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SERI PHOTOVOLTAIC VENTURE ANALYSIS: LONG TERM DEMAND ESTIMATION

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Energy Laboratory Report - MIT-EL-78-032

July 1978

ABSTRACT

This report presents the results of a sectoral demand analysis for photovoltaic power systems used in the residential sector [single family homes], the service, commercial, and institutional sector [schools] and in the central power sector. The results described are the output of a set of three normative modeling activities carried out by the MIT Energy Laboratory. They are based on the assumption that the actors, i.e., the utilities, schools, and homeowners, will switch to photovoltaic power systems when they are cost-effective relative to the competition, that is, centralized power generation using conventional fuels. In each case the assumption is made that the market for photovoltaic power systems will be a new market, not a retrofit market. As a result the annual (total for utilities) sales potential at a given price is estimated for each sector assuming a specific level of new installations in that sector, i.e., new single-family homes, new schools, and additions to utility stocks. As such, the results presented are maxima for a given application. While the methodology presented does not allow for any early acceptors, it does assume that once economic all new homeowners, school-builders, and utilities will buy to a fixed level.

SERI PHOTOVOLTAIC VENTURE ANALYSIS
Long Term Demand Estimation

I. Introduction

This report presents the results of a sectoral demand analysis for photovoltaic power systems used in the residential sector [single family homes], the service, commercial, and institutional sector [schools] and in the central power sector. The results described are the output of a set of three normative modeling activities carried out by the MIT Energy Laboratory. They are based on the assumption that the actors, i.e. the utilities, schools, and homeowners, will switch to photovoltaic power systems when they are cost-effective relative to the competition, that is, centralized power generation using conventional fuels. In each case the assumption is made that the market for photovoltaic power systems will be a new market, not a retrofit market. As a result the annual (total for utilities) sales potential at a given price is estimated for each sector assuming a specific level of new installations in that sector, i.e. new single-family homes, new schools, and additions to utility stocks. As such, the results presented are maxima for a given application. While the methodology presented does not allow for any early acceptors, it does assume that once economic all new homeowners, school-builders, and utilities will buy to a fixed level.

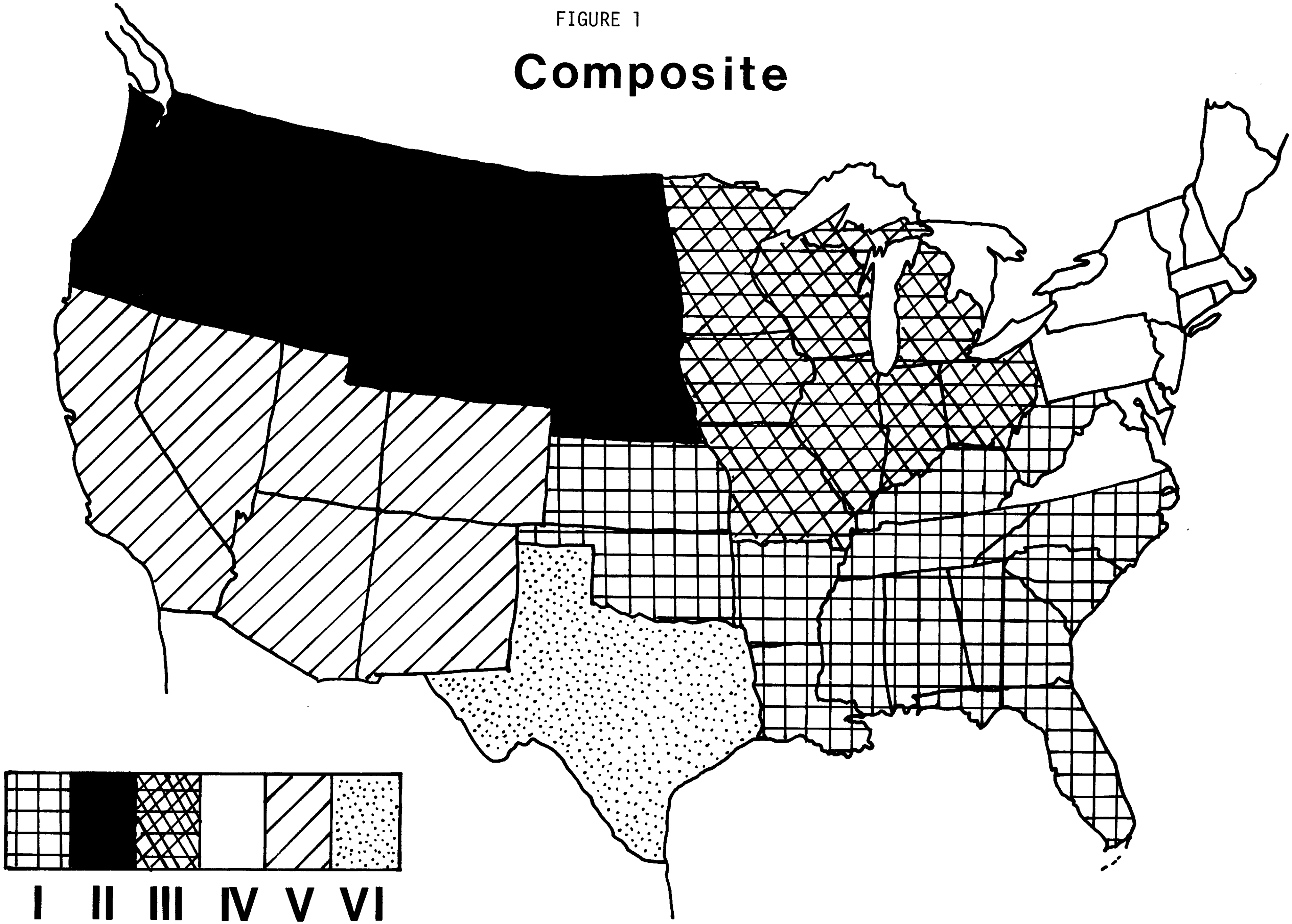
Each of the three sectors analyzed will be discussed in greater detail below. The methodology used for both the school and the residential analysis is a modification of that developed by Carpenter and Taylor in An Economic Analysis of Grid-Connected Residential Solar Photovoltaic Power Systems. This methodology measures the "worth" of a photovoltaic power system to the owner of the system. The worth is measured against the alternative available energy system, the purchase of electric power from a utility grid. Analysis of the value of photovoltaic power systems to a utility was carried out using a more detailed utility systems operating model, SYSGEN. The SYSGEN methodology allows the MIT Energy Laboratory to parallel the developmental work carried out by General Electric Electric Utility Systems Engineering Department for EPRI, in 1977. In the utility analysis we have looked at the value of a range of penetrations of photovoltaic power systems - 2 to 12% - into specific regional synthetic utilities as developed by EPRI.

This analysis utilized the solar planning regions developed by Tabors and Carpenter.[1] Figure 1 shows the region so defined. It should be noted that throughout the analysis which follows there is no consideration of the Northwest region. This region appears to have minimal potential for photovoltaic power systems as alternative power sources are relatively inexpensive, solar insolation is poor and the region as a whole is predicted to have only marginal growth in population.

The city of Omaha, Nebraska has been used as a surrogate for the North-

FIGURE 1

Composite



central region. This location was chosen because of utility cooperation, data availability, and similar weather conditions to much of the Northcentral region. As such it offers a fair surrogate for the analysis undertaken in this region. On the whole it is somewhat warmer and sunnier than such population areas such as Chicago and Detroit. The utility system load is similar to an industrial center with summer air conditioning and therefore is a good match with much of the load shape for the Northcentral area.

II. Single-Family Residences

It has been argued that single-family residences would offer an early potential market for photovoltaic power systems. The major advantages of this market to photovoltaics are 1) favorable financial borrowing power on the part of the homeowner; 2) if constructed as a portion of a new building, photovoltaic systems do not require specific support structures and are able to take advantage of a credit for roof material not utilized. 3) The load is co-terminus with the generation source and as a result there are no transmission and distribution losses.

The analyses which follow have utilized the methodology developed by Carpenter and Taylor to evaluate the worth of photovoltaic power systems to a residential user. The Carpenter and Taylor work, and that by Tatum[2] which preceeded it, utilizes a simulation model of a residence with fixed appliance load and operating characteristics, as shown on Table 1. The photovoltaic power system provides electricity to the load when there is sufficient insolation. When insufficient insolation exists, the load is supplied from the grid in whole or in part. Because electric power is more expensive to generate on peak than it is on base, the analysis utilizes a modified marginal cost system or time-of-day pricing with which to value the electricity not purchased from the utility by virtue of the existance of a photovoltaic power system on an individual's roof. In addition, the homeowner is able to provide power back to the utility when he has excess capacity relative to his own demands. Within the analysis, the value of power bought back by the utility is set at three levels for parametric analysis. The first level is zero percent buyback, i.e. no credit for excess generation. The second level is at fifty percent buyback, i.e. that the utility is willing to buy from the homeowner at half the time-specific price that the utility charges that homeowner for his electric power; and third, one hundred percent buyback, i.e. that the utility is willing to pay the homeowner exactly what they charge the homeowner (the California model). We believe that the middle of these three options is the most reasonable upper bound for the economic behavior of a utility. Furthermore, an analysis is required on a utility-by-utility basis to justify the precise value of excess electric power to the utility itself. In the absence of that complete analysis, a 50% buyback rate represents a fair approximation of the split between fuel and operating costs. The resulting values for the worth of photovoltaic power systems to an owner range between $.80 and $.20 per watt(peak) module at a fifty percent buyback rate. These values represent a conservative estimate of the value of photovoltaic systems to residential owners. Table 2 summarizes the system configuration and efficiency assumptions used in this analysis.

Table 3 summarizes by region the worth of photovoltaic systems in the residential market. The system net present value given in Table 3 is found by comparing the homeowner's electric bill with and without the photovoltaic system. The net present value of the difference in these electric bills is the amount that the homeowner would be willing to pay for the entire system. The second

TABLE 1

APPLIANCE USE AND BEHAVIORAL ASSUMPTIONS

Load #	Appliance	Rating	Yearly Consumption	Comments
1	Refrigerator	615W	1829kWh	Unit is on continuously but draws load (i.e. is running) only one-third of the time to maintain proper temperature (runs only 20 min. each hour).
2 & 3	Dryer	4850W	1008kWh	Eight half-hour loads. May be run at any time during day/night but four loads must be run in each half of each week.
4 & 5	Washer	500W	103kWh	Same as dryer.
6	Water heater	2500W	4270kWh	Unit is on from 6 a.m. to midnight but runs only one-fourth of each hour to maintain temperature.
Range loads			1205kWh	Meal loads represent different combinations of oven, broiler, and range-top burners that might be used for each meal. Each load is 30 min. in duration. Breakfast, lunch, and dinner start times are 6-7:30 a.m., 11:30-12:30 p.m., and 6-8 p.m., respectively.
7.	Dinner	9100W		
8.	Lunch	2400W		
9.	Breakfast	2700W		

TABLE 1 continued

APPLIANCE USE AND BEHAVIORAL ASSUMPTIONS (continued)

Load #	Appliance	Rating	Yearly Consumption	Comments
10	TV	200W	440kWh	Unit runs for 6 hours per day beginning in the late afternoon or early evening.
11	Dishwasher	1250W	363kWh	Runs consist of two 30-min. or one 1-hour cycle each day. May be run after either breakfast or dinner.
12	Lighting	2400W	1314kWh	Lighting for a 6-7 room home. Roughly one-fourth of the lights are on at any time during evening lighting hours.
13	Central Air Conditioning	5000W	Variable	A/C mode is triggered by two days with temperatures greater than 25.5°C. Once in A/C mode unit is turned on when temperature reaches 21.9°C and runs continuously until house is cooled to 20.9°C.

TABLE 2

Residential Simulation (SOLOPS) Assumptions

Array Size	$33M^2$
Array Tilt Angle	Latitude Less 10^o
Encapsulated Cell Efficiency	.12
Wiring and Mismatch Efficiency	.95
Inverter Efficiency	.88
Packing Factor	.80
Storage	NONE
Utility Rate Structure	Time of Day
Cell Degradation Rate	5% years 1 and 2 .7% years 3 to 20
System Lifetime	20 years
Discount Rate	3% (Real)
Fuel Escalation Rate	3% (Real)
Balance of System Cost	\$500 Fixed \$11/m^2 Variable

TABLE 3

Photovoltaic System Worth: Residential
Utility Buyback: 0%, 50%, 100%

	System Net Present Value (1975$)			$Wp(Module) for System* (1975$)			$Wp Module** (1975$)		
	0%	50%	100%	0%	50%	100%	0%	50%	100%
South (Miami)	1887	2272	2659	.60	.72	.84	.33	.44	.57
Northwest	-	-	-	-	-	-	-	-	-
Northcentral (Omaha)	1333	1745	2168	.42	.55	.68	.15	.28	.41
Northeast (Boston)	1744	2269	2832	.55	.72	.89	.28	.44	.62
Southwest (Phoenix)	2877	3422	3976	.91	1.08	1.25	.64	.81	.98
Texas (Fort Worth)	1101	1289	1482	.35	.41	.47	.08	.14	.19

*Wp(Module) for System = Net Present Value of $\left(\frac{\text{Energy + Fixed + Variable Costs}}{\text{Module Watts Peak}}\right)$

**Wp Module = Net Present Value of $\frac{\text{Energy Costs}}{\text{Module Watts Peak}}$

column in Table 3 gives the net present value of the difference in the electric bills per peak module watt. This gives the value of the entire system per peak module watt. (To evaluate the worth for an individual homeowner, this number should be converted into delivered watts since the homeowner would be concerned with the delivered power rather than the power available from the module.) The third column in Table 3 has the rest of system costs (fixed and variable) subtracted out to give the net present value of the array per module watt.

The analysis of potential market size for photovoltaic power systems in residences is based upon a normative model of economic behavior. In this model it is assumed that when a photovoltaic power system is cost effective in lifecycle cost economic terms, it will be purchased. As such it represents an upper bound on demand. To calculate the total demand requires both an estimation of the value of the photovoltaic power system to its owner at a specific location or within a specific region, and the number of annual housing starts in a given region. Once again the analysis takes into account only new housing starts as potential markets for photovoltaics. It does not utilize retrofits because it is felt that these will be economic later in each region.

The analysis of new housing starts is based on estimates made by CONAES as reported in "Macroeconomic Scenarios" prepared by Donavan, Hamester, and Rattien, Inc. (DHR) for SERI's Photovoltaic Venture Analysis. DHR reports a total housing stock for the United States in the year 1990 of 93 million units. This is compared with a housing stock of 70.4 million housing units in 1975. Using OBERS projection of population to 1990 by region in the United States, we were able to allocate the total housing stock across the U.S. Single family homes were then allocated within regions as a proportion of the existing housing stock in single families. Table 4 shows the resulting number of single family homes by region in the United States. The annual additions to stock were taken as the geometric rate of increase in housing stock, 1970 [the last date for which we had region housing stock] to 1990. Table 4 contains the resultant annual increments to stock in the year 1990.

Assuming a normative behavioral pattern on the part of residential consumers, the early penetration of photovoltaics into a southwest market would account for an annual market for photovoltaics of 360 megawatts at module prices of $.81/Wp or less given the system configuration in this analysis. The second regions to be cost-effective for photovoltaics will be the northeast and the south. Again assuming conservative parameter values and a fifty percent buyback rate, these become economic at 44 cents per peak watt. The total annual demand at 44 cents a peak watt is then calculated to be the summmation of the Southwest plus the South plus the Northeast regions, or roughly 1650 megawatts. The final point on the curve shows a value of photvoltaics of 28 cents per peak watt and the addition of the Northcentral region expanding the potential market to 2250 megawatts. These data are summarized in Figure 2.

In summary, then, it can be seen that using the assumptions contained in this analysis, the value of photovoltaic power systems in the hot dry climate of the southwest is roughly 81 cents per peak watt assuming a 50 percent buyback rate. The market potential for the Southwest at this price in annual sales to new dwelling units would amount to approximately 114,000 housing units out of a total of 706,000 single family housing units estimated to be added to the national housing stock per annum in the year 1990. The

TABLE 4

Regional Distribution of New Housing Starts 1990

(Values x 10^3)

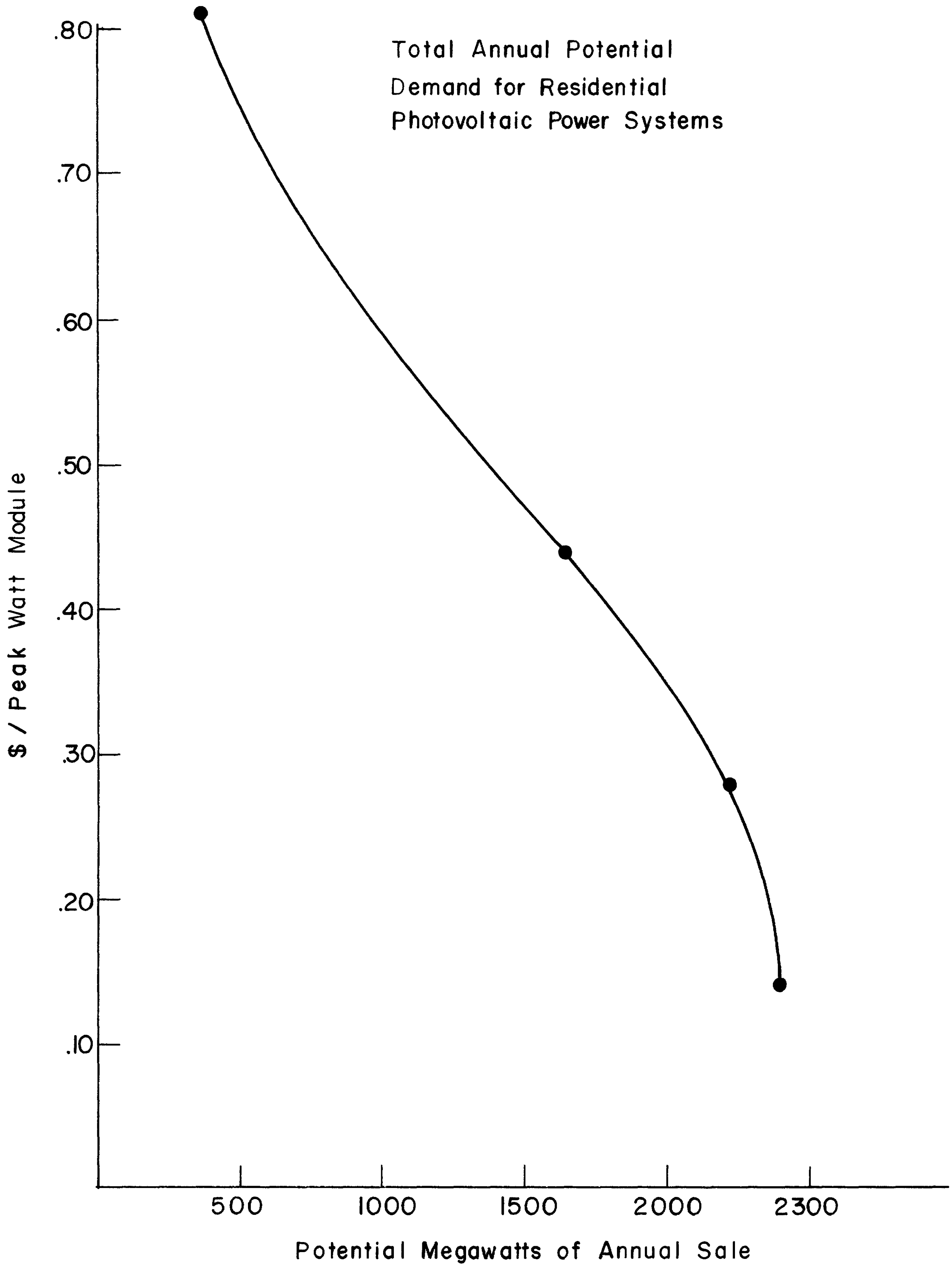
	1970[1] Single Family Housing	1990 Total Housing	1990[2] Single Family Housing	Annual[3] Additions to Single Family Housing
	(Housing Units)			
I. South	11,470	21,101	15,485	234
II. Northwest	2,633	4,122	2,948	17
III. Northcentral	11,900	23,063	15,190	187
IV. Northeast	9,615	26,715	12,567	169
V. Southwest	5,992	12,838	7,972	114
VI. Texas	3,010	5,162	3,837	47
Total	44,620	93,000	58,000	766

[1]Source: Bureau of Census, 1970

[2]Source: CONEAS as reported in Donavan, Hamester, and Rattier for SERI Venture Analysis. Values proportional to OBERS Series E Population Projections (State) for the U.S.

[3]Assumed uniform geometric growth 1970 to 1990. Values are 1990 increment.

Figure 2


Total Annual Potential
Demand for Residential
Photovoltaic Power Systems
.80
.70
.60
.50
.40
.30
.20
.10
$ / Peak Watt Module
500
1000
1500
2000
2300
Potential Megawatts of Annual Sale

demand curve produced is downward sloping to the right, indicating an increase in demand as a function of price decline. The steepness of the slope indicates the likely sensitivity of the analysis contained herein to the regional setting and the number of potential homes in each region. Because the Southwest represents a major growth area in the United States, as does the South, these areas require considerable further analysis if more accurate demand projections are to be made.

III. Service/Commercial/Institutional Sector, School Buildings in the United States

The analysis of a representative building type (a school) from the service/commercial/institutional sector in the United States was undertaken using an abbreviated version of the SOLOPS model for residences described above. Schools offer a potential early market for photovoltaics given their relatively light daylight loads and their generally flat roofed structure. Schools have been chosen as surrogates for the highly heterogeneous building stock in the service/commercial/institutional sector. The simplifying assumptions made were the following: 1) Four weekly runs were used to simulate longer periods of time during the year. 2) These four weekly runs were then expanded into a yearly estimate of energy savings. 3) Loads modeled were only lighting, light appliances, and circulating fans. No account was made for potential energy requirements for compressors for air conditioning or any resistance heating. 4) The load curve for schools was adapted from that prepared by Educational Services, Inc. 5) The area of the school was 100,000 square feet. 6) The area of the array was 5,400 square meters. 7) The angle of the array was latitude minus 10 degrees. 8) The assumed utility buyback rates were set at zero and fifty percent. 9) Rest of system costs were set at 82,000 and $\$18/m^2$ variable. All other assumptions are the same as those that apply to residences as described above.

While the simplifying assumptions made above limit the precision of the simulation model as it is run for school buildings, the baseline results are expected to be ordinally correct. Table 5 summarizes the results of the school analysis for the five case areas, Phoenix, Boston, Omaha, Fort Worth, and Miami, for both a zero percent buyback rate and a fifty percent buyback rate. As can be seen from Table 5, Phoenix has the highest value; and Omaha and Miami the lowest value for photovoltaic power systems in solar applications.

The estimation of the number of school buildings constructed annually in the United States was done in a manner similar to that discussed above for residences. Estimates of total school enrollment in 1990 were available from the Census Bureau.[3] These numbers were then allocated to the six regions of the United States as a function of OBERS projections of total U.S. population by state to 1990. Given the number of anticipated students in 1990 relative to 1970, it is possible to calculate an average annual increase in school-age population. The final step in the estimation procedure was to assume that all students would be housed in schools of 100,000 square feet at a density no greater than 87 square feet per student, the average for school building in the U.S. in 1975. As can be seen from Table 6, there are a relatively small number of schools expected to be built annually in the six regions. If we assume, however, that these schools will switch to photovoltaics when it is cost-effective within that region, it is possible to develop an annual demand curve as shown in Figure 3

TABLE 5

Photovoltaic System Worth: Schools
Utility Buyback: 0%, 50%, 100%

	Net Present Value (1975$)			\$$W_p$(Module) For System*(1975$)			\$$W_p$Module**(1975$)		
	0%	50%	100%	0%	50%	100%	0%	50%	100%
South	256,960	303,616	350,272	.50	.59	.68	.15	.24	.33
Northwest	-	-	-	-	-	-	-	-	-
Northcentral	236,224	288,064	339,904	.46	.56	.66	.11	.21	.31
Northeast	234,352	376,192	518,032	.63	.73	1.00	.28	.38	.65
Southwest	381,376	469,504	557,632	.74	.91	1.08	.39	.56	.73
Texas	303,616	355,456	407,295	.39	.69	.79	.24	.34	.44

* See Note Table 4

**See Note Table 4

TABLE 6

Regional Distribution of New Schools, 1990

	1974[1] School Building Stock	1990[2] Estimated School Building Stock	Annual[3] Additions to Stock 1990
I. South	20,936	24,102	125
II. Northwest	8,146	9,430	49
III. Northcentral	22,941	27,855	138
IV. Northeast	20,214	25,338	121
V. Southwest	10,522	12,164	63
VI. Texas	5,287	5,994	32
Total	88,046	108,645	528

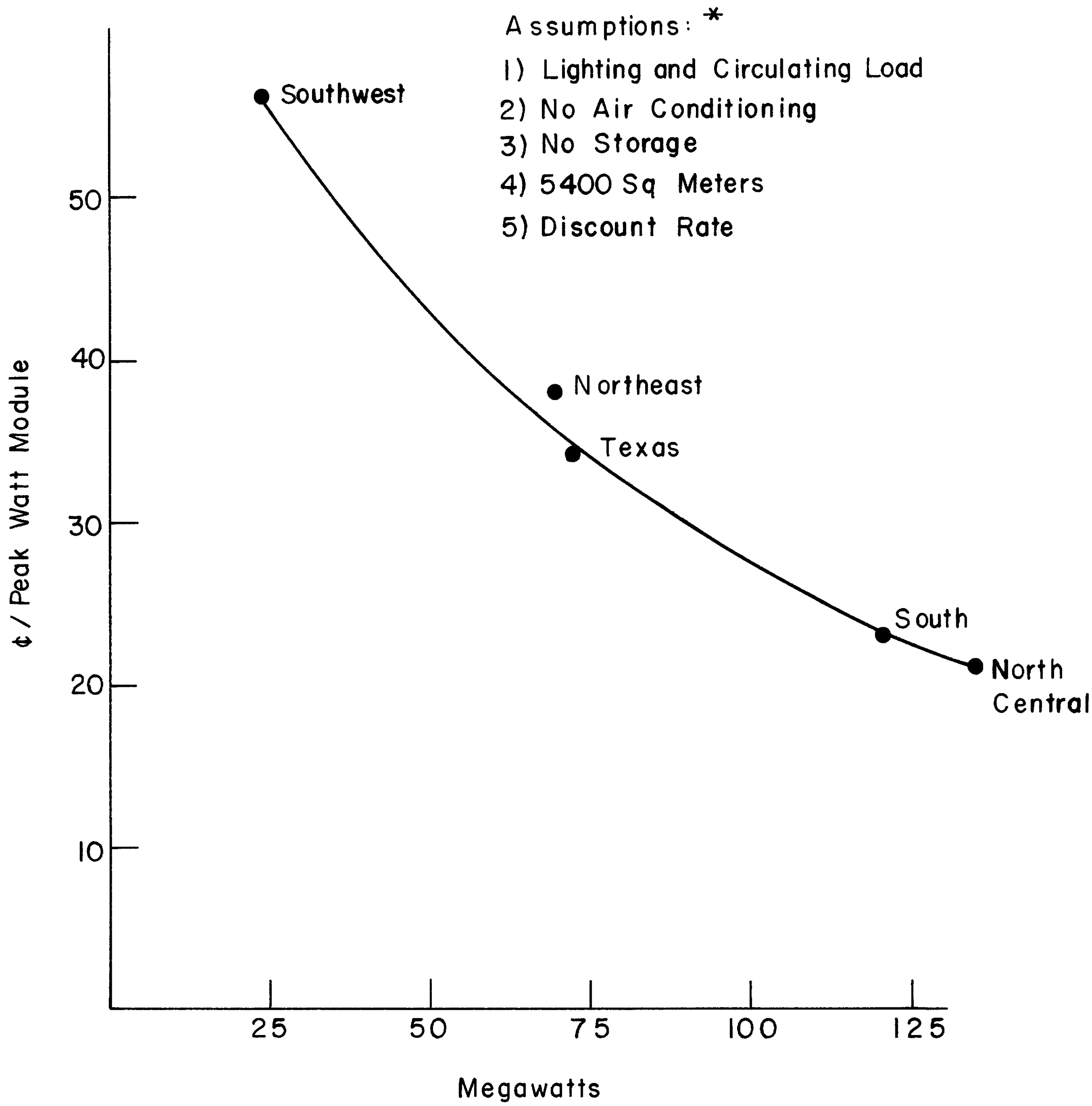
[1]Source: United States Department of Health, Education and Welfare; National Center for Education Statistics. Digest of Education Statistics, 1976 Edition

[2]Source: Department of Commerce, Bureau of Census; Demographic Projections of the United States, CPR, P-25, No. 476, Feb. 1972. Distributed according to OBERS Series E Population Projections.

[3]Assumes a uniform geometric growth 1974 to 1990. Values are 1990 increment.

Figure 3

Annual Potential for Photovoltaics on New School Buildings



*Calculations cover specific weekly periods through seasons and therefore are not full simulation runs.

for schools in the United States. The Southwest region shows the largest potential benefits to photovoltaic-powered schools at a value of $.56 per peak watt. The Northcentral region, represented by Omaha, has the lowest potential for photovoltaic systems. In summary, while schools do not offer a large potential market for photovoltaics, they do offer, as do residences, a bridge between the dispersed non-grid interconnected applications and the centralized central power applications.

IV. Central Power

The U.S. central utility market represents the major potential long-term market for photovoltaics as it does for all other non-conventional electric power generation systems. The level of infrastructure currently invested in transmission and distribution systems make it unlikely that the utilities will lessen their role in provision of energy to U.S. consumers; the discussion which follows is focused on long-term utility use of photovoltaic power systems. Throughout this analysis it is assumed that the photovoltaic systems are located on utility-owned property and as a result are charged a land-cost as well as other area and land related costs not required by schools or residences. There is no specific assumption concerning the size of individual generating units or their location, only that they are utility-owned and that they gain no credit by being located on a building.

The analysis which follows calculates the value of photovoltaic power systems to a given utility as a function of the operating system of the utility and the level of photovoltaic penetration into that utility. The hypothesis in this work is that with decreasing cost to the utility, photovoltaic power systems will become more attractive in larger quantities within a given system. As a result, a "utility demand curve" will be downward sloping and to the right. The analysis requires the use of a detailed utility-operations simulation model, SYSGEN, a set of assumptions concerning the operating characteristics of the photovoltaic power systems, and a matched data set of hourly loads and hourly solar insolation. There are a set of critical uncertainties associated with this analysis. The most significant of these is the total dollar requirements for the systems costs.

The second critical uncertainty in this analysis is the rate of real escalation of capital costs of conventional generation equipment. Capacity costs are required in calculation of the worth of photovoltaic systems to the regional utilities. As little information is available on future capital costs, we have assumed that the capital costs available for <u>new</u> installations in 1976 fairly represent those anticipated over the nest decade and a half, i.e. that there will be no real escalation costs of capital. Again, these results and underlying assumptions are reported for ease in parametric analysis.

The methodology employed in estimation of the value of photovoltaic power systems to central utilities is centered on the use of the utility operating simulation model, SYSGEN, developed at the MIT Energy Laboratory. SYSGEN is a production costing/reliability model that assumes a fixed generating capacity for the utility. The version of SYSGEN used in this analysis has been adapted to incorporate photovoltaic, weather-dependant, generation sources into an operating system of a traditional utility. The SYSGEN model was applied to four of the six synthetic utilities developed by EPRI.[4] The synthetic utilities represent scaled, simplified utilities developed by EPRI for the purpose of general systems analysis. These synthetic utilities can be modified for use in any given region within the United States without the need to gather specific operating characteristics for individual utilities.

Because of the nature of photovoltaic power systems, it is desirable to analyze their effectiveness within a specific utility power system by detailed hourly simulations which match the electrical demand for such services as air conditioning with the provision or availability of electric power from the photovoltaic arrays. As a result, our work has matched data for loads on specific utilities with solar insolation data taken from the SOLMET data series. The load data was scaled to match the generating capacity and operating characterisitics of the synthetic utilities. Load data was provided to the MIT Energy Laboratory by four utilities: Omaha Public Power District, Florida Power and Light, Arizona Public Service, and Boston Edison, whose assistance in this effort is gratefully acknowledged.

The capital stock of each of the synthetic utilities represents roughly seven thousand megawatts of installed capacity. For each region, a specific synthetic utility was chosen for analysis and for load matching; the synthetic utility matched as nearly as possible the regional generating mix within which each case study utility was located. It should be pointed out that because the purpose of this analysis was regional estimation, not estimation of the operating characteristics of a specific utility, system generating characteristics were matched to regional characteristics rather than those of a specific utility. This was done more nearly to reflect an average or regional total system worth, It is felt that the results of this analysis are more valid across the region than would be the results of detailed analyses of only specific utilities.

The modeling process begins with the running of SYSGEN for a specific load as a base case. The loss-of-load probability generated in this run is held constant for all future runs with photovoltaic systems in place. The second step is to install a fixed capacity of photovoltaic power systems in the utility structure, re-run SYSGEN, and balance the loss-of-load probability resulting from the introduction of the photovoltaic power systems. The result is a decrease in the requirement for conventional generating capacity and a decrease in use of conventional fuels. Fuel savings are calculated directly by SYSGEN. Capacity savings are calculated from the final reliability curve produced by SYSGEN, using a variation of the standard methodology for computing the effective load carrying capability of a plant. The effective load carrying capability of the photovoltaic plants represents the amount of generation that the photovoltaics can replace without changing the reliability of the system. The value of a megawatt saved is then evaluated parametrically as a function of four types of conventional capacity: oil, coal, nuclear, or a weighted average of all systems. While it is possible to calculate the precise capacity savings given the simulation run, the sensitivity of the results to specific values for capacity types was seen to be great enough to require that this be handled parametrically. The results of this analysis will be seen in the section which follows.

The results of the analysis undertaken for central power are summarized in Tables 7 to 11 and Figures 4 and 5. Table 7 shows the analysis carried

TABLE 7
EPRI SYNTHETIC UTILITY

REGION: Southeast SCENARIO F
SYSTEM LOAD: Florida Power and Light 1975
WEATHER: SOLMET Miami, 1975
NAMEPLATE CAPACITY: 6550 MW

CAPACITY	EFFECTIVE CAPACITY	% OF SYSTEM NAME PLATE	$/WP OPERATING	CAPACITY CREDIT* / TOTAL CREDIT OIL/TOTAL #	AVE./TOTAL	COAL/TOTAL	NUC/TOTAL
200	33.29	3.1	0.433	.042/.475	.055/.487	.077/.510	.102/.534
400	58.71	6.1	0.412	.037/.450	.048/.461	.068/.481	.090/.502
600	84.87	9.2	0.403	.036/.439	.046/.450	.066/.469	.086/.490
800	115.66	12.2	0.401	.037/.438	.048/.449	.067/.469	.088/.490
1000	145.44	15.3	0.392	.037/.429	.048/.440	.068/.460	.089/.481
1200	167.86	18.3	0.390	.036/.426	.046/.436	.065/.455	.085/.476

*CAPACITY CREDIT IS THE REPLACEMENT COST OF THE CAPACITY THAT THE PHOTOVOLTAICS DISPLACE. THE CAPACITY CREDIT IS GIVEN FOR FOUR CASES:

1) THE CAPACITY DISPLACED IS OIL-FIRED CAPACITY
2) THE CAPACITY DISPLACED IS THE AVERAGE OF ALL GENERATION TYPES
3) THE CAPACITY DISPLACED IS COAL-FIRED CAPACITY
4) THE CAPACITY DISPLACED IS NUCLEAR CAPACITY.

THE COLUMN MARKED # IS THE COLUMN THAT BEST REPRESENTS THE TYPE OF CAPACITY THAT THE PV DISPLACES IN THIS SCENARIO.

TABLE 8
EPRI SYNTHETIC UTILITY

REGION: Northeast
SYSTEM LOAD: Boston Edison 1975
WEATHER: SOLMET Boston, 1975
NAMEPLATE CAPACITY: 6550 MW

SCENARIO F

CAPACITY	EFFECTIVE CAPACITY	% OF SYSTEM NAME PLATE	$/WP OPERATING	CAPACITY CREDIT* / TOTAL CREDIT			
				OIL/TOTAL #	AVE./TOTAL	COAL/TOTAL	NUC/TOTAL
200	62.76	3.1	0.472	.080/.552	.103/.575	.146/.618	.192/.664
400	112.67	6.1	0.470	.072/.542	.093/.563	.131/.601	.172/.642
600	154.15	9.2	0.467	.065/.533	.084/.552	.119/.587	.157/.624
800	194.17	12.2	0.469	.062/.531	.080/.549	.113/.582	.148/.618
1000	230.29	15.3	0.465	.059/.523	.076/.540	.107/.572	.141/.605
1200	261.61	18.3	0.464	.055/.519	.072/.535	.101/.565	.133/.597

*CAPACITY CREDIT IS THE REPLACEMENT COST OF THE CAPACITY THAT THE PHOTOVOLTAICS DISPLACE. THE CAPACITY CREDIT IS GIVEN FOR FOUR CASES:

1) THE CAPACITY DISPLACED IS OIL-FIRED CAPACITY
2) THE CAPACITY DISPLACED IS THE AVERAGE OF ALL GENERATION TYPES
3) THE CAPACITY DISPLACED IS COAL-FIRED CAPACITY
4) THE CAPACITY DISPLACED IS NUCLEAR CAPACITY.

THE COLUMN MARKED # IS THE COLUMN THAT BEST REPRESENTS THE TYPE OF CAPACITY THAT THE PV DISPLACES IN THIS SCENARIO.

TABLE 9

EPRI SYNTHETIC UTILITY

REGION: Southwest SCENARIO B
SYSTEM LOAD: Arizona Public Service 1975
WEATHER: SOLMET Phoenix, 1975
NAMEPLATE CAPACITY: 7550 MW

CAPACITY	EFFECTIVE CAPACITY	% OF SYSTEM NAME PLATE	$/WP OPERATING	CAPACITY CREDIT* / TOTAL CREDIT			
				OIL/TOTAL #	AVE./TOTAL	COAL/TOTAL	NUC/TOTAL
200	107.77	2.6	0.355	.137/.492	.177/.532	.250/.605	.329/.684
400	202.27	5.3	0.365	.129/.493	.166/.531	.235/.600	.309/.674
600	289.34	7.9	0.363	.123/.486	.158/.521	.224/.587	.294/.657
800	369.45	10.6	0.371	.117/.489	.152/.523	.214/.586	.282/.653
1000	447.26	13.2	0.379	.114/.492	.147/.526	.208/.586	.273/.652
1200	506.41	15.9	0.380	.107/.488	.139/.519	.196/.576	.258/.638

*CAPACITY CREDIT IS THE REPLACEMENT COST OF THE CAPACITY THAT THE PHOTOVOLTAICS DISPLACE. THE CAPACITY CREDIT IS GIVEN FOR FOUR CASES:

1) THE CAPACITY DISPLACED IS OIL-FIRED CAPACITY
2) THE CAPACITY DISPLACED IS THE AVERAGE OF ALL GENERATION TYPES
3) THE CAPACITY DISPLACED IS COAL-FIRED CAPACITY
4) THE CAPACITY DISPLACED IS NUCLEAR CAPACITY.

THE COLUMN MARKED # IS THE COLUMN THAT BEST REPRESENTS THE TYPE OF CAPACITY THAT THE PV DISPLACES IN THIS SCENARIO.

TABLE 10
EPRI SYNTHETIC UTILITY

REGION: Northcentral
SYSTEM LOAD: Omaha 1975
WEATHER: SOLMET Omaha, 1975
NAMEPLATE CAPACITY: 7400 MW

SCENARIO C

CAPACITY	EFFECTIVE CAPACITY	% OF SYSTEM NAME PLATE	$/WP OPERATING	CAPACITY CREDIT* / TOTAL CREDIT			
				OIL/TOTAL #	AVE./TOTAL	COAL/TOTAL	NUC/TOTAL
200	27.34	2.7	0.398	.035/.433	.045/.443	.063/.461	.083/.481
400	41.06	5.4	0.381	.026/.407	.034/.415	.048/.429	.063/.444
600	47.17	8.1	0.379	.020/.399	.026/.405	.037/.416	.048/.428
800	49.48	10.8	0.364	.016/.380	.020/.384	.029/.393	.038/.402
1000	50.45	13.5	0.355	.013/.368	.017/.371	.023/.378	.031/.386
1200	51.26	16.2	0.350	.011/.361	.014/.364	.020/.370	.026/.376

*CAPACITY CREDIT IS THE REPLACEMENT COST OF THE CAPACITY THAT THE PHOTOVOLTAICS DISPLACE. THE CAPACITY CREDIT IS GIVEN FOR FOUR CASES:

1) THE CAPACITY DISPLACED IS OIL-FIRED CAPACITY
2) THE CAPACITY DISPLACED IS THE AVERAGE OF ALL GENERATION TYPES
3) THE CAPACITY DISPLACED IS COAL-FIRED CAPACITY
4) THE CAPACITY DISPLACED IS NUCLEAR CAPACITY.

THE COLUMN MARKED IS THE COLUMN THAT BEST REPRESENTS THE TYPE OF CAPACITY THAT THE PV DISPLACES IN THIS SCENARIO.

out for the South region of the United States. The system load taken was that for Florida Power and Light for 1975; it was matched against Miami weather data for 1975. The nameplate capacity for the syste as a whole was 6,550 megawatts. As can be seen in Table 7, the dollars per watt peak of system operating costs decreased as additional capacity was added from 200 through 1200 megawatts. Photovoltaic generation additions represented an increase from roughly two percent of total capacity to twenty percent of name plate capacity. The effect of the addition of photovoltaic systems was primarily to decrease the required capacity of oil-fired intermediate generation through 800 megawatts of photovoltaics. At roughly 800 megawatts of installed capacity, the photovoltaic power systems became complementary with pumped hydro in the system, thereby decreasing other oi-fired plants and showing an increase in the overall value of the system. (See Figure 4.) The same pattern was seen at 1,000 and 1,200 megawatts of photovoltaic power systems, though here the value of the total system per peak watt was less than had been the case at 800 megawatts of installed capacity.

Table 8 summarizes the worth calculations for an oil scenario for the Northeast region. In this scenario, photovoltaics replaces intermediate and peaking oil and other fossil systems. As was the case in the South region, at roughly 800 megawatts of installed photovoltaic systems, photovoltaics becomes complementary with pumped hydro and as a result there is an upward swing in the value of the photovoltaic system brought about primarily by a major increase in use of hydro and photovoltaics relative to oil-fired systems. This increase is quite striking both in operating cost savings and in capacity credit.

The Southwest region synthetic utility chosen was Scenario B. This was run utilizing Arizona Public Service load data for 1975 and SOLMET Phoenix 1975 weather data. The nameplate capacity for the system was 10,700 megawatts. This is a typical structure for a southwest utility though less so for Arizona Public Service. The impact of photovoltaics on such a system is to replace initially the intermediate oil systems, some peaking combustion capacity, and some hydro. As shown in Table 9, the value of the photovoltaic power systems remains relatively even and high through the range of penetration levels. Photovoltiacs replace intermediate oil and conventional hydro to the point at which the competition with hydro ceases. Given that there is no operating advantage to replacing hydro, it is only when photovoltaics replace in the more expensive fuel systems such as coal and oil that one sees an increase in the value of photovoltaics.

Table 10 summarizes the utility worth calculations for Omaha which has been used as a surrogate for the Northcentral region. As can be seen the worth to the utility is almost entirely in terms of fuel savings. A careful analysis of Omaha peak demand periods and potential power provided by the phtovoltaic systems showed little overlap between photovoltaic availability and the peak accounting for the extremely small capacity credit.

Table 11 summarizes the potential for total generating capacity in the United States to the year 1990. The table contains the regional distribution of installed capacity in 1975; it shows the total capacity projected to exist

Figure 4

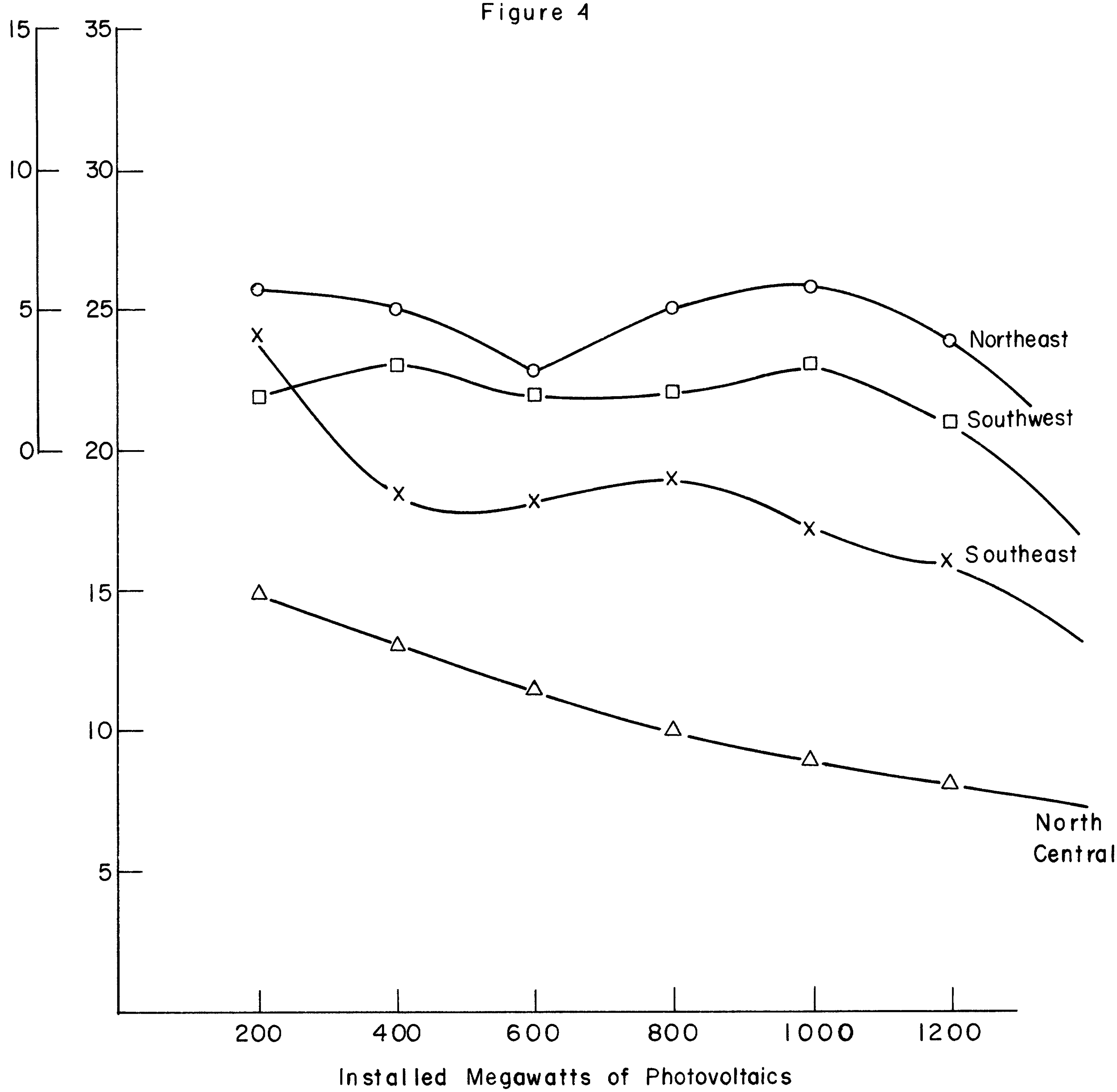
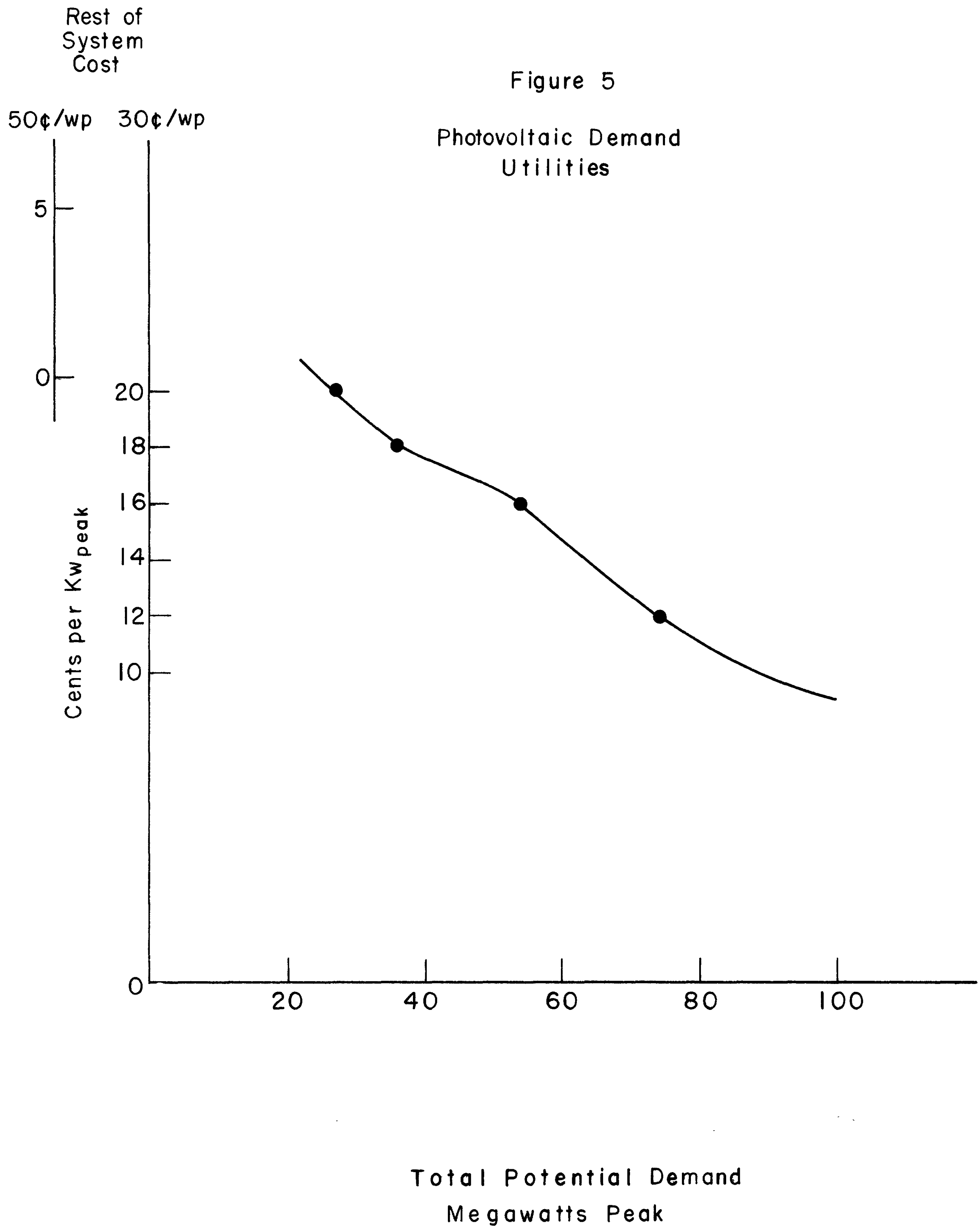

15
10
5
0
35
30
25
20
15
10
5
Northeast
Southwest
Southeast
North Central
200
400
600
800
1000
1200
Installed Megawatts of Photovoltaics

Figure 5

Photovoltaic Demand
Utilities



in 1990 by Electric World in their 28th Annual Electrical Industry Forecast and the predicted level of new capacity additions in 1990. Using 1990 as a baseline for analysis of photovoltaic penetration, Figure 5 presents a composite of regional demand calculations at specific prices for photovoltaic power systems. The values on the y-axis of Figure 5 are ranged from $.30 to $.50 rest-of-systems cost, showing the sensitivity of the results to the assumptions made concerning other than photovoltaic power systems costs. Total demand ranges from 25,000 to 70,000 MW at module cost of 0 to $.70 per peak watt. In summary, the potential for photovoltaics penetration into the central power sector appears to be highly sensitive to the assumption one makes concerning the types of capacity that will be displaced in the future, the costs of that capacity and the non-array systems costs.

V. Summary

The simulation work carried on by the MIT Energy Laboratory has focused on measurement of the estimation of the worth of photovoltaic power systems to owners in the residential, commercial, and central power sectors. This analysis has focused on the benefits of load and weather-matching on an hourly basis throughout the year. The analysis has shown the value of residential systems to be greater than those of either school or central power systems. All analyses are highly sensitive to assumptions concerning the non-modular system costs. In addition, results are sensitive to fuel escalation, discount rate, and assumptions concerning future costs of alternative capital stocks. One significant result which emerges from this analysis is that while the potential for storage at the dispersal site appears minimal, centralized storage in the form of pumped hydro as a complement to photovoltaics appears to have a highpotential. Complementarity of these two potential sources requires additional analysis.

TABLE 11
1990 Annual Additions to Capacity by Region

	I	II	III	IV	V	VI	TOTAL
1975 Installed Capacity in Megawatts	148,883	38,929	114,859	108,061	54,369	41,411	507,312
Population 1990	55,507	10,844	60,669	70,275	33,771	13,579	244,645
Additions to Stock of Generating Capacity in 1990*(MW)	9556	1867	10,445	12,098	5,814	2338	42,117
Total Installed Capacity in 1990 (MW)	213,365	41,684	233,208	270,133	129,814	52,197	940,400

*Source: Electrical World,"28th Annual Electrical Industry Forecast," September 15, 1977

FOOTNOTES

[1]Richard Tabors and Paul Carpenter. Methodology and Definition of Solar Photovoltaic Planning Regions, Massachusetts Institute of Technology Energy Laboratory. Technical Report Forthcoming.

[2]Jesse Tatum. "Photovoltaic/Hybrid Simulation Model for Grid Interconnected Residential Applications", April 1978, forthcoming.

[3] U.S. Department of Commerce, Bureau of Census. Demographic Projections Of The United States, CRR P-24, No. 476, February 1972.

[4]EPRI, Synthetic Electric Utility Systems for Evaluating Advanced Technologies EPRI EM-285 February 1977.

APPENDIX I

Methodology for Calculation of Capacity Credit Values
For Photovoltaic Central Power Applications

The value of capacity replaced (effective capacity) for photovoltaic power systems used in Central Power Applications has been calculated using 1976 average cost of capital figures for small-scale plants (500 MW) taken from Electrical World.

To equate the photovoltaic generation capacity to the actual quantity of megawatts replaced requires consideration of the forced outage rate of the conventional system as well.

Capital costs were:

	$/KW*	Forced Outage Rate**	Cost Comparison ($/KW)
Base/Intermediate Oil	212	.835	254
"All Stations"	275	.833	230
Coal	387	.835	463
Nuclear	450	.736	611

*Source: Electrical World, "20th Station Cost Survey," November 15, 1977.

**Source: EPRI Synthetic Utilities Assumptions Concerning Forced Outage Rates.

APPENDIX II

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*************************************************************************
*                                                                       *
*                              G.E.M.                                   *
*              THE M.I.T. GENERATION EXPANSION MODEL                    *
*                                                                       *
*                           MIAMI RUN M                                 *
*              MULTIPLE VALVE POINTS 6 200 MW PV PLANTS                 *
*                      BASED ON SCENARIO F                              *
*               MIAMI LOAD AND COST DATA FOR 1975                       *
*                                                                       *
*        START YEAR: 1975                          END YEAR:    1995    *
*        PERIODS:     20                         LENGTH(HR): 8736.      *
*                    DISCOUNT RATE:* 10.000 %                           *
*                                                                       *
*                         6/24/78  3*31*49.00                           *
*                                                                       *
*                    LOAD CARRYING CAPABILITY REPORT                    *
*                                                                       *
*                                                                       *
*************************************************************************
```

* Nominal Discount Rate. Real Discount Rate ≃ 3%

MIAMI RUN M

BASE CASE:

CLASS	BASE CASE CLASS CAPACITY	BASE CASE CLASS CAPACITY FACTOR	BASE CASE ENERGY (MWH/YR)	BASE CASE FUEL COST (THOU $)	BASE CASE O&M COST (THOU $)	TOTAL COST (THOU $)
COAL INTR	200.0	0.8484	1482314.0	238479.9	14395.1	252874.9
OIL INTR	3600.0	0.4453	14004296.0	4215926.0	47602.0	4263528.0
OIL BASE	600.0	0.7286	3819232.0	1111176.0	12982.1	1124158.0
CT PEAK	200.0	0.0154	26848.5	11435.5	632.1	12067.6
NUC BASE	1200.0	0.7764	8139110.0	534336.9	60271.3	594608.2
PHY PEAK	250.0	0.0010	2264.3	383.2	0.0	383.2
CHY INTR	500.0	0.2464	1076170.0	0.0	0.0	0.0
TOTALS:	6550.0	0.4989	28550208.0	6111735.0	135882.6	6247617.0

COSTS ARE NET PRESENT VALUE OF THE ANNUAL OPERATING COSTS OVER A LIFETIME OF 20 YEARS

EFFECTIVE LOAD CARRYING CAPABILITY OF 0. MWS = 0.0 MEGAWATTS

MIAMI RUN M

CASE: 2 1.0 200. MW PLANTS

CLASS	NEW CLASS CAPACITY FACTOR	CHANGE IN CLASS CAPACITY FACTOR	CHANGE IN ENERGY (MWH/YR)	CHANGE IN FUEL COST ($/WATT)	CHANGE IN O&M COST ($/WATT)	NET BENEFITS ($/WATT)
COAL INTR	0.8481	-0.0003	-538.0	-0.000	-0.000	0.000
OIL INTR	0.4358	-0.0095	-297531.0	-0.460	-0.005	0.465
OIL BASE	0.7286	-0.0000	-55.0	-0.000	0.0	0.000
CT PEAK	0.0139	-0.0014	-2506.7	-0.005	-0.000	0.006
NUC BASE	0.7764	0.0	0.0	0.0	0.0	0.0
PHY PEAK	0.0010	-0.0000	-24.1	-0.000	0.0	0.000
CHY INTR	0.2472	0.0009	3809.0	0.0	0.0	0.0
TOTALS:	0.4938		-296845.7	-0.466	-0.005	0.472

COSTS ARE NET PRESENT VALUE OF THE BENEFIT OF THE ADDITIONAL PLANTS OVER A LIFETIME OF 20 YEARS

EFFECTIVE LOAD CARRYING CAPABILITY OF 200. MWS = 33.29 MEGAWATTS

MIAMI RUN M

CASE: 3 2.0 200. MW PLANTS

CLASS	NEW CLASS CAPACITY FACTOR	CHANGE IN CLASS CAPACITY FACTOR	CHANGE IN ENERGY (MWH/YR)	CHANGE IN FUEL COST ($/WATT)	CHANGE IN O&M COST ($/WATT)	NET BENEFITS ($/WATT)
COAL INTR	0.8474	-0.0010	-1745.0	-0.001	-0.000	0.001
OIL INTR	0.4271	-0.0182	-571110.0	-0.440	-0.005	0.444
OIL BASE	0.7286	-0.0001	-326.0	-0.000	-0.000	0.000
CT PEAK	0.0130	-0.0023	-4055.9	-0.004	-0.000	0.005
NUC BASE	0.7764	0.0	0.0	0.0	0.0	0.0
PHY PEAK	0.0011	0.0001	192.1	0.000	0.0	-0.000
CHY INTR	0.2480	0.0016	7060.0	0.0	0.0	0.0
TOTALS:	0.4890		-569984.7	-0.445	-0.005	0.450

COSTS ARE NET PRESENT VALUE OF THE BENEFIT OF THE ADDITIONAL PLANTS OVER A LIFETIME OF 20 YEARS

EFFECTIVE LOAD CARRYING CAPABILITY OF 400. MWS = 58.71 MEGAWATTS

MIAMI RUN M

CASE: 4 3.0 200. MW PLANTS

CLASS	NEW CLASS CAPACITY FACTOR	CHANGE IN CLASS CAPACITY FACTOR	CHANGE IN ENERGY (MWH/YR)	CHANGE IN FUEL COST ($/WATT)	CHANGE IN O&M COST ($/WATT)	NET BENEFITS ($/WATT)
COAL INTR	0.8461	-0.0023	-4025.0	-0.001	-0.000	0.001
OIL INTR	0.4186	-0.0266	-837956.0	-0.430	-0.005	0.435
OIL BASE	0.7284	-0.0003	-1345.0	-0.001	-0.000	0.001
CT PEAK	0.0124	-0.0029	-5151.5	-0.004	-0.000	0.004
NUC BASE	0.7764	0.0	0.0	0.0	0.0	0.0
PHY PEAK	0.0014	0.0004	818.5	0.000	0.0	-0.000
CHY INTR	0.2486	0.0022	9825.0	0.0	0.0	0.0
TOTALS:	0.4843		-837834.0	-0.435	-0.005	0.440

COSTS ARE NET PRESENT VALUE OF THE BENEFIT OF THE ADDITIONAL PLANTS OVER A LIFETIME OF 20 YEARS

EFFECTIVE LOAD CARRYING CAPABILITY OF 600. MWS = 84.87 MEGAWATTS

MIAMI RUN M

CASE: 5 4.0 200. MW PLANTS

CLASS	NEW CLASS CAPACITY FACTOR	CHANGE IN CLASS CAPACITY FACTOR	CHANGE IN ENERGY (MWH/YR)	CHANGE IN FUEL COST ($/WATT)	CHANGE IN O&M COST ($/WATT)	NET BENEFITS ($/WATT)
COAL INTR	0.8443	-0.0041	-7113.0	-0.001	-0.000	0.001
OIL INTR	0.4100	-0.0353	-1111382.0	-0.428	-0.005	0.433
OIL BASE	0.7279	-0.0007	-3855.0	-0.001	-0.000	0.001
CT PEAK	0.0119	-0.0035	-6037.2	-0.003	-0.000	0.003
NUC BASE	0.7764	0.0	0.0	0.0	0.0	0.0
PHY PEAK	0.0021	0.0011	2331.1	0.001	0.0	-0.001
CHY INTR	0.2515	0.0051	22338.0	0.0	0.0	0.0
TOTALS:	0.4797		-1103717.0	-0.433	-0.005	0.438

COSTS ARE NET PRESENT VALUE OF THE BENEFIT OF THE ADDITIONAL PLANTS OVER A LIFETIME OF 20 YEARS

EFFECTIVE LOAD CARRYING CAPABILITY OF 800. MWS = 115.66 MEGAWATTS

MIAMI RUN M

CASE: 6 5.0 200. MW PLANTS

CLASS	NEW CLASS CAPACITY FACTOR	CHANGE IN CLASS CAPACITY FACTOR	CHANGE IN ENERGY (MWH/YR)	CHANGE IN FUEL COST ($/WATT)	CHANGE IN O&M COST ($/WATT)	NET BENEFITS ($/WATT)
COAL INTR	0.8419	-0.0065	-11337.0	-0.002	-0.000	0.002
OIL INTR	0.4022	-0.0431	-1354835.0	-0.417	-0.005	0.421
OIL BASE	0.7271	-0.0016	-8151.0	-0.002	-0.000	0.002
CT PEAK	0.0110	-0.0043	-7565.2	-0.003	-0.000	0.003
NUC BASE	0.7764	-0.0000	-46.0	-0.000	-0.000	0.000
PHY PEAK	0.0033	0.0023	4920.1	0.001	0.0	-0.001
CHY INTR	0.2497	0.0033	14506.0	0.0	0.0	0.0
TOTALS:	0.4751		-1362507.0	-0.423	-0.005	0.428

COSTS ARE NET PRESENT VALUE OF THE BENEFIT OF THE ADDITIONAL PLANTS OVER A LIFETIME OF 20 YEARS

EFFECTIVE LOAD CARRYING CAPABILITY OF 1000. MWS = 145.44 MEGAWATTS

MIAMI RUN M

CASE: 7 6.0 200. MW PLANTS

CLASS	NEW CLASS CAPACITY FACTOR	CHANGE IN CLASS CAPACITY FACTOR	CHANGE IN ENERGY (MWH/YR)	CHANGE IN FUEL COST ($/WATT)	CHANGE IN O&M COST ($/WATT)	NET BENEFITS ($/WATT)
COAL INTR	0.8397	-0.0087	-15208.0	-0.002	-0.000	0.002
OIL INTR	0.3939	-0.0514	-1617846.0	-0.414	-0.005	0.418
OIL BASE	0.7258	-0.0028	-14642.0	-0.003	-0.000	0.003
CT PEAK	0.0102	-0.0051	-8990.0	-0.003	-0.000	0.003
NUC BASE	0.7764	-0.0000	-434.0	-0.000	-0.000	0.000
PHY PEAK	0.0052	0.0041	8983.9	0.001	0.0	-0.001
CHY INTR	0.2538	0.0074	32371.0	0.0	0.0	0.0
TOTALS:	0.4707		-1615765.0	-0.421	-0.005	0.426

COSTS ARE NET PRESENT VALUE OF THE BENEFIT OF THE ADDITIONAL PLANTS OVER A LIFETIME OF 20 YEARS

EFFECTIVE LOAD CARRYING CAPABILITY OF 1200. MWS = 167.86 MEGAWATTS

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G.E.M.
THE M.I.T. GENERATION EXPANSION MODEL

BOSTON RUN
MULTIPLE VALVE POINTS 6 200 MW PV PLANT
*BASED ON SCENARIO F*
BOSTON LOAD AND COST DATA FOR 1975

START YEAR: 1975                                  END YEAR:    1995
PERIODS:     20                                   LENGTH(HR): 8736.
                  DISCOUNT RATE:*  10.000 %

                  6/24/78  3*14*21.00

                  LOAD CARRYING CAPABILITY REPORT
```

* Nominal Discount Rate. Real Discount Rate = 3%

BOSTON RUN

BASE CASE:

CLASS	BASE CASE CLASS CAPACITY	BASE CASE CLASS CAPACITY FACTOR	BASE CASE ENERGY (MWH/YR)	BASE CASE FUEL COST (THOU $)	BASE CASE O&M COST (THOU $)	TOTAL COST (THOU $)
COAL INTR	200.0	0.8536	1491385.0	239901.4	14484.1	254385.5
OIL INTR	3600.0	0.5253	16520691.0	5200939.0	56154.6	5257093.0
OIL BASE	600.0	0.7898	4139796.0	1255890.0	14072.0	1269962.0
CT PEAK	200.0	0.0563	98354.9	55614.9	2315.9	57930.8
NUC BASE	1200.0	0.7763	8138617.0	534305.2	71134.7	605439.9
PHY PEAK	250.0	0.0006	1290.3	170.1	0.0	170.1
CHY INTR	500.0	0.2712	1184490.0	0.0	0.0	0.0
TOTALS:	6550.0	0.5518	31574576.0	7286819.0	153161.2	7444980.0

COSTS ARE NET PRESENT VALUE OF THE ANNUAL OPERATING COSTS OVER A LIFETIME OF 20 YEARS

EFFECTIVE LOAD CARRYING CAPABILITY OF 0. MWS = 0.0 MEGAWATTS

BOSTON RUN

CASE: 2 1.0 200. MW PLANTS

CLASS	NEW CLASS CAPACITY FACTOR	CHANGE IN CLASS CAPACITY FACTOR	CHANGE IN ENERGY (MWH/YR)	CHANGE IN FUEL COST ($/WATT)	CHANGE IN O&M COST ($/WATT)	NET BENEFITS ($/WATT)
COAL INTR	0.8532	-0.0004	-618.0	-0.000	-0.000	0.001
OIL INTR	0.5159	-0.0094	-295333.0	-0.473	-0.005	0.478
OIL BASE	0.7848	-0.0000	-101.0	-0.000	-0.000	0.000
CT PEAK	0.0493	-0.0070	-12289.2	-0.035	-0.001	0.036
NUC BASE	0.7763	0.0	0.0	0.0	0.0	0.0
PHY PEAK	0.0006	0.0000	64.1	0.000	0.0	-0.000
CHY INTR	0.2632	-0.0029	-12796.0	0.0	0.0	0.0
TOTALS:	0.5462		-321073.1	-0.509	-0.006	0.515

COSTS ARE NET PRESENT VALUE OF THE BENEFIT OF THE ADDITIONAL PLANTS OVER A LIFETIME OF 20 YEARS

EFFECTIVE LOAD CARRYING CAPABILITY OF 200. MWS = 62.76 MEGAWATTS

BOSTON RUN

CASE: 3 2.0 200. MW PLANTS

CLASS	NEW CLASS CAPACITY FACTOR	CHANGE IN CLASS CAPACITY FACTOR	CHANGE IN ENERGY (MWH/YR)	CHANGE IN FUEL COST ($/WATT)	CHANGE IN O&M COST ($/WATT)	NET BENEFITS ($/WATT)
COAL INTR	0.8524	-0.0012	-2143.0	-0.001	-0.000	0.001
OIL INTR	0.5064	-0.0189	-593864.0	-0.476	-0.005	0.481
OIL BASE	0.7896	-0.0002	-979.0	-0.001	-0.000	0.001
CT PEAK	0.0445	-0.0118	-20628.7	-0.029	-0.001	0.030
NUC BASE	0.7763	0.0	0.0	0.0	0.0	0.0
PHY PEAK	0.0009	0.0003	624.7	0.000	0.0	-0.000
CHY INTR	0.2684	-0.0028	-12200.0	0.0	0.0	0.0
TOTALS:	0.5408		-629190.0	-0.506	-0.006	0.513

COSTS ARE NET PRESENT VALUE OF THE BENEFIT OF THE ADDITIONAL PLANTS OVER A LIFETIME OF 20 YEARS

EFFECTIVE LOAD CARRYING CAPABILITY OF 400. MWS = 112.67 MEGAWATTS

BOSTON RUN

CASE: 4 3.0 200. MW PLANTS

CLASS	NEW CLASS CAPACITY FACTOR	CHANGE IN CLASS CAPACITY FACTOR	CHANGE IN ENERGY (MWH/YR)	CHANGE IN FUEL COST ($/WATT)	CHANGE IN O&M COST ($/WATT)	NET BENEFITS ($/WATT)
COAL INTR	0.8509	-0.0027	-4779.0	-0.001	-0.000	0.001
OIL INTR	0.4969	-0.0284	-892784.0	-0.476	-0.005	0.481
OIL BASE	0.7890	-0.0008	-4238.0	-0.002	-0.000	0.002
CT PEAK	0.0411	-0.0152	-26539.2	-0.025	-0.001	0.026
NUC BASE	0.7763	0.0	0.0	0.0	0.0	0.0
PHY PEAK	0.0018	0.0012	2650.0	0.001	0.0	-0.001
CHY INTR	0.2673	-0.0039	-16938.0	0.0	0.0	0.0
TOTALS:	0.5353		-942628.2	-0.504	-0.006	0.510

COSTS ARE NET PRESENT VALUE OF THE BENEFIT OF THE ADDITIONAL PLANTS OVER A LIFETIME OF 20 YEARS

EFFECTIVE LOAD CARRYING CAPABILITY OF 600. MWS = 154.15 MEGAWATTS

BOSTON RUN

CASE: 5 4.0 200. MW PLANTS

CLASS	NEW CLASS CAPACITY FACTOR	CHANGE IN CLASS CAPACITY FACTOR	CHANGE IN ENERGY (MWH/YR)	CHANGE IN FUEL COST ($/WATT)	CHANGE IN O&M COST ($/WATT)	NET BENEFITS ($/WATT)
COAL INTR	0.8483	-0.0053	-9254.0	-0.002	-0.000	0.002
OIL INTR	0.4871	-0.0382	-1200406.0	-0.480	-0.005	0.485
OIL BASE	0.7376	-0.0022	-11423.0	-0.004	-0.000	0.004
CT PEAK	0.0386	-0.0177	-30949.7	-0.022	-0.001	0.023
NUC BASE	0.7763	-0.0000	-303.0	-0.000	-0.000	0.000
PHY PEAK	0.0039	0.0034	7335.1	0.002	0.0	-0.002
CHY INTR	0.2704	-0.0007	-3203.0	0.0	0.0	0.0
TOTALS:	0.5300		-1248202.0	-0.506	-0.006	0.512

COSTS ARE NET PRESENT VALUE OF THE BENEFIT OF THE ADDITIONAL PLANTS OVER A LIFETIME OF 20 YEARS

EFFECTIVE LOAD CARRYING CAPABILITY OF 800. MWS = 194.17 MEGAWATTS

BOSTON RUN

CASE: 6 5.0 200. MW PLANTS

CLASS	NEW CLASS CAPACITY FACTOR	CHANGE IN CLASS CAPACITY FACTOR	CHANGE IN ENERGY (MWH/YR)	CHANGE IN FUEL COST ($/WATT)	CHANGE IN O&M COST ($/WATT)	NET BENEFITS ($/WATT)
COAL INTR	0.8454	-0.0082	-14376.0	-0.002	-0.000	0.002
OIL INTR	0.4781	-0.0473	-1486007.0	-0.476	-0.005	0.481
OIL BASE	0.7855	-0.0043	-22764.0	-0.007	-0.000	0.007
CT PEAK	0.0368	-0.0195	-34130.0	-0.019	-0.001	0.020
NUC BASE	0.7762	-0.0002	-1940.0	-0.000	-0.000	0.000
PHY PEAK	0.0077	0.0071	15478.3	0.003	0.0	-0.003
CHY INTR	0.2712	-0.0000	-66.0	0.0	0.0	0.0
TOTALS:	0.5248		-1543803.0	-0.501	-0.006	0.507

COSTS ARE NET PRESENT VALUE OF THE BENEFIT OF THE ADDITIONAL PLANTS OVER A LIFETIME OF 20 YEARS

EFFECTIVE LOAD CARRYING CAPABILITY OF 1000. MWS = 230.29 MEGAWATTS

BOSTON RUN

G.E.M.

CASE: 7 6.0 200. MW PLANTS

CLASS	NEW CLASS CAPACITY FACTOR	CHANGE IN CLASS CAPACITY FACTOR	CHANGE IN ENERGY (MWH/YR)	CHANGE IN FUEL COST ($/WATT)	CHANGE IN O&M COST ($/WATT)	NET BENEFITS ($/WATT)
COAL INTR	0.8416	-0.0120	-20994.0	-0.003	-0.000	0.003
OIL INTR	0.4688	-0.0565	-1777068.0	-0.473	-0.005	0.478
OIL BASE	0.7825	-0.0073	-33121.0	-0.009	-0.000	0.009
CT PEAK	0.0344	-0.0219	-38260.9	-0.018	-0.001	0.019
NUC BASE	0.7757	-0.0007	-6870.0	-0.000	-0.000	0.000
PHY PEAK	0.0135	0.0130	28295.1	0.004	0.0	-0.004
CHY INTR	0.2734	0.0022	9803.0	0.0	0.0	0.0
TOTALS:	0.5196		-1843214.0	-0.499	-0.006	0.506

COSTS ARE NET PRESENT VALUE OF THE BENEFIT OF THE ADDITIONAL PLANTS OVER A LIFETIME OF 20 YEARS

EFFECTIVE LOAD CARRYING CAPABILITY OF 1200. MWS = 261.61 MEGAWATTS

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G.E.M.
THE M.I.T. GENERATION EXPANSION MODEL

PHOENIX RUN M
MULTIPLE VAVE POINTS  6 200 MW PV PLANTS
BASED ON SCENARIO B
PHOENIX LOAD AND COST DATA FOR 1975

START YEAR: 1975                                END YEAR:    1995
PERIODS:    20                                  LENGTH(HR): 8736.
DISCOUNT RATE:* 10.000 %

6/24/78  2*30*50.00

LOAD CARRYING CAPABILITY REPORT
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* Nominal Discount Rate. Real Discount Rate = 3%

BASE CASE:

CLASS	BASE CASE CLASS CAPACITY	BASE CASE CLASS CAPACITY FACTOR	BASE CASE ENERGY (MWH/YR)	BASE CASE FUEL COST (THOU $)	BASE CASE O&M COST (THOU $)	TOTAL COST (THOU $)
COAL INTR	200.0	0.8477	1481133.0	86252.2	17081.0	103333.2
COAL BASE	1400.0	0.7134	8725228.0	465048.2	100624.2	565672.5
OIL INTR	1600.0	0.7095	9916484.0	3290583.0	33706.8	3324289.0
OIL BASE	800.0	0.8030	5611836.0	1712648.0	19075.1	1731723.0
CT PEAK	400.0	0.2207	771074.2	193013.3	18159.5	211172.7
PHY PEAK	200.0	0.0000	52.7	9.7	0.0	9.7
CHY INTR	2950.0	0.1243	3202546.0	0.0	0.0	0.0
TOTALS:	7550.0	0.4504	29708320.0	5747553.0	183646.6	5936199.0

COSTS ARE NET PRESENT VALUE OF THE ANNUAL OPERATING COSTS OVER A LIFETIME OF 20 YEARS

EFFECTIVE LOAD CARRYING CAPABILITY OF . 0. MWS = 0.0 MEGAWATTS

PHOENIX RUN M

CASE: 2 1.0 200. MW PLANTS

CLASS	NEW CLASS CAPACITY FACTOR	CHANGE IN CLASS CAPACITY FACTOR	CHANGE IN ENERGY (MWH/YR)	CHANGE IN FUEL COST ($/WATT)	CHANGE IN O&M COST ($/WATT)	NET BENEFITS ($/WATT)
COAL INTR	0.8471	-0.0006	-1002.0	-0.000	-0.000	0.000
COAL BASE	0.7134	0.0	0.0	0.0	0.0	0.0
OIL INTR	0.6965	-0.0129	-180801.0	-0.295	-0.003	0.298
OIL BASE	0.8030	-0.0000	-99.0	-0.000	0.0	0.000
CT PEAK	0.1977	-0.0230	-80215.8	-0.079	-0.009	0.089
PHY PEAK	0.0000	0.0000	1.8	0.000	0.0	-0.000
CHY INTR	0.1203	-0.0040	-102973.0	0.0	0.0	0.0
TOTALS:	0.4449		-365089.0	-0.374	-0.013	0.387

COSTS ARE NET PRESENT VALUE OF THE BENEFIT OF THE ADDITIONAL PLANTS OVER A LIFETIME OF 20 YEARS

EFFECTIVE LOAD CARRYING CAPABILITY OF 200. MWS = 107.77 MEGAWATTS

PHOENIX RUN M

CASE: 3 2.0 200. MW PLANTS

CLASS	NEW CLASS CAPACITY FACTOR	CHANGE IN CLASS CAPACITY FACTOR	CHANGE IN ENERGY (MWH/YR)	CHANGE IN FUEL COST ($/WATT)	CHANGE IN O&M COST ($/WATT)	NET BENEFITS ($/WATT)
COAL INTR	0.8459	-0.0019	-3236.0	-0.000	-0.000	0.001
COAL BASE	0.7134	0.0	0.0	0.0	0.0	0.0
OIL INTR	0.6806	-0.0288	-403185.0	-0.327	-0.003	0.330
OIL BASE	0.8029	-0.0001	-503.0	-0.000	-0.000	0.000
CT PEAK	0.1869	-0.0338	-118117.6	-0.060	-0.007	0.067
PHY PEAK	0.0001	0.0000	56.7	0.000	0.0	-0.000
CHY INTR	0.1171	-0.0072	-184387.0	0.0	0.0	0.0
TOTALS:	0.4397		-709371.8	-0.387	-0.010	0.398

COSTS ARE NET PRESENT VALUE OF THE BENEFIT OF THE ADDITIONAL PLANTS OVER A LIFETIME OF 20 YEARS

EFFECTIVE LOAD CARRYING CAPABILITY OF 400. MWS = 202.27 MEGAWATTS

PHOENIX RUN M

CASE: 4 3.0 200. MW PLANTS

CLASS	NEW CLASS CAPACITY FACTOR	CHANGE IN CLASS CAPACITY FACTOR	CHANGE IN ENERGY (MWH/YR)	CHANGE IN FULL COST ($/WATT)	CHANGE IN O&M COST ($/WATT)	NET BENEFITS ($/WATT)
COAL INTR	0.8437	-0.0040	-7058.0	-0.001	-0.000	0.001
COAL BASE	0.7134	0.0	0.0	0.0	0.0	0.0
OIL INTR	0.6658	-0.0436	-609787.0	-0.332	-0.003	0.335
OIL BASE	0.3027	-0.0003	-1776.0	-0.001	-0.000	0.001
CT PEAK	0.1765	-0.0441	-154175.6	-0.053	-0.006	0.059
PHY PEAK	0.0001	0.0001	111.1	0.000	0.0	-0.000
CHY INTR	0.1136	-0.0106	-274210.0	0.0	0.0	0.0
TOTALS:	0.4345		-1046895.4	-0.386	-0.010	0.396

COSTS ARE NET PRESENT VALUE OF THE BENEFIT OF THE ADDITIONAL PLANTS OVER A LIFETIME OF 20 YEARS

EFFECTIVE LOAD CARRYING CAPABILITY OF 600. MWS = 289.34 MEGAWATTS

PHOENIX RUN M

CASE: 5 4.0 200. MW PLANTS

CLASS	NEW CLASS CAPACITY FACTOR	CHANGE IN CLASS CAPACITY FACTOR	CHANGE IN ENERGY (MWH/YR)	CHANGE IN FUEL COST ($/WATT)	CHANGE IN O&M COST ($/WATT)	NET BENEFITS ($/WATT)
COAL INTR	0.8410	-0.0068	-11799.0	-0.001	-0.000	0.001
COAL BASE	0.7134	0.0	0.0	0.0	0.0	0.0
OIL INTR	0.6496	-0.0599	-637157.0	-0.344	-0.004	0.348
OIL BASE	0.8023	-0.0007	-5062.0	-0.002	-0.000	0.002
CT PEAK	0.1667	-0.0540	-188657.7	-0.049	-0.006	0.055
PHY PEAK	0.0002	0.0001	223.8	0.000	0.0	-0.000
CHY INTR	0.1112	-0.0130	-335551.0	0.0	0.0	0.0
TOTALS:	0.4295		-1378002.0	-0.396	-0.009	0.405

COSTS ARE NET PRESENT VALUE OF THE BENEFIT OF THE ADDITIONAL PLANTS OVER A LIFETIME OF 20 YEARS

EFFECTIVE LOAD CARRYING CAPABILITY OF 800. MWS = 369.45 MEGAWATTS

PHOENIX RUN M

CASE: 6 5.0 200. MW PLANTS

CLASS	NEW CLASS CAPACITY FACTOR	CHANGE IN CLASS CAPACITY FACTOR	CHANGE IN ENERGY (MWH/YR)	CHANGE IN FUEL COST ($/WATT)	CHANGE IN O&M COST ($/WATT)	NET BENEFITS ($/WATT)
COAL INTR	0.8372	-0.0105	-18336.0	-0.001	-0.000	0.001
COAL BASE	0.7134	0.0	0.0	0.0	0.0	0.0
OIL INTR	0.6323	-0.0772	-1078907.0	-0.355	-0.004	0.359
OIL BASE	0.8014	-0.0016	-11003.0	-0.003	-0.000	0.003
CT PEAK	0.1596	-0.0610	-213233.8	-0.045	-0.005	0.050
PHY PEAK	0.0002	0.0002	373.8	0.000	0.0	-0.000
CHY INTR	0.1095	-0.0148	-380452.0	0.0	0.0	0.0
TOTALS:	0.4246		-1701557.0	-0.405	-0.009	0.413

COSTS ARE NET PRESENT VALUE OF THE BENEFIT OF THE ADDITIONAL PLANTS OVER A LIFETIME OF 20 YEARS

EFFECTIVE LOAD CARRYING CAPABILITY OF 1000. MWS = 447.26 MEGAWATTS

PHOENIX RUN M

CASE: 7 6.0 200. MW PLANTS

CLASS	NEW CLASS CAPACITY FACTOR	CHANGE IN CLASS CAPACITY FACTOR	CHANGE IN ENERGY (MWH/YR)	CHANGE IN FUEL COST ($/WATT)	CHANGE IN O&M COST ($/WATT)	NET BENEFITS ($/WATT)
COAL INTR	0.8325	-0.0152	-26639.0	-0.001	-0.000	0.002
COAL BASE	0.7134	0.0	0.0	0.0	0.0	0.0
OIL INTR	0.6158	-0.0937	-1309157.0	-0.360	-0.004	0.363
OIL BASE	0.8001	-0.0028	-19862.0	-0.005	-0.000	0.005
CT PEAK	0.1555	-0.0652	-227705.1	-0.041	-0.004	0.045
PHY PEAK	0.0002	0.0002	383.4	0.000	0.0	-0.000
CHY INTR	0.1072	-0.0171	-440735.0	0.0	0.0	0.0
TOTALS:	0.4197		-2023714.0	-0.406	-0.008	0.415

COSTS ARE NET PRESENT VALUE OF THE BENEFIT OF THE ADDITIONAL PLANTS OVER A LIFETIME OF 20 YEARS

EFFECTIVE LOAD CARRYING CAPABILITY OF 1200. MWS = 506.41 MEGAWATTS

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G.E.M.
THE M.I.T. GENERATION EXPANSION MODEL

OMAHA RUN M
MULTIPLE VALVE POINTS 6 200 MW PV PLANT
BASED ON SCENARIO C
OMAHA LOAD AND COST DATA FOR 1975

START YEAR: 1975                              END YEAR:   1995
PERIODS:    20                                LENGTH(HR): 8736.
              DISCOUNT RATE:* 10.000 %

6/24/78  2*53*25.00

LOAD CARRYING CAPABILITY REPORT
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* Nominal Discount Rate. Real Discount Rate = 3%

BASE CASE:

CLASS	BASE CASE CLASS CAPACITY	BASE CASE CLASS CAPACITY FACTOR	BASE CASE ENERGY (MWH/YR)	BASE CASE FUEL COST (THOU $)	BASE CASE O&M COST (THOU $)	TOTAL COST (THOU $)
COAL PEAK	900.0	0.0182	143010.4	19875.3	1597.3	21472.6
COAL INTR	1600.0	0.3589	5016773.0	603864.9	56028.7	659893.6
COAL BASE	1000.0	0.7457	6514807.0	733384.2	72760.0	806144.2
OIL PEAK	450.0	0.0026	10387.2	3549.7	35.6	3585.4
OIL INTR	400.0	0.0774	270464.6	79663.6	919.5	80583.1
OIL BASE	800.0	0.6782	4739974.0	1315982.0	16111.9	1332093.0
CT PEAK	100.0	0.0037	3239.2	643.6	76.3	719.9
NUC BASE	1100.0	0.7683	7382750.0	503323.7	58255.6	561579.3
PHY PEAK	300.0	0.0478	125339.7	16798.2	0.0	16798.2
CHY INTR	750.0	0.2164	1418138.0	0.0	0.0	0.0
TOTALS:	7400.0	0.3964	25624848.0	3277082.0	205784.8	3482866.0

COSTS ARE NET PRESENT VALUE OF THE ANNUAL OPERATING COSTS OVER A LIFETIME OF 20 YEARS

EFFECTIVE LOAD CARRYING CAPABILITY OF 0. MWS = 0.0 MEGAWATTS

OMAHA RUN M

CASE: 2 1.0 200. MW PLANTS

CLASS	NEW CLASS CAPACITY FACTOR	CHANGE IN CLASS CAPACITY FACTOR	CHANGE IN ENERGY (MWH/YR)	CHANGE IN FUEL COST ($/WATT)	CHANGE IN O&M COST ($/WATT)	NET BENEFITS ($/WATT)
COAL PEAK	0.0164	-0.0018	-14384.5	-0.010	-0.001	0.011
COAL INTR	0.3390	-0.0199	-278212.0	-0.169	-0.016	0.184
COAL BASE	0.7401	-0.0056	-49041.0	-0.027	-0.003	0.030
OIL PEAK	0.0024	-0.0002	-835.1	-0.001	-0.000	0.001
OIL INTR	0.0640	-0.0134	-46349.4	-0.066	-0.001	0.067
OIL BASE	0.6644	-0.0138	-96582.0	-0.133	-0.002	0.135
CT PEAK	0.0034	-0.0003	-258.4	-0.000	-0.000	0.000
NUC BASE	0.7683	0.0	0.0	0.0	0.0	0.0
PHY PEAK	0.0467	-0.0011	-2933.8	-0.005	0.0	0.005
CHY INTR	0.2191	0.0027	17505.0	0.0	0.0	0.0
TOTALS:	0.3891		-471591.2	-0.412	-0.022	0.434

COSTS ARE NET PRESENT VALUE OF THE BENEFIT OF THE ADDITIONAL PLANTS OVER A LIFETIME OF 20 YEARS

EFFECTIVE LOAD CARRYING CAPABILITY OF 200. MWS = 27.34 MEGAWATTS

OMAHA RUN M

CASE: 3 2.0 200. MW PLANTS

CLASS	NEW CLASS CAPACITY FACTOR	CHANGE IN CLASS CAPACITY FACTOR	CHANGE IN ENERGY (MWH/YR)	CHANGE IN FUEL COST ($/WATT)	CHANGE IN O&M COST ($/WATT)	NET BENEFITS ($/WATT)
COAL PEAK	0.0153	-0.0029	-22868.5	-0.008	-0.001	0.009
COAL INTR	0.3212	-0.0377	-527422.0	-0.159	-0.015	0.173
COAL BASE	0.7319	-0.0138	-120581.0	-0.033	-0.003	0.037
OIL PEAK	0.0023	-0.0003	-1240.5	-0.001	-0.000	0.001
OIL INTR	0.0565	-0.0209	-73022.3	-0.053	-0.001	0.054
OIL BASE	0.6502	-0.0280	-195750.0	-0.135	-0.002	0.137
CT PEAK	0.0033	-0.0005	-394.9	-0.000	-0.000	0.000
NUC BASE	0.7683	-0.0000	-31.0	-0.000	-0.000	0.000
PHY PEAK	0.0457	-0.0022	-5647.5	-0.006	0.0	0.006
CHY INTR	0.2204	0.0039	25629.0	0.0	0.0	0.0
TOTALS:	0.3621		-921328.7	-0.395	-0.021	0.416

COSTS ARE NET PRESENT VALUE OF THE BENEFIT OF THE ADDITIONAL PLANTS OVER A LIFETIME OF 20 YEARS

EFFECTIVE LOAD CARRYING CAPABILITY OF 400. MWS = 41.06 MEGAWATTS

OMAHA RUN M

CASE: 4 3.0 200. MW PLANTS

CLASS	NEW CLASS CAPACITY FACTOR	CHANGE IN CLASS CAPACITY FACTOR	CHANGE IN ENERGY (MWH/YR)	CHANGE IN FUEL COST ($/WATT)	CHANGE IN O&M COST ($/WATT)	NET BENEFITS ($/WATT)
COAL PEAK	0.0146	-0.0036	-28317.7	-0.007	-0.001	0.007
COAL INTR	0.3049	-0.0540	-754626.0	-0.151	-0.014	0.165
COAL BASE	0.7206	-0.0252	-219816.0	-0.041	-0.004	0.045
OIL PEAK	0.0023	-0.0004	-1428.0	-0.001	-0.000	0.001
OIL INTR	0.0480	-0.0294	-102804.6	-0.050	-0.001	0.051
OIL BASE	0.6349	-0.0434	-303043.0	-0.140	-0.002	0.141
CT PEAK	0.0032	-0.0005	-464.7	-0.000	-0.000	0.000
NUC BASE	0.7677	-0.0005	-5275.0	-0.001	-0.000	0.001
PHY PEAK	0.0505	0.0027	7108.5	-0.004	0.0	0.004
CHY INTR	0.2207	0.0043	27962.0	0.0	0.0	0.0
TOTALS:	0.3750		-1380703.0	-0.393	-0.021	0.414

COSTS ARE NET PRESENT VALUE OF THE BENEFIT OF THE ADDITIONAL PLANTS OVER A LIFETIME OF 20 YEARS

EFFECTIVE LOAD CARRYING CAPABILITY OF 600. MWS = 47.17 MEGAWATTS

OMAHA RUN M

CASE: 5 4.0 200. MW PLANTS

CLASS	NEW CLASS CAPACITY FACTOR	CHANGE IN CLASS CAPACITY FACTOR	CHANGE IN ENERGY (MWH/YR)	CHANGE IN FUEL COST ($/WATT)	CHANGE IN O&M COST ($/WATT)	NET BENEFITS ($/WATT)
COAL PEAK	0.0142	-0.0040	-31531.6	-0.005	-0.000	0.006
COAL INTR	0.2936	-0.0653	-913260.0	-0.137	-0.013	0.150
COAL BASE	0.7095	-0.0362	-316185.0	-0.044	-0.004	0.048
OIL PEAK	0.0023	-0.0004	-1504.3	-0.001	-0.000	0.001
OIL INTR	0.0414	-0.0360	-125681.4	-0.045	-0.001	0.046
OIL BASE	0.6216	-0.0566	-395608.0	-0.137	-0.002	0.138
CT PEAK	0.0030	-0.0007	-590.1	-0.000	-0.000	0.000
NUC BASE	0.7653	-0.0030	-28354.0	-0.002	-0.000	0.003
PHY PEAK	0.0501	0.0022	5852.5	-0.005	0.0	0.005
CHY INTR	0.2209	0.0045	29442.0	0.0	0.0	0.0
TOTALS:	0.3689		-1777418.0	-0.377	-0.020	0.397

COSTS ARE NET PRESENT VALUE OF THE BENEFIT OF THE ADDITIONAL PLANTS OVER A LIFETIME OF 20 YEARS

EFFECTIVE LOAD CARRYING CAPABILITY OF 800. MWS = 49.48 MEGAWATTS

OMAHA RUN M

CASE: 6 5.0 200. MW PLANTS

CLASS	NEW CLASS CAPACITY FACTOR	CHANGE IN CLASS CAPACITY FACTOR	CHANGE IN ENERGY (MWH/YR)	CHANGE IN FUEL COST ($/WATT)	CHANGE IN O&M COST ($/WATT)	NET BENEFITS ($/WATT)
COAL PEAK	0.0139	-0.0043	-33950.5	-0.005	-0.000	0.005
COAL INTR	0.2830	-0.0759	-1061038.0	-0.128	-0.012	0.139
COAL BASE	0.6971	-0.0486	-424632.0	-0.047	-0.005	0.052
OIL PEAK	0.0023	-0.0004	-1539.6	-0.001	-0.000	0.001
OIL INTR	0.0378	-0.0396	-138323.9	-0.040	-0.000	0.041
OIL BASE	0.6077	-0.0705	-492703.0	-0.136	-0.002	0.138
CT PEAK	0.0030	-0.0007	-605.4	-0.000	-0.000	0.000
NUC BASE	0.7606	-0.0077	-73555.0	-0.005	-0.001	0.006
PHY PEAK	0.0500	0.0022	5710.9	-0.005	0.0	0.005
CHY INTR	0.2211	0.0046	30363.0	0.0	0.0	0.0
TOTALS:	0.3625		-2190271.0	-0.367	-0.020	0.387

COSTS ARE NET PRESENT VALUE OF THE BENEFIT OF THE ADDITIONAL PLANTS OVER A LIFETIME OF 20 YEARS

EFFECTIVE LOAD CARRYING CAPABILITY OF 1000. MWS = 50.45 MEGAWATTS

OMAHA RUN M

CASE: 7 6.0 200. MW PLANTS

CLASS	NEW CLASS CAPACITY FACTOR	CHANGE IN CLASS CAPACITY FACTOR	CHANGE IN ENERGY (MWH/YR)	CHANGE IN FUEL COST ($/WATT)	CHANGE IN O&M COST ($/WATT)	NET BENEFITS ($/WATT)
COAL PEAK	0.0132	-0.0050	-39129.2	-0.005	-0.000	0.005
COAL INTR	0.2714	-0.0876	-1223758.0	-0.123	-0.011	0.134
COAL BASE	0.6843	-0.0615	-536968.0	-0.050	-0.005	0.055
OIL PEAK	0.0022	-0.0004	-1564.1	-0.000	-0.000	0.000
OIL INTR	0.0359	-0.0415	-145036.8	-0.036	-0.000	0.036
OIL BASE	0.5933	-0.0849	-593240.0	-0.137	-0.002	0.138
CT PEAK	0.0030	-0.0007	-615.1	-0.000	-0.000	0.000
NUC BASE	0.7536	-0.0147	-141027.0	-0.008	-0.001	0.009
PHY PEAK	0.0554	0.0076	19916.0	-0.004	0.0	0.004
CHY INTR	0.2256	0.0091	59757.0	0.0	0.0	0.0
TOTALS:	0.3561		-2601724.0	-0.362	-0.020	0.382

COSTS ARE NET PRESENT VALUE OF THE BENEFIT OF THE ADDITIONAL PLANTS OVER A LIFETIME OF 20 YEARS

EFFECTIVE LOAD CARRYING CAPABILITY OF 1200. MWS = 51.26 MEGAWATTS