates the tax rate applicable to each level of possible taxable income that the firm may have. Here we find that the firm's tax rate has very little influence, because decreasing net energy savings due to increasing taxes are offset by increasing interest and depreciation advantages.

FIGURE 4-4

SENSITIVITY TO THE RATE OF ESCALATION IN ENERGY CHARGE (1980 DOLLARS)*

MADISON COMMERCIAL LOCATION

Escalation in Energy Charge (real)	Escalation rate per year 1980-2010	Escalation factor over first year 1980-2010	PV Cost**	Net Benefits (dollars)	Internal Rate of Return	Levelized Energy Cost (mills)	Levelized Energy Benefits (mills)	System BECC ($/Wp)	PV Module BECC ($/Wp)
1%/year		1.35	L	-10708	.01	46	25	.62	-.30
			M	-20847	-.012	67	25	.59	-.55
			H	-30967	-.026	87	25	.57	-.81
3%/year		2.43	L	- 7754	.026	46	31	.83	-.09
			M	-17893	.005	67	31	.80	-.35
			H	-28033	-.01	87	31	.77	-.60
5%/year		4.32	L	- 3654	.044	46	39	1.12	.20
			M	-13793	.022	67	39	1.09	-.06
			H	-23932	.007	87	39	1.06	-.31
7%/year		7.61	L	2068	.062	46	51	1.52	.60
			M	- 8070	.038	67	51	1.49	.35
			H	-18210	.024	87	51	1.47	.09
5%/year in 1980 to 0%/year in 2010		2.14	L	- 6706	.03	46	33	.90	-.01
			M	-16845	.007	67	33	.88	-.27
			H	-26984	-.007	87	33	.85	-.53
3%/year in 1980 to 0%/year in 2010		1.58	L	- 9092	.018	46	28	.73	-.18
			M	-19231	-.004	67	28	.71	-.44
			H	-29370	-.018	87	28	.68	-.70

*Assumes 5.7% Weighted Average Discount Rate, 3% Bond Interest Rate

**PV Cost Legend: L = low, M = DOE objective, H = high

Escalation in Utility Energy Charge

Various energy charge escalation scenarios are outlined in figure 4-4 and their influence upon the financial evaluation parameters is included in the same figure. It is seen that nowhere in this range of escalation schemes does the investment scene look ripe for photovoltaics for this establishment given the 1986 cost targets.

FIGURE 4-5
SENSITIVITY TO THE GENERAL INFLATION RATE*
MADISON COMMERCIAL LOCATION

General Inflation Rate	Escalation Rate Per year 1980-2010	Escalation Factor over first year 1980-2010	PV Cost**	Net Benefits (dollars)	Internal Rate of Return	Levelized Energy Cost (mills)	Levelized Energy Benefit (mills)	System BECC ($/Wp)	PV BECC ($/Wp)
0%/year		0.0	L	- 5121	.036	.043	.033	.98	.07
			M	-14469	.012	.062	.033	.95	-.19
			H	-23816	-.004	.081	.033	.92	-.45
5%/year		5.7	L	- 7062	.030	.047	.033	.89	-.03
			M	-17379	.007	.068	.033	.86	-.29
			H	-27697	-.008	.089	.033	.83	-.54
12%/year		3.0	L	- 9064	.024	.051	.033	.81	-.11
			M	-20382	.002	.074	.033	.78	-.37
			H	-21700	-.012	.097	.033	.76	-.62
12%-5% over 5 years 5%/year thereafter		5.0	L	- 6706	.03	.046	.033	.90	-.01
			M	-16845	.007	.067	.033	.88	-.27
			H	-26984	-.007	.087	.033	.85	-.53
12%-5% over 15 years 5%/year thereafter		6.0	L	- 7411	.029	.048	.033	.87	-.05
			M	-17903	.006	.069	.033	.85	-.30
			H	-28395	-.008	.090	.033	.82	-.56
12%-5% over 25 years 5%/year thereafter		10.6	L	- 7838	.028	.049	.033	.85	-.06
			M	-18543	.005	.070	.033	.83	-.32
			H	-29248	-.010	.092	.033	.80	-.57

*Assumes 5.7% Weighted Average Discount Rate, 3% Bond Interest Rate
**PV Cost Legend: L = low, M = DOE objective, H = high

Inflation

Six different inflation scenarios were mapped out according to figure 4-5 and the financial performance varied as shown in the same figure. We find that the economic outlook for investment grows dimmer with rising inflation, as would be expected. The levelized energy benefit figure is not influenced by inflation due to the balancing effect of rising energy and operating costs when discounting in nominal terms. Finance charges and depreciation allowances are on fixed schedules and are unaffected by inflation except for the influence of discounting.

FIGURE 4-6
SENSITIVITY TO THE VALUED COST OF OIL *#
MADISON COMMERCIAL LOCATION (1980 $)

	Oil Price ($/bbl)**	Energy Charge (mills)	Capacity Charge ($/kw/mo)	Net Benefits (dollars)	Internal Rate of Return	Levelized Energy Cost (mills)	Levelized Energy Benefits (mills)	System BECC $/Wp	PV BECC $/Wp
Boston Paper Mill	35	35.4	7.87	-1847	.01	69	35	.97	-.31
	65	68.3	7.87	-1558	.012	69	38	1.08	-.20
	95	99.7	7.87	-784	.037	69	51	1.54	.40
Phoenix Savings Bank	35	30.4	7.67	-1433	.017	44	25	.96	-.05
	65	58.9	7.67	-1235	.022	28	28	1.11	.10
	95	85.9	7.67	-416	.046	44	39	1.65	.64

*All costs assumed were the DOE objective.

#Each location shown used an undersized array.

**All energy charges based on $35/bbl oil were escalated at 5%/year (real) in 1980 declining linearly to 0%/year in 2010. All energy charges based on $65 and $95/bbl oil assumed that these were long run equilibrium rates and no escalation rate was applied above inflation.

The Assessed Cost of Oil

In this section we analyze the effect of oil prices on the costs of producing electricity and hence on the value of photovoltaics. Three different prices of oil were assumed starting in 1980 and electricity rates were computed for two regions of the base case analysis, as shown in figure 4-6. A commercial firm with moderate peak-shaving characteristics was selected for each region and an undersized array was modeled. The first cost case assumed market costs at $35/bbl with real cost escalation the same as for the base case analysis. The remaining two cost cases of $65/bbl and $95/bbl were assumed long-run equilibrium prices, so that no escalation rate was applied above inflation. These, in effect, may be taken as possible values for the social costs of using oil. The small increment in value from the $35/bbl to $65/bbl case reflects the influence of escalating the $35/bbl oil above the rate of inflation. Case E in figure 4-4 indicates that, in fact, the price of energy increases in real terms more than two-fold by 2010 at the base case escalation rate.

FIGURE 4-7
SENSITIVITY TO INVESTMENT TAX CREDIT
MADISON COMMERCIAL LOCATION (1980 $)

ITC %	PV Cost*	Net Benefits (dollars)	ROR	LEC (mills)	LEB	System BECC ($/Wp)	PV BECC ($/Wp)
0	L	-10714	.02	55	33	.75	-.17
	M	-22857	-.001	79	33	.73	-.42
	H	-35000	-.016	104	33	.70	-.67
10	L	- 6706	.03	46	33	.90	-.01
	M	-16845	.007	67	33	.88	-.27
	H	-26984	-.007	87	33	.85	-.53
20	L	- 2697	.044	38	33	1.14	.22
	M	-10833	.019	55	33	1.10	-.05
	H	-18969	.004	71	33	1.07	-.31
30	L	1310	.064	3	33	1.53	.62
	M	- 4621	.036	43	33	1.49	.34
	H	-10953	.018	55	33	1.44	.06
40	L	5318	.097	22	33	2.35	1.44
	M	1190	.064	31	33	2.28	1.14
	H	- 2937	.042	39	33	2.21	.84
50	L	9327	.181	14	33	5.07	4.16
	M	7202	.128	18	33	4.92	3.77
	H	5077	.098	23	33	4.76	3.39

*PV Cost Legend: L = low, M = DOE Objective, H = high

Investment Tax Credit

Figure 4-7 presents the results of varying the investment tax credit from zero to fifty percent for the Madison commercial firm. Whereas the profit (net benefits) figures increase at a fairly constant rate with each 10 percent increase in the ITC, the breakeven cost figures increase at an escalating rate. The ITC is found to have a large impact on photovoltaic investment prospects.

FIGURE 4-8
SENSITIVITY TO ALLOWED MANNER OF DEPRECIATION
MADISON COMMERCIAL LOCATION (1980 $)

		PV Cost* Net Benefits	ROR	LEC (mills)	LEB (mills)	System BECC ($/Wp)	PV BECC ($/Wp)
Straight Line	L	- 8841	.025	51	33	.81	-.10
	M	-20047	.002	73	33	.79	-.36
	H	-31253	-.012	96	33	.76	-.61
Sum of the Years	L	- 6706	.03	46	33	.90	-.01
	M	-16845	.007	67	33	.88	-.27
	H	-26984	-.007	87	33	.85	-.53
Double Declining Balance	L	- 7225	.029	48	33	.88	-.04
	M	-17624	.006	69	33	.85	-.29
	H	-28023	-.008	90	33	1.24	-.55
Accelerated (2 years)	L	- 1386	.049	36	33	1.24	.32
	M	- 8865	.024	51	33	1.20	.06
	H	-16345	.007	66	33	1.17	-.21

*PV Cost Legend: L = low, M = DOE Objective, H = high

Depreciation Allowances

The final sensitivity analysis contrasts the evaluation parameters with the allowed manner of depreciation for tax purposes. The base case analysis used the sum of the years method, and it is found that this is superior to all except the two year accelerated approach.

IV.2 Combined Policy Variable Sensitivity Analysis

The major objective of the above sensitivity study was to search for those parameters which heavily influenced photovoltaic worth so that likely "positive worth" scenarious could be identified. It is the objective of this section to combine various policy variables in an

Net Present Values of a Photovoltaic Investment
Phoenix Commercial Location (1981 Dollars)

	PV Cost*	1. Base Case	2. ITC=20%	3. Accelerated Depreciation	4. ITC=20%, R=5%	5. 3+4	6. 5 With No Credit Capacity
Flat Embedded	L	- 2319.	- 993.	- 560.	+ 117.	+1877.	+1458.
	M	- 6036.	-3974.	-3298.	-2896.	- 157.	- 577.
	H	- 9753.	-6954.	-6037.	-5909.	-2193.	-2612.
TOD Embedded	L	- 2386.	-1061.	- 627.	+ 32.	+1792.	+1373.
	M	- 6103.	-4041.	-3366.	-2981.	- 243.	- 662.
	H	- 9820.	-7021.	-6105.	-5994.	-2278.	-2697.
TOD Embedded (6:1)	L	- 4017.	-2691.	-2257.	-2031.	- 271.	- 690.
	M	- 7734.	-5671.	-4996.	-5044.	-2306.	-2725.
	H	-11451.	-8651.	-7735.	-8057.	-4341.	-4761.
Flat Marginal Oil at $35/bbl.	L	- 1870.	- 544.	- 110.	+ 682.	+2442.	+1458.
	M	- 5587.	-3524.	-2849.	-2331.	+ 406.	- 577.
	H	- 9304.	-6504.	-5588.	-5344.	-1629.	-2612.
Flat Marginal Oil at $65/bbl.	L	- 1428.	- 102.	+ 332.	+ 1124.	+2884.	
	M	- 5145.	-3082.	-2407.	-1889.	+ 849.	
	H	- 8862.	-6062.	-5146.	-4902.	-1186.	

* PV Cost Legend: L=Low, M=DOE Objective, H=High

effort to similarly identify profitable investment conditions. The results of this work are summarized in figure 4-9 for a Phoenix commercial location with an optimally sized array. Here, we examined only the net benefits figure so as to include on a single chart the range of policy options shown. The utility rate structures include four of our base case rate scenarios, and, in addition, we included a flat rate where energy charges were based on $65/bbl oil. This latter rate was computed as part of the study presented above (section IV.1) examining the sensitivity to the cost of oil. Again, no escalation rate was applied to the energy charge above the rate of inflation so as to represent a possible long-run equilibrium price.

The bold-face present value figures show the positive profit values. We find that only for those rates computed using capital replacement costs for the capacity charge does a photovoltaic investment turn a positive profit when the 1986 DOE cost goals are assumed, and this is true only when the expected rate of return is set to 4.2 percent. This is a weighted average utilizing a 3 percent interest rate, 5 percent return on equity, and .4 debt to debt plus equity ratio according to equation 1-1. The last column in this figure reveals the impact of not allowing the credit for reducing the monthly capacity change via load matching. The firm modeled here has moderate peak-shaving characateristics when compared against other firms in the Phoenix area.

IV.3 Conclusions

From the above sensitivity runs, the following set of conclusions can be drawn:

o Among the market/financial parameters most effective in increasing photovoltaic system worth include:

  - lower discount rates. Firms can expect to break even with photovoltaic investments when their expected rates of return fall below 3 percent (real, after tax).

  - high interest rates when levels of debt financing exceed .3 (debt to debt plus equity ratio).

  - high investment tax credits. ITC's above 30 percent begin to prove commercial sector photovoltaics economic when all other parameters are set constant.

  - the manner of depreciation allowed for tax purposes. Specifically, accelerated depreciation has a high impact on investment worth.

  - high escalation rates in utility energy charges. It was found that PV system breakeven capital costs rise roughly 10 cents for every 1 percent increase in yearly price escalation.

  - the cost of oil. Oil priced at expected long-run equilibrium values considerably improve the prospects for a PV investment in those regions of heavily oil dependent utilities.

- Those market/financial parameters less significantly effective in improving photovoltaic system worth include:
  - lowering of the firm's marginal tax rate.
  - low interest rates at low ratios (less than .3) of debt financing.
  - the rate of general inflation. It was shown that the system breakeven capital cost decreased by 1.5 cents for every 1 percent increase in the yearly inflation rate.
- Combining the policies of higher investment tax credits (up to 20 percent) and allowing accelerated depreciation begins to mark a financial environment which will provide positive returns on a photovoltaic investment in the commercial sector as early as 1986, given a reasonable range of private sector discount rates. This will only be the case, however, when operating against specific utility capacity charges based upon the replacement value of the utility's capital stock.

IV.3 Summary Analysis

This summary analysis is intended to flag some major caveats to the conclusions of sections III-3 and IV-3. We urge all readers to review this section.

At the very start, we must point out that these conclusions apply solely to our results using the defined set of market/financial parameters and by utilizing the financial methodology of figure 1-2. While this method is designed to accurately model investment cash flows, and reflect the manner in which a firm "should" evaluate an investment, we do not suggest that all firms will choose to do so. Furthermore, we examined only one means of project finance, that being the issuance of bonds. Alternative financing options may be available to distributed power generators such as photovoltaics, one example being leasing.

In addition, the load profiles which we used for the firms in this analysis consist of historical data figures. These figures are insensitive to anticipated rate structures for 1986 and to the likelihood that some form of load management will be instituted by that date. Although this does not change the maximum breakeven figures presented in the base case analysis in which no peak-shaving credit was allowed (figure 3-4), our results indicate that the peak-shaving credit is important and hence, any alteration in individual demand patterns will effect the economic desirability of photovoltaic systems. One would fully expect a photovoltaic array to compete with any form of load management system when such a credit is allowed.

Also, we are dealing in this report with numerous unknowns. There are unknowns concerning physical operating efficiencies, the utility interactive environment, anticipation of technology cost, the nature of such market parameters as the cost and availability of back-up utility energy, inflation rates, interest rates, and so on. All of these force us to issue our findings with a certain nervous caution. Significant changes in any one these parameters over current expectations would serve to alter the conclusions of our base case analysis. For this reason, the sensitivity study of section IV provides little more than an indication of the relative magnitude and direction specific changes would have on our investment criteria.

Finally, we we wish to underscore the frustrations encountered when doing this type of analysis where results are so dependent upon a single parameter such as the discount rate. Major conclusions of the base case analysis could have been reversed using a two percentage point difference in our base case assumption for this figure alone.

For the above reasons, our reader's are cautioned to interpret our results responsibly.

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