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PV1: AN INTERACTIVE COMPUTER MODEL TO SUPPORT COMMERCIALIZATION POLICY FOR PHOTOVOLTAICS POLICY ANALYSIS

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Preface

This report is designed to complement two others, the User Documentation and the Model Verficiation (MIT-EL-80-026 and MIT-EL-81-004, respectively). The Model Verification was written to document the theoretical bases for PV1, an interactive computer model to support commercialization policy for photovoltaics. It was also written to verify that the computer code, which is the essence of PV1, accurately performs the function that it was meant to perform.

As in many analytic procedures, there are two phases to the use of PV1: use of the model itself, and subsequent interpretation of the resutls. The first phase, the use of PV1, is covered in detail in the User Documentation. The User Documentation will evolve as PV1 evolves, as new features are added and improved data is incorporated.

The purpose of this report is to demonstrate the proper interpretation of results from PV1, to avoid abuse of these results, and to provide an example of an extended analysis. In addition, the conclusions drawn may be considered a guide for the establishment of preliminary PV commercialization policy.

Abstract

The purpose of this report is the demonstrate the use of PV1 as a policy analysis device. This analysis consists of the creation of a base case and the subsequent running of 50 additional cases to demonstrate the effects of changes in spending levels.

Acording to PV1, government policy to accelerate the commercialization of PV takes the form of spending in five areas: advertising, market development, subsidy, technology development and advanced research and development. Each of these spending areas, or policy options, has a unique effect on the acceptability of PV in the potential market, and on the price of PV. The effects of a particular policy are measured by using four policy criteria: the total number of KW_p of PV installed after 8 years; the rate at which the market is being penetrated during those 8 years; the percent of total KW_p installed after 8 years that orginates from the private sector; and the overall efficiency of the policy, as measured by the total cost of the policy divided by the total KW_p installed.

The purpose of the 50 cases was to illustrate the senstivity of the policy criteria to changes in the spending levels of the five policy options. Each of these cases is examined separately, and then the results were used to contrast multiple regression equations. The equations, one for each policy criterion as a dependent variable, have 50 cases and use the policy option spending levels as independent variables. These equations act as linear versions of PV1, and as such can help the policy maker to estimate the effects of various spending levels on the policy criteria for policies that are similar to the base case.

The most important conclusions involved subsidy and market development. It was found that both of these spending options would be most effective if they started at low levels and gradually increased over time. Compared to the base case, it was found that market development spending could be reduced and subsidy spending increased, thereby improving all of the policy criteria. In general, market development and subsidy spending should be coordinated.

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I. Introduction

I.1 Purpose

The purpose of this technical report is to demonstrate the use of PV1, an interactive computer model developed at the MIT Energy Laboratory. PV1 is designed to assist the photovoltaic policy maker in evaluating alternative policies for the accelerated commercialization of photovoltaics. To do this, PV1 has many variables that represent spending options to the policy maker, and many other variables that represent the commercialization levels that the spending is simulated to achieve. Because of the large number of these variables, a method has been chosen to summarize the relationships between the spending, or policy options (exogenously defined), and those variables that reflect commercialization levels (endogenous variables), or policy criteria.

The method used in this summary was to first select a base case involving a "most likely" set of spending levels for each policy option. The values of each of these spending levels was then changed, one at a time, in separate PV1 runs, to measure the effects on the policy options. This resulted in a total of 50 PV1 runs. The values of the 50 policy options (spending levels) and policy criteria (commercialization levels) were then used to create a data base, each case representing a different "reality", or scenario, with specific spending levels and degrees of PV commercialization, as simulated by PV1. Usng the policy criteria as dependent variables and the policy options as independent variables, this data base was then used to construct multiple linear regression equations, which could in turn be used to estimate an optimal policy for Commercialization.

It is acknowledged that the various policy options, such as market development and subsidy, may originate from different government agencies. This report is directed toward each of these separate agencies and to their consultants. If only one lesion is to be learned from this report it is that the policy options (and therefore efforts by the appropriate agencies) must be carefully coordinated for the construction of an effective and efficient overall policy for the accelerated commercialization of PV. We assume that the reader has a basic understanding of the technologies of photovoltaics (PV), and the PV1 model. Readers who are interested in the literature concerning the motivation for PV are referred to the Appendix of the PV1 User Documentation. The User Documentation (MIT Energy Laboratory Report MIT-EL-80-026) also describes the PV1 model in sufficient detail to allow the reader to use it directly if desired. The model is thoroughly documented in another recent report, MIT-EL-81-004, Model Verification.

I.2 Background

PV1 is a discrete-time, deterministic computer model, available to the user in an interactive mode via the MULTICS system at MIT. The model is designed to assess government actions, such as price subidies and market development, which are meant to make PV more acceptable in the market by making more potential users aware of PV, by reducing the price of PV, and by instilling confidence in the viability of PV as a technically and economically viable alternative energy technology. Other government actions, such as spending for technology development (TD) and for advanced research and development (AR+D), are expected to enhance the basic and production technologies for PV, thereby accelerating the rate at which the price of PV comes down over time.

The policy analysis performed here takes the form of sensitivity analyses. A base case is defined in terms of its spending levels, and these levels are then changed to illustrate the relative effectiveness of each policy option on the policy criteria. The policy options include subsidy, market development, advertising, technology development, and advanced research and development.

SUBSIDY (SUB): Subsidy is defined in PV1 as the percent of the purchase price that is paid by the government, with an upper limit or ceiling, to the PV purchaser. Subsidy, and all other policy options, may vary in the amount allocated or spent. In addition, the subsidy may vary over time, and from one sector to another. It is assumed that subsidies will be constant throughout all regions of the country.

MARKET DEVELOPMENT (MD): Market development is defined as money spent to construct government-owned PV installations, in any sector, time, and region of the country. Market development, or MD, serves to lower the price of PV to all users by increasing the production rate, and also increases the number of successful installations seen by potential buyers. This will help to convince potential buyers of the technical and economic viability of PV. Since MD may be allocated over regions, the shape of the MD policy can take on a very large number of forms. For example, these units may be constructed in many widely dispersed areas, or they may be concentrated in just a few regions.

ADVERTISING (ADV): Government expenditures on advertising help to increase the awareness of PV among potential users. It is assumed that a government advertising campaign will be associated with the market development program, so the spending for advertising is defined as an additional fraction of market development spending.

TECHNOLOGY DEVELOPMENT (TD) AND ADVANCED RESEARCH AND DEVELOPMENT (AR+D): Spending for technology development and for advanced research and development help to accelerate the arrival of new production and basic PV technologies.

These new technologies are expected to effect the manner in which the PV module price declines over time. It is projected in PV1 that this price reduction will occur in three distinct stages: during the first stage, the PV module price is a function of both the price of silicon (the element most likely to be used for PV in the near future) and the level of annual PV production; during the second stage, the module price is dependent only on the price of silicon, since it is assumed that the optimal production level will have been attained for each manufacturing facility (i.e., the module price will no longer depend on the annual production level); and during the third stage, an ultimate low price for the module will have been achieved.

The spending levels for TD and AR+D will, in PV1, accelerate the arrivals of stages 2 and 3, respectively. The PV1 user has a great deal of control over the manner in which these spending levels bring about the heat price reduction stage. For further details, consult the User Documentation, Section II.C "Cost Reduction."

I.3 Policy Criteria

For the purpose of this analysis, four evaluation criteria have been selected:

1) the total cumulative market penetration of PV by the last year of the planning horizon;
2) the rate at which the market is penetrated;
3) the efficiency of the policy in stimulating sales (that is, the total governmental spending per cumulative KW_p or PV installed);
4) the extent of private involvement in the market by the last year of the model.

The market penetration rate is defined as 'B' in the least squares regression equation:

$$\frac{x(t)}{L(t)} = A + Bt$$

where x(t) is the cumulative sales at time t, and L(t) is the total market at time t. Thus if B doubles from one policy to another, the second policy results in a market penetration that is twice as fast as the first.

A linear relationship between $\frac{X(t)}{L(t)}$ and B is justified here due to the nearly linear shape of the market penetration "S" curve in early years of the adoption of a new product; this is the period simulated by PV1. Also, care has been taken to avoid zero sales levels in early years (although very low values have been achieved in some runs), thereby averting exponential sales growth during the model's eight-year horizon.

For the best evaluation, a model should include as long a planning horizon as possible. However, long range planning models may be impractical from a computational point of view. Therefore the first two criteria, total cumulative market penetration and speed of penetration are used to indicate what has occurred by the last year of the model and what the trend is for future years, respectively.

There are two fundamental assumptions that go into constructing these criteria. First, the real goal of the government PV program is to maximize the total PV installed, in the private sector of the economy. The second assumption is that the government is indifferent to where, in terms of both sector (residential, commercial, etc.) and region, PV is installed, and that policies will be constructed to maximize this total for a given budget.

The use of the 4th policy criterion, the percent of private involvement, may be deceiving at low total sales levels. The 3rd policy criterion, policy efficiency, may also be deceiving at low market penetration and low budget levels. Also, the total cumulative market penetration, the 1st criterion, may be high but not increasing. Thus all 4 policy criteria must be used together.

A series of PV1 runs were used to examine the effectiveness of each of the policy options individually, both with respect to amounts and to policy "shapes." A policy "shape: refers to the increase or decrease of spending over time, and the distribution of spending over regions and sectors. Following this, an analysis of all policy options together were conducted to compare options as well as to provide a summary and guidelines for determining an "optimal" policy. It should be noted that this optimal policy is a function of the structure of the base case, that several optima may be found, and that the choice of an optimum may be ambiguous due to the use of more than one criterion.

Ideally, an optimal policy would be found through the use of four dynamic optimizations, one for each criterion. In an eight year, seven sector model with 469 utility districts, this would involve the evaluation of about 5×10^6 variables, an unworkably large number for dynamic optimization. Thus, a dynamic optimization will not be used, and instead the model will be run with a base case and approximately 50 additional cases to test the sensitivity of the criteria to the policy options. The end result will be a series of least-squares multiple regression equations that will summarize the workings of the PV1 model under the base case conditions.

We use several linear multiple regression equations because we are only interested in first-order effects of policy options in the vicinity of the base case. In addition, these equations are not in themselves designed to be policy analysis tools, but rather to be used as initial approximations for the policy maker who is considering a policy similar to the base case. If the policy under consideration by the policy maker is very different from the base case, the policy maker is advised to perform an analysis similar to this one to provide initial guidance in policy formulation.

I.4 Base Case Model

The base case used in this analysis is loosely defined by the basic funding level used in the Photovoltaic Energy Systems Program Element Report from the US Department of Energy, revised March 5, 1980. This basic budget level includes allocations for advanced research and development (AR+D), technology development (TD), market development (MD), systems, engineering standards, and tests and applications. Some of these categories have been redefined in this analysis to more closely conform with the definitions of the budget allocations as defined in PV1. Price subsidies for the base case are 40% of the purchase price for residences, with a limit of $4000 per installation on the amount of the subsidy, and 15% of the purchase price for all other sectors, with essentially no upper limit to the subsidy. These subsidies continue for the entire 8 years for which the base case model runs.

The basecase model allocates a total of $310.1 million over the eight years for AR+D, and $479.2 million for TD. Allocations are summarized in Table I.1.

Table I.1: Allocations for Base Case Model

($ Millions)

	Model Year							
	1	2	3	4	5	6	7	8
Advertising	6.5	14.5	15.0	15.0	15.0	16.0	20.0	20.0
Market Dev.	38.7	34.5	50.6	51.0	58.0	65.0	66.0	76.0

Subsidy

Residential: 40% of purchase price with $4000 ceiling per installation

Non-residential: 15% of purchase price, no ceiling

AR+D $310.1 total

TD: $479.2 total

The base case model includes seven sectors: new residential, retrofit residential, commercial (including office buildings, retail stores, banks, etc.), industrial, agricultural, central power, and public authority (including schools and offices). For the base case, all market development is assigned to the retrofit residential market, as is advertising.

PV installations in one sector have less than a one-for-one effect on the potential purchasers in another sector. The sectoral influence matrix is given in Table I.2. Note that the matrix is symmetrical about the diagonal, indicating that the influence of sector A on sector B is equal to the influence of sector B on sector A.

Table I.2: Sectoral Influence Matrix

		Influencing Sector						
		1	2	3	4	5	6	7
	1	1.00	0.90	0.20	0.10	0.30	0.10	0.10
	2	0.90	1.00	0.20	0.10	0.30	0.10	0.10
Influenced	3	0.20	0.20	1.00	0.70	0.80	0.30	0.10
Sector	4	0.10	0.10	0.70	1.00	0.50	0.60	0.20
	5	0.30	0.30	0.80	0.50	1.00	0.10	0.20
	6	0.10	0.10	0.30	0.60	0.10	1.00	0.20
	7	0.10	0.10	0.10	0.20	0.20	0.20	1.00

Sector Number	Sector
1	New Residential
2	Retrofit Residential
3	Commercial
4	Industrial
5	Agricultural
6	Central Power
7	Public Authority

Installations within a sector but in other regions will have a reduced influence as an inverse function of the square of the distance between the regions. For the base case model, the distance over which the influence will drop to 0.5 (the "Half-Influence" Distance) is 100 miles. This and other parameters are summarized in Table I.3 below.

Table I.3: Exogenous Parameters in Base Case Model

Half-Influence Distance:	100 miles
PV maintenance costs:	10% of annualized cost of capital
Mark-up and distribution costs:	20% of total system cost
PV system useful life expectancy:	20 years
Warranty period:	12 months
Loan parameters:	10 years at 20%
PV system conversion efficiency:	12%
Annual real increase in the cost of electricity:	3%
Cost of silicon:	$84/Kg
Ultimate module price:	$0.70/Wp
Buy-back rate:	60% of selling price
TOTAL Private TD expenditures:	$2 million

A note is appropriate here on the use of the word "model." PV1 is a computer "model" that is written in the PL/1 computer language. Using PV1, an individual creates a "submodel" that contains the values of the policy options and exogenous parameters. In the remainder of this text, we will use the word "model" to mean "submodel," for the sake of simplicity.

This completes the description of the parameters used in the base case model. The analyses that follow will examine the sensitivity of the policy criteria to allocations for AR+D, TD, MD, ADV, and SUB. Individual runs will be executed to test various policy "shapes" and spending levels. A series of PV characteristics will be tested, including expected useful system life, warranty period, and system conversion efficiency. The effects of the rise of electricity costs will also be examined. These individual tests will be covered in Chapter 2. Chapter 3 will aggregate the tests from the preceding chapter, and will summarize PV1 under base case conditions by presenting a series of multiple regression equations. Results, conclusions, and suggestions for further work are given in Chapter 4.

Summary

As a first step in developing an "optimal" policy, a base case was defined in terms of most likely spending levels for each of the policy options. Each of these spending levels was then changed, one at a time, to measure the sensitivity of the policy criteria to individual changes in spending. This generated a data base with 50 cases, each representing a different spending and commercialization scenario. These data were then used to construct linear multiple regression equations, which were in turn used to estimate an optimal policy. The details of these cases are dicussed in Chapter 2, and the regression eequations in Chapter 3.

II. Analysis of Policy Components

The total government policy toward the accelerated commercialization of PV includes spending for subsidy, market development, advertising, technology development, and advanced research and development. Each of these policy components includes characteristics regarding the allocation of spending over regions of the country, across sectors of the economy, timing of expenditures, and the total allocation. In this chapter, each of the components will be analyzed separately to determine the effectiveness of allocation, timing, etc., on the four policy evaluation criteria outlined in the Introduction, and on the ability of the policy to reduce the price of PV at the end of eight years.

II.1 Subsidy

The subsidization of PV is defined in PV1 as the reduction of the price of the PV installation to the owner by the direct reduction of income tax liability. More specifically, it is defined as the fraction of the purchase price paid by the government with an upper limit, or ceiling, that each owner may receive through this tax reduction. Further aspects of tax laws and regulations, such as "carry forward" or effects on capital gains, are not included in PV1. Also, the subsidy policy varies only over time and among sectors, not among states; state-wide subsidies are not included in the model. It is also an assumption of PV1 that policies will not vary between urban and rural areas, or among income levels or housing types in the residential sector. These variations will be addressed in later versions of PV1.

The subsidy instituted by the government has four attributes: the actual amount (or fraction of the purchase price), the ceiling on the amount. For each installation, the timing of the subsidy over the horizon of the model, and the allocation across sectors. The basecase model uses the current DOE subsidy levels of 40% for new and retrofit residential installations with a \$4000 limit per installation, and 15% with no upper limit for all other sectors. These subsidies remain constant through all eight years of the base case model. This results in a total spending level of \$31.0 million for subsidy over the eight years and 158.0×10^3 Kw_p total installed PV of which 23.1% is privately owned (that is, not the result of government market development). This base case policy has an effectiveness of $8.77 \times 10^3 \$/Kw_p$. The value of B, the market penetration rate, for the base case is .297 (omitting the factor of 10^{-4} for the sake of clarity).

One of the issues concerning subsidies is the existence of ceilings. By simply eliminating the ceilings on the residential sectors' subsidies, the total government spending or subsidy does not change substantially from the base case levels (see Case SUB-1, Table II.1.A); it increases from \$31.01 million to \$31.03 million. Similarly, the elimination of these ceilings does not alter the penetration rate, B; the total Kw_p of PV installed after eight years; the fraction of the PV installed after eight years; the fraction of the installed Kw_p that is private; nor the spending per Kw_p installed. In addition, the gross system price remains unchanged at \$2.83 per W_p, and the average subsidized (or net) system price at \$1.82. Therefore, the presence of a subsidy ceiling is relatively unimportant, given the basecase subsidy levels.

To test the effects of reduced subsidy spending, a model was run with a subsidy of 40% with a \$4000 ceiling, for the new residential sector only. This did result in reduced subsidy spending (to \$0.72 million), and decreased spending per Kw_p, since the total Kw_p installed remained virtually unchanged. But all of the other criteria also remained the same as the base case.

To evaluate market penetration effects of higher subsidy rates, it is desirable to remove one source of confusion--the subsidy ceiling. As long as ceilings are in effect, an increase in the subsidized fraction of the purchase price may generate results that are ambiguous because the ceiling may reduce the effective subsidy rate. For this reason, (and because it is not the purpose of this paper to determine thresholds) the remaining subsidy analysis will not include any ceilings.

Increasing the fraction of the purchase price that is subsidized from 40% for the residential sectors to 80%, and other sectors from 15% to 50%, with no ceilings as in case SUB-2 (see Table II.1), a substantial impact on the policy criteria results. While the amount spent on subsidies increases to $142.5 million over the eight years, the total Kw_p of PV installed also increases by almost 21% compared to a total spending increase of only 8%. The total Kw_p of PV increases to 191×10^3, the fraction of total Kw_p installed that is private increases to 35%, and the value of the parameter 'B' increases to .357. Also, the gross system cost is reduced to $2.69, and the net system cost is reduced to $0.65. Increased subsidy spending is therefore an effective means for enhancing the policy criteria. A question remains as to the timing of the subsidy over the period of the model.

<u>SUBSIDY TIMING</u>: In order to simplify the analysis of the timing of subsidy, the fraction of the purchase price covered by the subsidy is increased in all sectors to 80%. If this level is maintained for all eight years, the results are similar to the previous case (see Case

SUB-3): subsidy spending is increased to \$161.7 million, total Kw_p of PV installed is 190.8×10^3 with 34.7% of the installations originating from the private sector, 'B' is .357, and the 8th year prices are \$2.70 gross and \$0.54 net. If 80% is considered the maximum subsidy, could subsidy spending be reduced in earlier or later years with an acceptably small sacrifice in the policy criteria?

A case was run (SUB-4) in which the maximum of 80% subsidy was maintained for the first 4 years of the model. It was then reduced to 60% in the fifth year, 30 percent in the sixth year, and zero for the last two years. This reduced the subsidy spending to \$62 million, but at the same time reduced all of the criteria to basecase levels. Therefore, the additional \$31 million spent over the basecase is not justified if it is allocated in this manner. This is because the early subsidy spending is being used to purchase fewer, more expensive units than later subsidy spending. Could this mean that the optimal subsidy policy is one which waits for the price to come down?

A model was run (SUB-5) that was the mirror image of the previous run: the subsidy was zero for the first two years, 30% the second year, 60% the third, and 80% for the last 4 years of the model. This resulted in subsidy spending of \$136.4 million, and policy criteria that are similar to the case (SUB-3) in which the subsidy was maintained at 80 percent for all eight years: total Kw_p installed, 190.8×10^3; percent private, 34.7; 'B', .357. The gross and net system prices were also the same. The total spending per Kw_p installed was 7.95×10^3 for the case of 80% for all years, 8.97×10^3 for the case in which the subsidy declined to zero after seven years, and 7.81×10^3 for the case that increased from zero after two years. Thus if subsidy spending is to be increased over the base case level, it is best to wait a few years before beginning this subsidy.

Another timing alternative is to wait until the price of PV is substantially reduced before initiating subsidy spending, and then gradually reducing this spending over time. A model was run (SUB-6) in which the subsidy was begun in the fourth year of the model at a full 80% (with no ceiling), then dropped to 60%, 40%, and then 30%. A similar model (SUB-7), beginning subsidies after only 3 years, showed similar results. These proved to be about as efficient as the base case, with only slight improvements in the other policy criteria, and in terms of all of the criteria, not as desirable as the subsidy policy that is delayed for a few years and builds slowly over time.

Table II.1.A: Summary of Subsidy Runs

Case No.	Subsidy Spending ($millions)	Total Kwp Installed	B	Percent Private Install-ations	Total Spending per Kwp Installed	Net System Cost ($/wp)	Gross System Cost ($/wp)
SUB-1	31.03	157,967	.297	23.1	8774	1.82	2.83
SUB-2	142.50	190,658*	.357*	34.6	7854	0.65	2.69*
SUB-3	161.71	190,839*	.357*	34.7*	7948	0.54*	2.70
SUB-4	61.97	157,971	.297	23.1	8970	2.83	2.83
SUB-5	136.35	190,836*	.357*	34.7*	7815*	0.54*	2.70
SUB-6	39.34	160,354	.303	24.1	8695	1.99	2.84
SUB-7	53.04	160,355	.303	24.1	8781	1.99	2.84

*Most desirable in terms of this criterion

Table II.1.B: Subsidy Correlations*

Correlation coefficients of subsidy spending with:

Variable	Correlation
Total Kwp installed	0.5495
Percent Private Installations	-.1765
Spending per Kwp installed	-.3007
B	.5172
Gross System Cost	-.3851

*Includes cases discussed but not shown in Table II.1.A.

As shown in Table II.1.B, subsidy spending itself has a positive influence on the policy criteria, except for the percent of the installations that are private. (This negative correlation is the result of cases with wasteful early subsidy spending.) Subsidy spending also tends to reduce the gross system cost after 8 years.

There are two further conclusions that may be drawn from these analyses regarding subsidies. First, increased subsidies are effective in improving some policy criteria, but if the fraction of the purchase price covered by the subsidy is substantially larger than 40%, ceilings on subsidies will have to be increased or eliminated to make the increased subsidy effective. Second, it could be advantageous to delay the subsidy, or at least maintain it at a low level, until PV prices are reduced through increased production, and then to increase the subsidy steadily over time.

II.2 Market Development (MD)

Allocations for MD provide government "buys" that are used to demonstrate the technical viability of PV. The amount spent on MD is defined here in terms of dollars, as opposed to purchased Kw_p. In addition to defining the total amount allocated to MD, this policy component has parameters relating to its allocation to the various sectors, over time, and to the various regions, or utility districts. Testing all possible combinations would require an enormous number of simulations, so a few cases have been selected to illustrate the effects of these parameters.

In the base case model, all MD is allocated to the residential retrofit sector. In all, eleven cases were run to illustrate the effects of MD spending on the policy criteria. These are summarized in Table II.2.A.

Table II.2.A: Market Development Cases

Case	MD Spending	Total Kw_p	Total Spending/ Kw_p	B	Percent Private
MD-1	360.0	122987	11077	.227	33.3
MD-2	480.0	148074	9710	.275	24.1
MD-3	480.0	159917	9000	.298	22.6
MD-4	439.8	157800	8782	.297	23.0
MD-5	439.8	156417	8852	.294	22.4
MD-6	439.8	157471	8799	.296	22.9
MD-7	440.0	96138	14477	.151	24.9
MD-8	442.0	177547	7756	.348	12.0
MD-9	240.0	89906	12564	.165	28.3
MD-10	720.0	231378*	7561*	.433*	16.5
MD-11	37.3	39264	25170	.063	93.1*

*Most desirable according to this criterion

According to Table II.2.A, there is an ambiguous ranking of the policies tested. Case MD10 appears to be highly desirable in terms of total market penetration, policy efficiency, and rate of market penetration. Unfortunately, only 16.5% of the cumulative market penetration after eight years is from the private sector of the economy.

The qualitative aspects of these policies require extensive explanation. In Case MD-1 subsidy is set at 80% of the purchase price with no effective ceiling, for all sectors. The market development spending for this case is 0.0 for the public authority, central power, and residential sectors. Annual MD spending is $15 million each in the commercial, industrial, and agricultural sectors, for a total of $360 million MD spending for the eight year model. Case MD-2 increases this total to $480 million, or $20 million annually per sector for these same sectors, while decreasing the subsidy to the base case level. From the previous section, it was noted that an increase of the subsidy from the basecase level to 80% without a ceiling, for all sectors and years, resulted in substantial increases in the total market penetration, percent private installations, and the speed of market penetration. Reducing MD spending to below the base case level (case MD-1) more than offset the increase, due to increased subsidy, in all criteria except the percent of private installations. Even if total MD spending is increased to an amount above the basecase level, the redistribuition of MD funds out of the residential retrofit sector into the commercial, industrial, and agricultural sectors, as in case MD-2, does not substantially affect the policy criteria. This is also true if the same amount of increased MD spending is completely allocated to the industrial sector, as in case MD-3.

Three regional allocations schemes were tested for mearket development:

1. 20% to California, 10% to Nevada, 10% to Arizona, 10% to New Mexico, 10% to Hawaii, 40% evenly distributed throughout the country (MD-4). The purpose of this scheme was to test the effectiveness of allocating MD to those areas of greatest solar radiation.
2. All MD funds were allocated to California (MD-5); and
3. 75% of MD was allocated to the 15 utility districts with the highest values of solar radiation times the price of electricity (MD-6). This would allow early PV users to take advantage of both high solar radiation levels and attractive PV economics. That is, the value per square meter of PV was highest in these areas. The remaining 75% was allocated to the rest of the country.

None of these three reallocations (MD-4, MD-5, and MD-6) substantially improved the policy criteria over the basecase. The optimal MD allocation scheme across regions of the country and across sectors would therefore be the one that is simplest to administer, on the bases of criteria that are not included in this analysis.

The timing of MD spending is the essential difference between cases MD-7 and 8. Case MD-7 provides $110 million per year for the first four years of the model, in the residential retrofit sector only. This results in substantially reduced market penetration as well as penetration rate ('B'), while the total MD spending level is close to the base case. Early MD spending is apparently disadvantageous. By spending approximately the same MD but in later years, as in case MD-8, considerably higher market penetration is achieved, at a faster rate, and at twice the efficiency of case MD-7, but at the expense of a lower percentage private involvement in the market (although the total Kw_p of private PV installations is 12% higher in MD-7 than MD-8). This may be an acceptable trade-off if the allocation of MD spending is discontinued shortly after the last year of the model horizon.

The last three cases MD-9, 10, and 11, represent differences in spending levels in the residential retrofit market only. These levels are $240 million, $720 million, and $37.3 million totals, respectively. In addition, case MD-11, with its low MD expenditure, also has an increase in the amount of spending in technology development (TD) sufficient enough to accelerate the arrival of stage 2 production technology by one year. The results of these three cases illustrate the fact that increased MD spending results in an increase in all of the policy criteria except the percent of the total installations that are private.

Table II.2.B: Correlations for MD Spending*

Correlation coefficients of MD spending with:

Variable	Correlation
Percent Private Installations	-.7118
Total Installations	.8009
B	.7240
Gross System Cost	-.0847
Spending per Kwp installed	-.8264

*Includes case TD-1 (MD-11) and TD-2 (not included in Table II.2.A).

This conclusion is supported by the figures in Table II.2.B, for all eleven MD cases. MD spending tends to improve all policy criteria, except the percent of the installations that are private, and decreases the 8th year gross system cost.

II.3 Advertising

The amount spent on advertising is defined in PV1 as a fraction of the amount spent on MD for a given year. This amount directly affects the awareness of PV among the potential buyers. The amount spent on advertising (ADV) is therefore a function of the allocations to MD, over time and sectors. To simplify this analysis, the basecase MD allocation was used in cases ADV-1 through ADV-5. This means that all ADV is being allocated to the residential retrofit sector.

Market development installations also have have an advertising value since MD spending increases awareness of PV. It is assumed in PV1 that 60 percent of the expenditures for MD will have a similar dollar-for-dollar effect on the awareness of PV among the potential market as advertising. Thus the total effective advertising expenditures for each year of the model are defined as:

effective ADV = (A .60) MD

where A = fraction of MD spending that is directly allocated to ADV, in addition to original MD spending.

In all, five cases were run to test the sensitivity of the policy criteria to changes in the level of advertising spending. The advertising fraction of the MD spending level was varied between 0.00 and 1.00. In addition, cases illustrating gradually increasing and gradually decreasing levels, over time, were tested. In the worst case (ADV-1,

Table II.3.A), when ADV was reduced to 0.00 percent, the total market penetration after eight years was only 0.82 percent less than the basecase. In the best case, when the ADV was increased to 100 percent of the MD spending, the total market penetration was only 1.11 percent higher than the basecase. Similar effects were seen on the other criteria except spending per Kw_p. This is to a large extent the result of the large awareness effects of MD spending. Any conclusions that are drawn from the effects of advertising on the policy criteria are very much a result of the assumptions made in the construction of PV1.

Table II.3.A: Summary of Advertising Cases

Case No.	Advertising Spending ($millions)	Total Kwp Installed	$B \times 10^4$	Percent Private Installation	Total Spending per Kwp Installed
ADV-1	0	157,679	.297	22.5	8036
ADV-2(1)	175.9	158,326	.298	23.3	9040
ADV-3(2)	439.8	159,721	.300	23.9	8685
ADV-4(3)	288.0	159,087	.299	23.6	9736
ADV-5(4)	315.1	158,625	.299	23.4	9932

(1) Advertising is 40% of MD spending for all years.

(2) Advertising spending equals MD spending for all years.

(3) Advertising percent of MD by year: 100, 100, 100, 90, 80, 70, 40, 0.

(4) Advertising percent of MD by year: 0, 0, 40, 70, 90, 100, 100, 100.

Table II.3.B: Correlations for ADV Spending

Correlation coefficients of ADV spending with:

Variable	Correlation
Percent Private Installations	.9785
Total Installations	.9676
B	.9810
Gross System Cost	.0000
Spending per Kwp installed	.5255

In reference to Table II.3.B, it appears that advertising 1) is effective in accelerating market penetration and private involvement in the market, 2) has no effect on the eighth year gross system cost, and 3) is inefficient in that it tends to increase the spending per installed Kwp. These correlations must be viewed in the context of the relatively minute variance in the policy criteria resulting from large changes in ADV spending. The correlations only imply that increases in ADV spending will most likely be accompanied by increases in market penetration and private involvement, but not the extent to which this will occur. Spending for advertising, as defined in PV1, does not seem very important in its effect on the policy criteria.

II.4 Technology Development (TD), and Advanced Research and Development (AR+D)

These two policy options are treated together here because the algorithms for computing the effects of both TD and AR+D spending are similar. As shown in the PV1 User Documentation, the effects of these spending options are to accelerate the arrivals of new stages of production technologies. During the first production technology stage of

PV1, the price of the PV module is a function of both the level of production and the price of silicon. It is assumed that by the time the second stage arrives, the most efficient production plant sizes will have been established and constructed, so the module price is only a function of the cost of silicon. The arrival of this second stage is accelerated by increasing the amount spent on TD. In the third production technology stage, the module price is assumed to have reached an ultimate low price, as defined by the PV1 user. For these analyses, the value is set at \$0.70 per Kw_p.

The algorithm used to compute the years of arrival of the two stages, from year zero, is defined as:

$$T = (t_2 - t_0)[1 - \frac{X^\beta}{\gamma + X^\beta}] + t_0$$

where $$\beta = \text{Log}_2 (\frac{t_2 - t_3}{t_3 - t_0} \cdot \frac{t_1 - t_0}{t_2 - t_1})$$

$$\gamma = D_1^\beta \cdot \frac{t_1 - t_0}{t_2 - t_1}$$

and

T	=	date of arrival of next stage
X	=	total TD spending (for stage 2 arrival) or AR+D spending (for stage 3 arrival)
D_1	=	most likely total government spending level (\$ million)
t_0	=	earliest possible date for arrival of next stage if unlimited funds are spent
t_1	=	most likely date of arrival of next stage at the most likely spending level, D_1
t_2	=	date of arrival of next stage if no spending is allocated
t_3	=	the most likely date for the arrival of the next stage if the spending level is $X=2D_1$.

The values for t_0 through t_3 and for D_1 are based loosely on the Photovoltaic Energy Systems Program Element Report, revised March 5, 1980, from the Department of Energy. The values of t_0 through t_3 that are used in this analysis given in Table II.4.A, and sample curves for estimating the arrival dates derived from these 't' values are shown in Figure II.1.

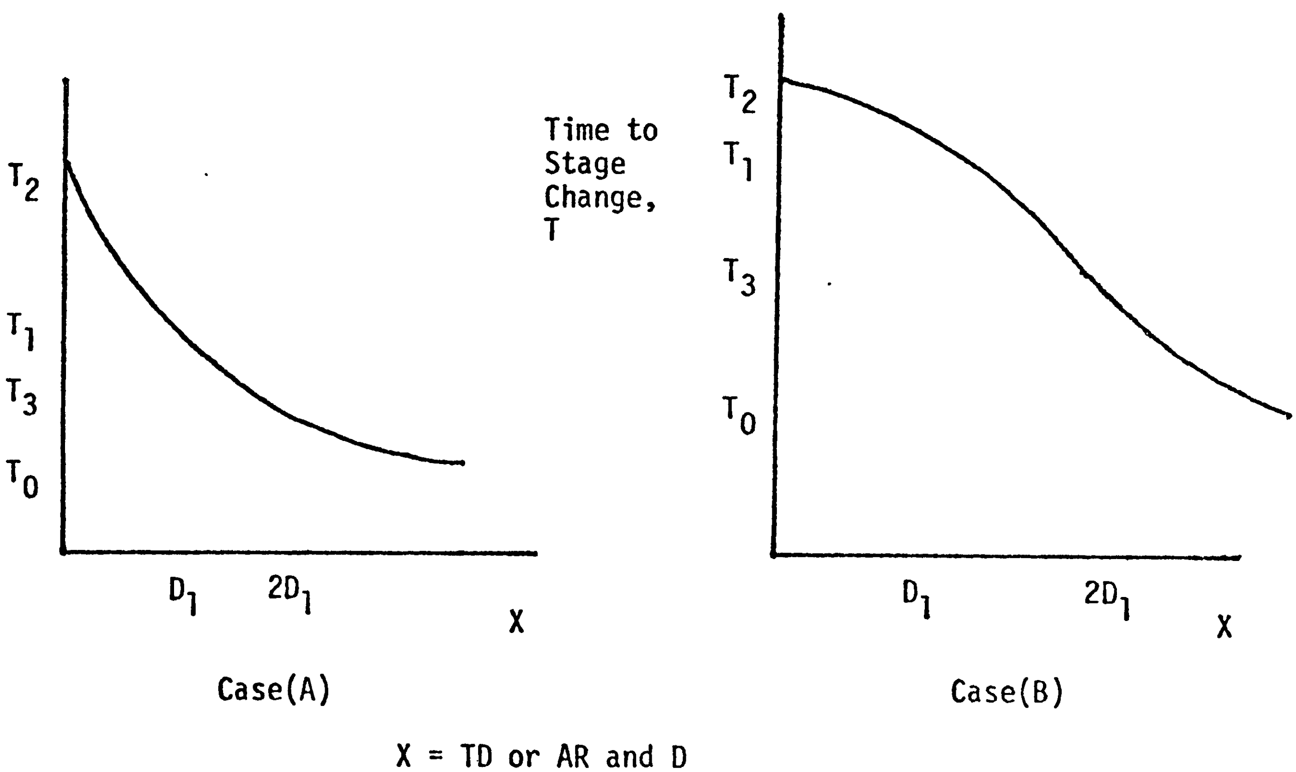


Figure II- 4 Illustration of the Effects of Values of T_0, T_1, T_2, and T_3 on the Computation of Staging Times, T

Table II.4.A: Values of t_0, t_1, t_2, and t_3 for Estimating the Arrivals of Stages 2 and 3.

	t_0	t_1	t_2	t_3
TD (Stages 1 to 2)	1	5	13	2
AR+D (Stages 2 to 3)	3	9	20	5

The use of this rather complex algorithm for estimating the arrival of new production technology stages illustrates the difficulty in determining the effects of TD and AR+D spending on cost reduction. Since the results of these analyses may depend to a large extent on the choices for the parameters in these algorithms, this section will include discussions of the effects of both spending and dates of stage changes.

The PV1 algorithm cuts off any spending for TD after the arrival of stage 2, and similarly cuts off spending for AR+D once stage 3 has arrived. This is in contrast to the DOE program element report, which continues spending in these areas even after PV has achieved technology and commercial readiness stages. Since it is the purpose of these analyses to test the effects of spending levels for AR+D and TD, the entire allocations in these policy options were spent in year one of the model. Timing effects of these policy options are difficult to assess because their effects on price reductions are difficult to model in general, as stated above. Spending the entire amounts in year one will not affect the arrival of stages 2 and 3, and assures that all allocations for AR+D and TD are indeed spent in the model.

Six cases were run to test the sensitivity of the policy criteria to TD spending, and five were run to test for AR+D. These runs are summarized in Table II.4.B.

Table II.4.B: Models Run for TD and AR+D

Case	TD Spent	AR+D Spent	Stage 2	Stage 3	B	Spend per Kw_p ($000's)	Perc Priv.	Total Kw_p Instal. ($000's)
TD-1	606.0	310.1	4	9	.063	25.2	93.1*	39.3
TD-2	604.0	310.1	4	9	.322	9.0	21.8	167.8
TD-3	354.0	310.1	7	9	.237	9.4	27.0	134.7
TD-4	404.0	310.1	6	9	.268	8.9	24.8	147.2
TD-5	454.0	310.1	5	9	.268	9.3	24.8	147.2
TD-6	1000.0	310.1	2	9	.343	10.4	20.1	182.2
ARD-1	475.0	410.0	5	7	.319	8.3	20.6	177.5
ARD-2	600.0	510.0	4	6	.445	7.1*	15.4	238.2
ARD-3	800.0	610.0	2	5	.446*	8.2	15.0	244.7*
ARD-4	800.0	610.0	2	5	.233	14.0	27.8	124.7
ARD-5	800.0	710.0	2	5	.255	13.9	26.9	132.8

*Indicates most desirable in terms of this criterion.

Although cases ARD-1 through ARD_5 are used to evaluate the effects in changes in AR+D spending, TD spending was also increased in these cases to ensure that the arrival of stage 3 was later than the arrival of stage 2.

Cases TD-1, ARD-4, and ARD-5 are used to illustrate the interactions between TD and AR+D, respectively, with MD as determined by the effects on the policy criteria. Case TD-1 (see case MD-11, Table II.2.A) has an elevated TD spending level, sufficient to accelerate the arrival of stage 2 by one year, as well as a lower MD spending level, only $37.3 million. This case represents an increase of more than 26 percent for TD, and with the lower MD spending, the market is penetrated at a much slower rate.

Although the private sector is highly involved in this market, the low market response to this policy reflects the trade-off between TD and MD spending.

Case TD-2 is a return to the base case MD spending level. The policy criteria for case TD-2 show substantial improvement over TD-1, except for the extent of private involvement in the market. Case TD-2 even shows some improvement over the base case. This illustrates that increased TD spending, if it is sufficient to accelerate the arrival of stage 2 by at least one year, is effective in increasing market penetration. When compared to the basecase, TD-2 represents an increase in B of 8 percent, and a 6 percent increase in the total market penetration after eight years, but a small decrease in the percent private installations.

Cases TD-2 through TD-6 reflect basecases with TD spending levels varying between $354 million and $1 billion spent over the eight year period of the model. Each of the differences of TD spending from one case to the next was sufficient to change the year in which stage 2 arrives by one year. The appropriate correlation coefficients for Cases TD-2 through TD-6 are given in Table II.4.C.

Table II.4.C: Technology Development Correlation Coefficients

Correlation coefficients of TD spending with:

Variable	Correlation
Percent Private Installations	-.0005
Total Installations	.2459
B	.2873
Gross System Cost	.2405
Spending per Kwp installed	.1427

Clearly, TD spending that is sufficient to accelerate the arrival of new production technology has a positive effect on the rate of market penetration and on the total number of installations after eight years. The effects on ultimate gross system cost, on the spending efficiency, and on the percent of the total installations that are private, are negative.

To understand the effects of AR+D spending, it is necessary to compare cases with equal stage 2 arrival dates. Cases TD-5 and ARD-1 both have stage 2 arrival dates in year 5, but the arrival dates of stage 3 are 9 and 7, respectively, due to increased AR+D spending in case ARD-1. The increased spending in case ARD-1 results in improvements in almost all policy criteria. With an increase in AR+D spending of 32 percent, the market is penetrated at a 19 percent faster rate (B), an eighth year market penetration that is almost 21 percent higher, a drop in the spending per installed peak kilowatt of almost 11 percent, but a decrease as well in the percent of private installations of almost 17 percent. Similar results are found when comparing cases TD-2 to ARD-2 and TD-6 to ARD-3. It may be concluded, therefore, that AR+D spending is effective in improving 3 of the 4 policy criteria, generally at the expense of increased government participation in the market.

Cases ARD-4 and ARD-5 further illustrate the trade-off involved in MD spending with other policy options. As in TD-1, where reduced MD spending reduced the effectiveness of TD spending in improving the policy criteria, ARD-4 and ARD-5 illustrate that reduced MD spending also reduces the effectiveness of AR+D spending. Interactions and the relative effectivenesses of the policy options will be discussed in greater detail in Chapter III.

II.5 Exogenous Parameters

In PV1, there are 4 parameters that are exogenously defined that may have substantial effects on the results of the model. They are exogenous in that they are user-defined and they are not related to policy options. Three of these parameters (expected lifetime of the PV system, average PV system conversion efficiency, and warranty period) are certainly related to PV technology, but no attempt was made in PV1 to make these parameters functions of TD or AR+D spending, due to the difficulty in describing the functional nature of these relationships. The fourth such parameter, the average annual rate of increase in the real price of conventionally generated electricity, is exogenous to PV technology as well. It is primarily a function of the current cost of fuels and capital used in generating electricity. The cases used to examine the effects of these parameters are summarized in cases EX-1 through EX-14 in Table II.5.A.

Table II.5.A: Models Run to Test for Exogenous Parameters

Case	Life, Years	Rate Rise,%	System Effic.	Warranty, Months	B	Spend/ Kw_p ($000's)	% Priv.	Total Kw_p Installed
EX-1	30	3.0	.12	12	.322	8.10	29.1	172.4
EX-2	40	3.0	.12	12	.322	8.09	29.1	172.4
EX-3	10	3.0	.12	12	.247	10.55	8.2	129.5
EX-4	20	0.0	.12	12	.297	8.77	23.1	158.0
EX-5	20	5.0	.12	12	.297	8.77	23.1	158.0
EX-6	20	20.0	.12	12	.297	8.77	23.1	158.0
EX-7	20	75.0	.12	12	1.770	1.54	88.3	1128.5
EX-8	20	50.0	.12	12	1.071	2.34	80.7	687.6
EX-9	20	3.0	.25	12	.370	7.09	38.0	199.0
EX-10	20	3.0	.18	12	.331	7.90	30.8	177.1
EX-11	20	3.0	.06	12	.262	9.93	13.3	138.2
EX-12	20	3.0	.12	6	.277	9.37	17.9	147.0
EX-13	20	3.0	.12	24	.431	6.41	46.8	233.9
EX-14	20	3.0	.12	36	.450	5.91	48.9	244.3

Electricity Rate Rise

The rate at which the price of electricity rises over time appears to have an enormous effect on the policy parameters. This rate rise is in real terms, over and above the general inflation rate. On closer examination, however, the price of conventionally generated electricity can rise at an average rate of 20 percent per year, without any noticeable effects on the policy parameters. Not until this rate of price increase is above 20 percent, and probably close to 50 percent, do the policy parameters show any response. The rate of increase of electricity is difficult to project since it is highly sensitive to international energy prices, capital and regulatory expenses, and disparities between installed capacity and peak load demands. This rate increase is therefore subject to international and domestic political forces, as well as a utility's ability to plan for future expansion with accuracy.

The other exogenous parameters, PV system life and efficiency, and warranty period, are characteristics of PV that may be affected by policy options (such as TD and AR+D spending) and by characteristics of PV that are the result of the PV production industry's confidence in the systems they sell as reflected in the warranty period.

PV System Life

A decrease in the usable life of a PV system will substantially reduce the appeal of PV in the market, as in case EX-3, but an increase above the base case level of 20 years, as in EX-1 and EX-2, does not substantially improve the policy parameters. Increasing the usable life of PV systems does not appear to be a productive endeavor once the twenty year life has been attained.

PV System Efficiency

By increasing the system conversion efficiency to approximately the theoretical maximum for PV (25%), as in EX-9, the rate at which the market is penetrated is increased by more than 24 percent, the total Kw_p installed by almost 26 percent, the percent private by more than 64 percent (from 23 to 38%) and government spending per total installed Kw_p is reduced by 19 percent compared to the base case. More modest results are achieved with a more realistic projection of future average system efficiency of 18 percent, as in EX-10, but as in EX-9, all policy criteria are improved with increasing system efficiency. As expected, reducing the system efficiency below the base case level resulted in increased spending per Kw_p installed and reduced market penetration and private involvement in the market, as in EX-11. Increased system efficiency, and its effect on the PV user economics, seems highly desirable, and should therefore have a high priority within the PV production industry.

PV System Warranty

The system warranty period has effects on the policy criteria that are similar to those of system lifetime. Doubling the warranty period from 12 to 24 months as in EX-13 causes an increase in the rate of market penetration by 45 percent, an increase in the total market penetration to 48 percent, an increase in the percent of the market that is private of more than 86 percent, and a reduction in government spending per installed Kw_p by almost 30 percent, all compared to the base case. This trend is continued in EX-12 and EX-14. An increase in the PV warranty period may be the result of improved PV technology. This could be accelerated by increasing TD and AR+D spending, although the relationship of these policy options with the warranty period is unclear. The warranty period may also be increased by raising the price of PV to cover the added expenses of the warranty to the manufacturer. This could represent an alternative policy option, that is, a government price subsidy for PV by direct payments to the manufacturers for the purpose of increasing their warranty periods.

These relationships are further clarified in Table II.5.B. The correlation coefficients in this table indicate the directions of the relationships. Since different cases are used, the quantities are not directly comparable.

Table II.5.B: Correlation Coefficients for Exogenous Parameters

Policy Option	System Life	Rate Rise	System Efficiency	Warranty Period
% Private	.8988	.9497	.9962	.8320
Total Install.	.9139	.9792	1.0000	.9520
B	.9136	.9778	1.0000	.9521
Spending per Kwp	-.8960	-.9484	-.9959	-.9397
Gross System Cost	.8677	-.9800	.9313	.9177
Cases EX-	1-4	5-8	9-11	12-14

II.6 Summary

This section has been a discussion of individual cases, and individual policy options. The correlation coefficients that are given reflect only those cases that were run to test for specific policy options or exogenous parameters, and only provide a preliminary guide to the direction of influence on the four policy criteria. No conclusions regarding policy should be drawn from them alone.

The next section establishes a more comprehensive analysis that compares the relative relationships of the policy options with the policy criteria. Section II is therefore only background information, and provides a foundation on which to construct the policy analysis of Section III.

III. Policy Analysis

In the previous chapter, the individual components of PV policy were analyzed with respect to their relationships with the four policy criteria. The ability of each of the components to enhance the criteria was discussed, but a comparison among the components was not. In this chapter, a set of ordinary least squares regression equations using all 50 cases is developed for two purposes: first, to estimate the relative strengths and weaknesses of the policy components in affecting the policy criteria, and second, to act as a summary of the basecase model in terms of a linear model. This second purpose is meant to assist the policy maker in preliminary assessments of proposed policies. In this sense, the regression equations should be used only as a first approximation for a policy analysis, and as such should not be taken as the final result. These regressions could form a guideline, for example, for the construction of a new basecase that interests the policy maker. In general, this chapter is a discussion of policy trade-offs and policy options coordination.

III.1 Introduction

Four regressions were run, one for each of the policy criteria. Each equation includes independent variables relating to spending amounts and the exogenous parameters. There are four regressions because it is left to the policy maker to evaluate the relative importance of each of the four policy criteria.

In addition to the variables listed in Table III.1.A, a variable C has been created that is used as a dependent variable in the regression equations in lieu of PCTPRIV, in order to prevent this dependent variable from being less than zero or greater than 1.0:

$$C = \ln\left(\frac{PCTPRIV + .5}{1.5 - PCTPRIV}\right)$$

For this chapter, we define the following variables:

Table III.1.A

Variables Used in PV1 Policy Analysis

Policy spending variables

TD	\$ million spent after eight years for technology development
MD	\$ million spent after eight years for market development
ARD	\$ million spent after eight years for advanced research and development
SUB	\$ million spent after eight years for subsidy
ADV	\$ million spent after eight years for advertising

Intermediate variables

GSC	Gross system cost, after eight years, $\$/W_p$
NSC	Net system cost, after eight years, $\$/W_p$
RR	Average annual rate of increase of the price of electricity

Policy criteria variables

TOTINST	Total installed Kw_p of PV after eight years
SPGPKW	Government spending per total Kw_p of PV installed after eight years
B	The coefficient of t in the regression equation: $\frac{x(t)}{L(t)} = A + Bt$ Where x(t) is the Kw_p installed at time t, L(t) is the total market at time t, in Kw_p
PCTPRIV	Percent of the total installed Kw_p that is private (that is, installations that are not the result of government market development)

PV Characteristics

LIFE	The expected useful life of PV, in years
WARR	Warranty period, in months
PVEF	Average system conversion efficiency, percent

One main purpose of this report is to estimate the effects of policy options on the policy criteria. This measures the effectiveness of specific amounts of government dollars spent in specific areas, such as market development and subsidy. Unfortunately, the effects of policies relating to TD and AR+D cannot be determined directly, but rather in terms of the arrival dates of Stages 2 and 3. Table III.1.B summarizes these relationships.

Table III.1.B

Policy Variables

(1) A PRIORI DEFINABLE VARIABLES	(2) RELATED VARIABLES NOT ABLE TO BE SPECIFIED BY POLICY MAKERS
TD Spending	Stage 2 arrival date (STG2)
AR+D Spending	Stage 3 arrival date (STG 3)

To understand thoroughly and describe the meanings of various spending levels, 2 subsets of regression equations were used. The first used only spending levels. The second equations used the variables from column (2) in Table III.1.B, above (in lieu of TD and ARD), as well as MD and other variables. The coefficients generated are useful in projecting the outcomes for the policy criteria as functions of the policy options. This results in the generation of 8 equations. One equation was generated for each of the 2 subsets described above, and for each of the four policy criteria.

To use these equations for understanding the relative strengths of relationships between policy options and criteria, standardized regression coefficients (called betas) are also given. The value of each beta coefficient is the change in the number of standard deviations of the dependent variable from the mean that will be caused by a one standard deviation change in each of the independent variables. If 'b' is the regression coefficient, then beta is defined as:

$$\text{beta} = b\left(\frac{S_d}{S_i}\right)$$

where S_d and S_i are the standard deviations of the dependent and independent variables, respectively. With these 'normal equations', the total number of regression equations is 16.

As a preliminary step to performing the regressions, correlation coefficients using all of the cases were calculated. These are given in Table III.1.C. From this table, it appears that the correlations with 'B' are similar to the correlations with the total Kwp installed. In fact, these two variables are very highly correlated with each other, with a value of .9978, although there is reason to suspect that they will not always be highly correlated. In the regression equations there are differences in the coefficients that are large enough to warrant the use of both variables.

Table III.1.C

Correlation Coefficients Using All Cases

	Total Kwp Installed	B	Private Installations	Spending per Kwp Installed
Subsidy	.8732	.8655	.7071	-.4973
MD	.1815	.2172	-.4460	-.7178
ADV	.0669	.0854	-.4460	-.7178
TD	-.0402	-.0306	-.0412	.3010
AR+D	-.0311	-.0224	-.1243	.1940
STG2	.0317	.0208	.0333	-.3024
STG3	.0231	.0131	.1416	-.1626
Life	.0012	.0061	.0743	-.0828
Rate Rise	.9489	.9322	.6575	-.4539
PV efficiency	.0188	.0268	.1233	-.1120
Warranty Period	.0671	.0836	.2384	-.1880
Net System Cost	-.0257	-.0531	.1708	.2135
Gross System Cost	-.2976	-.3224	.0764	.2660

III.2 General Policy Considerations

This section is a discussion of the relative merits of the policy options in terms of their abilities to effect improvements in the policy criteria. This includes a discussion of the effects of the exogenous parameters. All of the regression coefficients are listed in the appendix to chapter III, Tables III.A.1 through III.A.8.

The relative strengths of the relationships of the policy option spending levels and the exogenous parameters are reflected in the values of Beta, the 2nd column of the tables, in Tables III.A.1 through III.A.4. In these tables, net system cost is included as an independent variable. It would have been preferable to use net system cost (NSC) as an intermediate variable. In this form, NSC would have been the dependent variable with the five policy options as independent variables. In turn, NSC and the exogenous parameters would be independent variables, and the policy criteria, dependent variables. Unfortunately, only a small fraction of the variance of NSC could be explained by the policy options, about 25 percent, so this form is not used (see Table IV.1).

III.2.1 Spending per Kw_p Installed (SPGPKW)

The spending per Kwp installed is a measure of the efficiency of a policy. The lower the value of SPGPKW, the more efficient the policy; therefore a negative coefficient indicates a contribution toward a more efficient policy. Caution must be exercised in using this criterion in cases that are run with extremely low government spending levels. In a PV1 run such as this, any incidental market penetration will generate an overly optimistic value for this criterion that could easily be misleading. Therefore, the use of this policy criterion is only recommended for use in sensitivity-type analyses which avoid extremely small government expenditure levels, such as the analysis that is presented here.

Only two of the five policy options have negative coefficients for this criterion (see Table III.A.1), MD and ARD. The coefficient for ARD is negligible. However, the policy efficiency is, on a percentage basis, more sensitive to changes in MD than to any one of the other policy options, or, in fact, to any of the exogenous parameters. This means that an increase in MD spending can easily offset efficiency losses from spending in the other policy option areas, or from, for example, a real decrease in the price of electricity over time. This also means that any policy that includes expenditures for TD, SUB, or ADV should also include some spending for MD, or the overall policy will tend to be inefficient.

There is one other idea that is illustrated here, and is repeated consistently throughout this analysis, and that is that an increase in the real price of electricity over time will improve every one of the policy criterion, although to varying degrees.

III.2.2 Total Kw_p Installed (TOTINST)

The most important coefficient in this normalized equation is the average annual rise in the real price of electricity (see Table III.A.2). A percentage increase in this figure will contribute more to the total market penetration after eight years than any other factor considered.

Among the policy options, the most important is SUB, followed by MD and ARD. This and other results indicate the vital necessity of coordination between MD and SUB spending. ARD is discussed in more detail in Section III.3.

One surprising value is the coefficient for the varible NSC. This Beta is .0451, which means that a high NSC will generate increased market penetration. This implies that the acceleration of market penetration should be attacked directly, with less emphasis on the reduction of net system prices and that NSC should not be used as an indicator of the degree of success or failure of a PV policy. This is counter-intuitive, and contrasts markedly with current government policy emphasis.

III.2.3 Market Penetration Rate (B)

Many of the observations made concerning TOTINST are also true of B (see Table III.A.3): the most important factor is the rate of the increase of the real price of electricity; NSC is surprisingly unimportant; and the same three policy options are the most important (SUB, MD, and ARD), although in different order. On a percentage basis, SUB will contribute slightly more to the speed of market penetration than will MD. This also indicates the need to coordinate these two policy options.

The relative results regarding the importance of NSC and SUB in the equations with both B and TOTINST as dependent variables would be spurious if NSC and SUB were highly correlated. This would mean that only one of them (SUB or NSC) should be used as an independent variable, and that the low Beta coefficient for NSC is misleading. It is true that NSC and SUB have a relationship (with GSC as an intervening variable), but fortunately the Pearson correlation for SUB and NSC is only -.215. Other correlations also tend to substantiate the beta coefficients.

Pearson Correlation Coefficients

	B	TOTINST	NSC	SUB
B	1.00	.998	-.053	.865
TOTINST	.998	1.00	-.026	.873
NSC	-.053	-.026	1.00	-.215
SUB	.865	.873	-.215	1.00

Therefore, the beta coefficients of NSC and SUB in the equations for B and TOTINST are meaningful.

III.2.4 Percent Private Installations (C)

The variable "C" is a transformation of the actual fraction of the market that is private:

$$C = \ln\left(\frac{PCTPRIV + .5}{1.5 - PCTPRIV}\right)$$

As expected, the value of the Beta coefficient for MD spending is negative for this policy criterion; the more MD spending for government installations, the lower the percent of the total installations that are private. It was not expected, however, that the coefficient for NSC would be positive. This means that the higher the net system cost, the higher the percentage of private involvement in the market. This further illustrates the inappropriateness of NSC as a policy criterion.

Fortunately, the coefficient for SUB is positive, and larger in value than that for MD. The reduction in the percent of the market that is private as a result of MD spending can therefore be more than offset by SUB spending of an equal amount.

The importance of the average annual rise in the real price of electricity is less important to this policy criterion than to the others. Among the exogenous parameters, the most important here is the warranty period, although even this value is relatively small.

Later sections include more detailed discussions of the tradeoffs between MD and SUB, the two policy options that appear to be the most critical in terms of the policy criteria.

III.2.5 Summary

Among the policy options, the most important appear to be MD and SUB. In the equations for two of the policy criteria ('C' and SPGPKW), these two options have opposite signs. There is no clear pattern to these sign changes; MD contributes to the positive aspect of SPGPKW in that its sign is negative, but naturally reduces the percentage of private involvement in the market. SUB also reverses signs and senses. Both contribute positively to 'B' and TOTINST. Only in the equation for SPGPKW is SUB less important than other policy options.

This further illustrates the need to coordinate the spending levels for SUB and MD. One approach to this policy coordination is given in section III-3.

Among the exogenous parameters, the most important for all of the policy criteria except 'C' is the average annual rate of the increase of the price of electricity, and even in this criterion, RR is more important than TD spending. Among the remaining exogenous parameters, (those that may be controlled by policy makers and/or manufacturers), the warranty period is the most important. This implies an alternative policy focus, in lieu of an extension of the useful life for PV units or their system conversion efficiency.

III-3 Optimal Policy Spending Levels

The formulation of an "optimal" policy must be the result of the application of much subjective reasoning and judgment. We have noted that the signs of two of the policy options reverse between two of the policy criteria. This means that increases in each of these options will involve improvements in some criteria and sacrifices in others.

The method used here to deal with these tradeoffs is to set bounds on the policy criteria. These limits are set here on the basis of the experience from the 50 cases run during the analysis, which provided guidance in terms of the range of feasibility of each of the criteria. In order to simplify the analysis, and since is appears to have little impact on the policy criteria, the level of ADV spending was set to the basecase level of $126 million for the eight year period.

III.3.1 ARD and TD Spending Levels

Policy regarding the spending levels of ARD and TD should be coordinated since they both relate to the reduction of module prices, and because it would be pointless to overemphasize the importance of the arrival of stage 3 production technology through increase ARD spending without a corresponding emphasis on the arrival of stage 2 through increased TD spending.

Two assumptions made the first estimation of optimal ARD and TD spending levels an easier task: 1) given basecase spending levels for other policy optons and basecase values for the exogenous parameters, the rate that the market is penetrated should be at least $.35 \times 10^{-4}$ (or, as used in Table III.A.7, 35,000; the decimal has been moved to facilitate the computation of reasonable coefficients); and 2) the combined effect of the arrival of stages 2 and 3 should be to contribute, or at least not to detract from, the value of SPGPKW, as given in Table III.A.5. (that is, the combined effect should be no greater than zero).

The first assumption leads to the inequality:

$$12.58 > .139\ (\text{Stage } 3) + \text{Stage } 2$$

and the second assumption generates the approximate inequality:

$$\text{Stage } 2 < \text{Stage } 3 < 2(\text{Stage } 2)$$

where Stage 2 and Stage 3 refer to the number of years from the beginning of the 8-year planning period to the arrivals of Stages 2 and 3, respectively.

Allowing some flexibility in the first assumption, and seeking the highest values for Stage 2 and Stage 3 (to minimize cost), there are two combinations that will satisfy the constraints: Stage 3 = 7, Stage 2 = 4; and Stage 3 = 6, Stage 2 = 5. There appears to be little difference between the two either in terms of spending levels or in abilities to meet the constraints. Strictly as a matter of judgement, therefore, the first of the two combinations was chosen. From the 50 cases run, it appears that this requires spending levels of $410 million for ARD, and $606 million for TD, over the eight year period.

These spending levels would appear to violate assumption (2) above, with regard to Table III.A.1. In this table, the coefficients for TD and ARD are 3.527 and -2.315. If the combined effects of these two policy options are not to increase the value of SPGPKW, then ARD should be at least 1.52 times TD. Unfortunately, this would bring the arrival of stage 3 sooner than the arrival of stage 2, and could contribute substantially to the decrease in the variable 'C', as shown in Table III.A.4. If further constraints, with MD and SUB spending levels, cannot be met, spending levels for ARD and TD will be reviewed.

III.3.2 SUB and MD Spending Levels

The spending levels for ADV, ARD and TD have been established in the previous sections. It should be noted that these spending levels should be considered flexible, since the policy criteria appear to be less sensitive to them than to SUB and MD spending levels. In addition, these estimates are based on linear least-squares regression equations, which are themselves subject to error (that is, their R^2 values are all less than 1.00).

Substituting the values for ADV, ARD, and TD that were calculated in the previous section, and the basecase values for the exogenous parameters, into the equations for 'C' (Table III.A.4), TOTINST (Table III.A.2), and SPGPKW (Table III.A.1), and setting constraints on these three variables, a solution space was derived from which the least cost combination of spending levels was estimated. The values of SPGPKW and TOTINST, judging from what is feasible and desirable from the 50 cases that were run initially, were constrained to being no more than 6,000 and no less than 200,000, respectively. If the percent of private involvement is to be at least 35 percent, then the value of 'C' should be -0.30, or greater. Substituting and simplifying, the following three inequalities are derived:

$$1.00 \leq .0019(MD) - .00012(SUB) \qquad \text{(SPGPKW)}$$

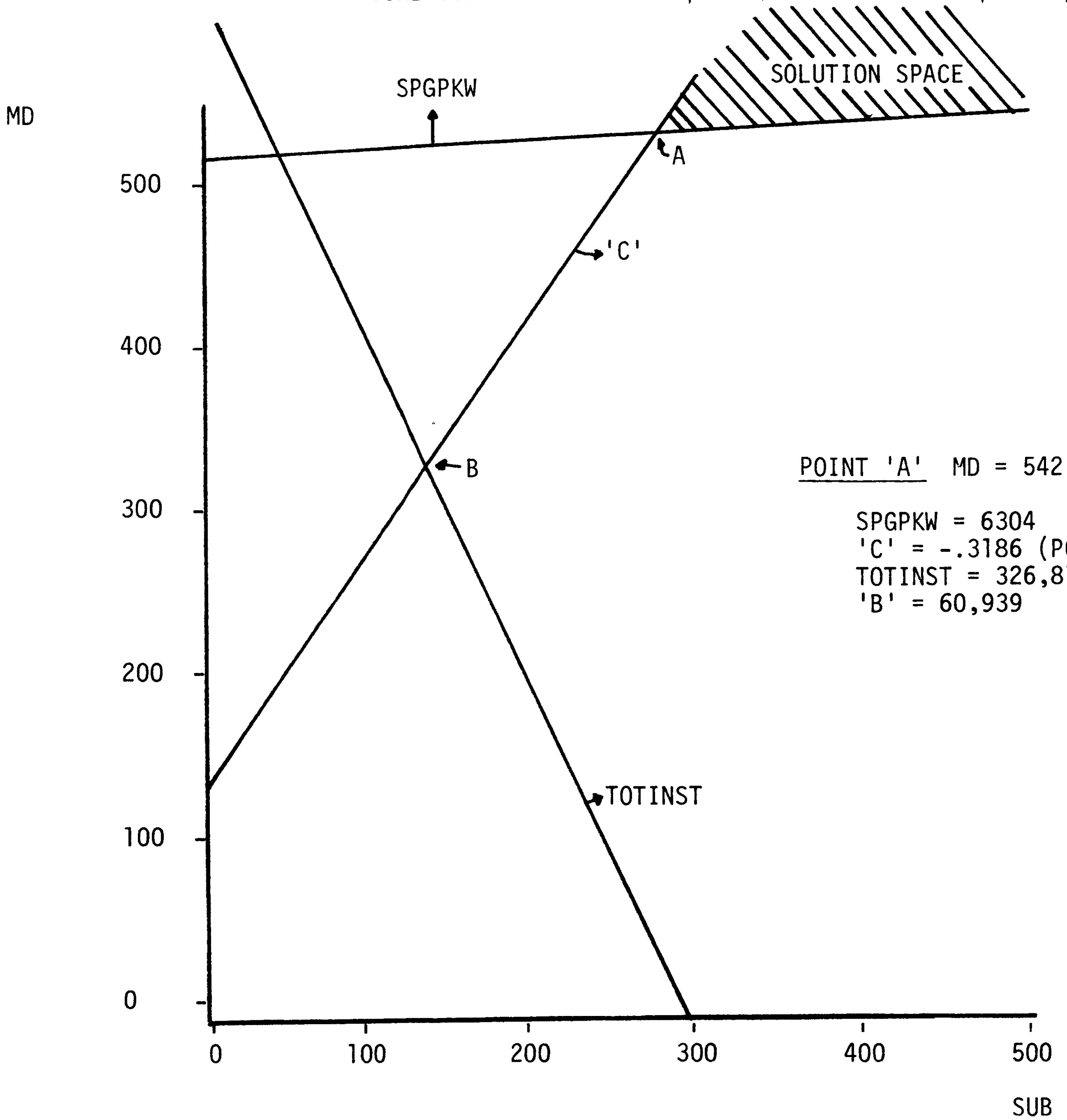
$$1.00 \leq .0017(MD) + .0036(SUB) \qquad \text{(TOTINST)}$$

$$1.00 \geq .0075(MD) - .012(SUB) \qquad \text{('C')}$$

The solution space is indicated in Figure III.1. Within the solution space, the point nearest the origin represents the point of least cost. In Figure III.1, this is point 'A', where MD spending is $542 million, and SUB is $255 million.

The total spending for this policy is therefore $1.94 billion, which is substantially above the basecase level of $1.39 billion. The first

FIGURE III.1: Solution Space for MD and SUB Spending



<u>POINT 'A'</u> MD = 542, SUB = 255

SPGPKW = 6304
'C' = -.3186 (PCTPRIV = 34.2%)
TOTINST = 326,813
'B' = 60,939

areas to trim could be ARD and TD, as stated above.

To allow the arrivals of Stages 2 and 3 to occur one year later required a decrease in TD to \$480 million and ARD to \$310 million. In addition, the spending per KWp was allowed to increase to 8000, and the percent private involvement was relaxed to 30 percent (C = .405). With the hope that the value of 'B' was still within an acceptable range, this generated three new inequalities:

$$1.00 \leq .0014(MD) + .0029(SUB) \qquad (TOTINST)$$

$$1.00 \leq .0026(MD) + .00016(SUB) \qquad (SPGPKW)$$

$$1.00 \geq .0048(MD) + .0074(SUB) \qquad ('C')$$

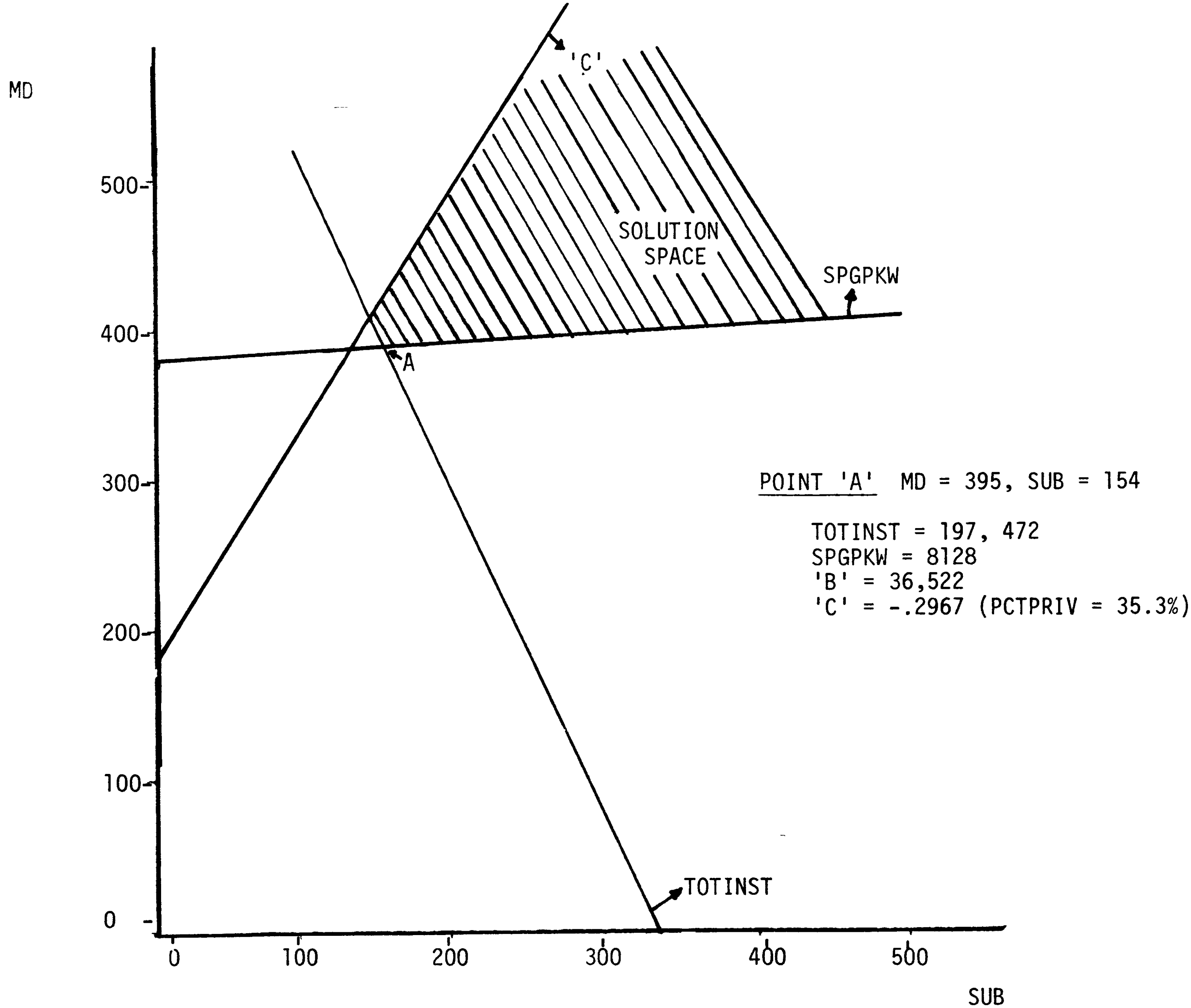
This alternate set of inequalities is illustrated in Figure III.2, with the point corresponding to the least cost combination at 'A'. This combination of policy options should result in a total spending level of \$1.47 billion over the eight year period.

III.4 Summary

In this chapter, we have discussed the relative importance of each of the policy options and the exogenous parameters in their effects on the policy criteria and on total policy costs. We have compared two policy option combinations to illustrate trade-offs among the policy options and total government spending, particularly with regard to MD and SUB spending. It has been shown that, as a preliminary estimate, a small decrease in MD spending and a substantial increase in SUB spending, compared to the basecase, can provide a marked improvement in the policy criteria with only a modest increase in total spending.

It was found that policy criteria could be estimated on the bases of policy options, and an "optimal" level could be estimated as well:

FIGURE III.2: Alternate Solution Space for MD and SUB Spending



	Options ($\$ \times 10^6$)		Criteria
ADV	126	'B'	35,622
ADV	480	'C'	-.2967 (PCTPRIV= 35.3 percent
ARD	310	SPGDW	8128
SUB	154	TOTINST	197,472
MD	395		
TOTAL	1,465		

Thus, by increasing the total spending by only 5.7 percent, the estimated values of TOTINST increased by 25 percent, 'B' increased by almost 23 percent, the percent private involvement, by nearly 53 percent, and the value of SPGKW, the total amount spent by the government per total installed KWp of PV, decreased by more than 7 percent. By spending more for subsidy and less for market development, all of the policy criteria were projected to be enhanced.

APPENDIX TO CHAPTER III

(For definitions of variables, see Table III.I.A)

Table III.A.1

Dependent Variable: SPGPKW

MEAN: 9125 STANDARD DEVIATION: 3200

Independent Variable	b	Beta	Mean	Standard Deviation
LIFE	-86.33	-.0938	20.4	3.5
RR	-125.78	-.4808	5.7	12.2
PVEF	-186.16	-.1254	12.3	2.2
WARR	-170.68	-.2070	12.6	3.9
MD	-26.17	-.7007	425.4	85.7
NSC	13.71	.2441	175.0	57.0
TD	3.527	.1215	511.9	110.2
ADV	4.935	.0738	127.6	47.8
ARD	-2.315	-.0617	336.0	85.3
SUB	1.633	.0333	53.9	65.3
Constant	22975.34	-----		

R^2 = .8189

Number of Cases: 50

Table III.A.2

Dependent Variable: TOTINST

MEAN: 192263 STANDARD DEVIATION: 158500

Independent Variable	b	Beta	Mean	Standard Deviation
LIFE	933.40	.0205	20.4	3.5
RR	9092.26	.7016	5.7	12.2
PVEF	2264.02	.0315	12.3	2.2
WARR	2427.55	.0594	12.6	3.9
MD	353.14	.1909	425.4	85.7
SUB	725.86	.2992	53.9	65.3
ARD	207.23	.1115	336.0	85.3
TD	80.76	.0562	511.9	110.2
NSC	125.44	.0451	175.0	57.0
ADV	26.782	.0081	127.6	47.8
Constant	-262,676.8	----		

R^2 = .9599

Number of Cases: 50

Table III.A.3

Dependent Variable: B

Independent Variable	b	Beta	Mean	Standard Deviation
LIFE	185.28	.0265	20.4	3.5
RR	1383.67	.6974	5.7	12.2
PVEF	453.67	.0412	12.3	2.2
WARR	493.74	.0790	12.6	3.9
MD	65.48	.2311	425.4	85.7
NSC	8.007	.0188	175.0	57.0
TD	16.203	.0736	511.9	110.2
SUB	106.80	.2875	53.9	65.3
ARD	31.90	.1121	336.0	85.3
ADV	4.268	.0084	127.6	47.8
Constant	-43,235.70	----		

R^2 = .9518

Number of Cases: 50

Table III.A.4

Dependent Variable: C

MEAN: -0.4339 STANDARD DEVIATION: 0.3524

Independent Variable	b	Beta	Mean	Standard Deviation
SUB	.0034	.6365	53.9	65.3
MD	-.0022	-.5241	425.4	85.7
ADV	.00004	.0055	127.6	47.8
TD	.00004	.0137	511.9	110.2
ARD	-.00046	-.1122	336.0	85.3
NSC	.0013	.2174	175.0	57.0
LIFE	.0086	.0849	20.4	3.5
RR	.0036	.1251	5.7	12.2
PVEF	.0183	.1143	12.3	2.2
WARR	.0152	.1670	12.6	3.9
Constant	-.4203	----		

R^2 = .8750

Number of Cases: 50

Table III.A.5

Dependent Variable: SPGPKW

MEAN: 9125 STANDARD DEVIATION: 3200

Independent Variable	b	Beta	Mean	Standard Deviation
LIFE	-86.295	-.0938	20.4	3.5
RR	-118.830	-.4543	5.7	12.2
PVEF	-180.873	-.1245	12.3	2.2
WARR	-167.567	-.2033	12.6	3.9
MD	-26.069	-.6980	425.4	85.7
NSC	12.740	.2269	175.0	57.0
STG2	-474.612	-.1359	4.8	0.9
STG3	286.846	.0952	8.7	1.1
ARV	4.7757	.0714	127.6	47.8
Constant	23917.23	-----		

R^2 = .8187

Number of Cases: 50

*F-level or Tolerance-level insufficient to include SUB

Table III.A.6

Dependent Variable: TOTINST

MEAN: 192263 STANDARD DEVIATION: 158500

Independent Variable	b	Beta	Mean	Standard Deviation
LIFE	899.53	.0197	20.4	3.5
RR	8897.83	.6866	5.7	12.2
PVEF	2174.83	.0302	12.3	2.2
WARR	2305.32	.0565	12.6	3.9
MD	353.25	.1909	425.4	85.7
SUB	767.53	.3163	53.9	65.3
STG3	18942.4	.1269	8.7	1.1
NSC	164.96	.0593	175.0	57.0
STG2	-8306.16	-.0480	4.8	0.9
ADV	27.393	.0083	127.6	47.8
Constant	47012.75	-----		

R^2 = .9614

Number of Cases: 50

Table III.A.7

Dependent Variable: B

MEAN: 34787 STANDARD DEVIATION: 24269

Independent Variable	b	Beta	Mean	Standard Deviation
LIFE	179.84	.0258	20.4	3.5
RR	1358.00	.6844	5.7	12.2
PVEF	440.41	.0400	12.3	2.2
WARR	476.67	.0762	12.6	3.9
MD	65.700	.2322	425.4	85.7
STG3	-2711.88	-.1186	8.7	1.1
SUB	112.17	.3019	53.9	65.3
STG2	1944.92	-.0734	4.8	0.9
NSC	13.228	.0311	175.0	57.0
ADV	4.2323	.0083	127.6	47.8
Constant	7827.986	----		

R^2 = .9533

Number of Cases: 50

Table III.A.8

Dependent Variable: C

MEAN: 0.4339 STANDARD DEVIATION: 0.3524

Independent Variable	b	Beta	Mean	Standard Deviation
SUB	.0035	.6486	53.9	65.3
MD	-.0021	-.5182	425.4	85.7
ADV	.00004	.0053	127.6	47.8
STG2	.0045	.0118	4.8	0.9
STG3	.0257	.0774	8.7	1.1
NSC	.0014	.2272	175.0	57.0
LIFE	.0085	.0843	20.4	3.5
RR	.0033	.1144	5.7	12.2
PVEF	.0181	.1134	12.3	2.2
WARR	.0150	.1647	12.6	3.9
Constant	-.8148	----		

R^2 = .8729

Number of Cases: 50

IV. Summary and Policy Recommendations

It is not the purpose of this work to establish exact levels of optimal spending. Instead, it is meant to provide general guidelines for policy focus, for general relationships between government spending and the resulting PV commercialization levels, and for trade-offs among the spending alternatives. There are five such alternatives incorporated into PV1: advertising, technology development, advaned research and development, subsidy, and market development. The ability of these spending options to accelerate the commercialization of PV are easured using four criteria: the total KW_p of PV installed after 8 years, the rate at which the market has been penetrated over this 8-year period, the percent of the total installed KW_p that results from private sales (using a logarithmic transformation), and the total government expenditures per total KW_p installed.

In comparing the effectiveness of these policy options, the beta values from Tables III.A.1 to III.A.8 are used. it is important to note that these betas, the standardized regression coefficients, reflect the changes about the means in terms of numbers of standard deviations, and that these values are only valid for the 50 cases that are in the vicinity of the base case. A choice of another base case could easily result in different betas.

Advertising

The algorithm used in PV1 for the effects of advertising on the awareness of PV among potential buyers causes very weak relationships between advertising and the four policy criteria. None of the beta values for ADV are greater than .0738 in any of the multiple regressions (Tables III.A.1-8). According to the assumptions in PV1, the entire task of increasing the awareness of PV could be undertaken by market development, reducing ADV to zero, and the total market penetration after 8 years would be reduced by less than 1 percent.

Technology Development and Advanced Market Research and Development

The assumptions made in PV1 regarding these 2 spending options are that: 1) TD spending will reduce the time required by industry that is needed to produce PV modules using the most efficiently sized manufacturing facilities (the arrival of stage 2); and 2) ARD spending will reduce the time for the development of the PV module that will represent the ultimate in terms of both technology and low price (the arrival of stage 3).

It is possible that the production and basic technologies for PV modules may occur in more (or less) than 3 stages. It is difficult to determine the effectiveness of these policy options on price reductions. It is indeed difficult to measure the benefits of TD and ARD spending in any area. It may be the most appropriate strategy for the funding agency to interact frequently with those organizations receiving funds for TD and ARD, to adjust future spending levels.

While these recommendations are beyond the scope of PV1, the results of this analysis indicate that neither policy option (TD nor ARD) has a large effect on the policy criteria. The larges beta value has a magnitude of only .1214 (Table III.A.1). The arrival dates of the new production technologies (Stages 2 and 3) also have small effects on the criteria. However, these spending options will have large impacts on the gross system costs for PV, and although the GSC does not strongly affect the early market penetration of PV, it could have a substantial impact on this penetration in later years, once it has become a widely accepted technology.

There are othger possible effects of TD and ARD spending: the improvements in PV system life and efficiency. However, the cause and effect relationships are unclear, and the beta coefficients for LIFE and LVEF have low magnitudes.

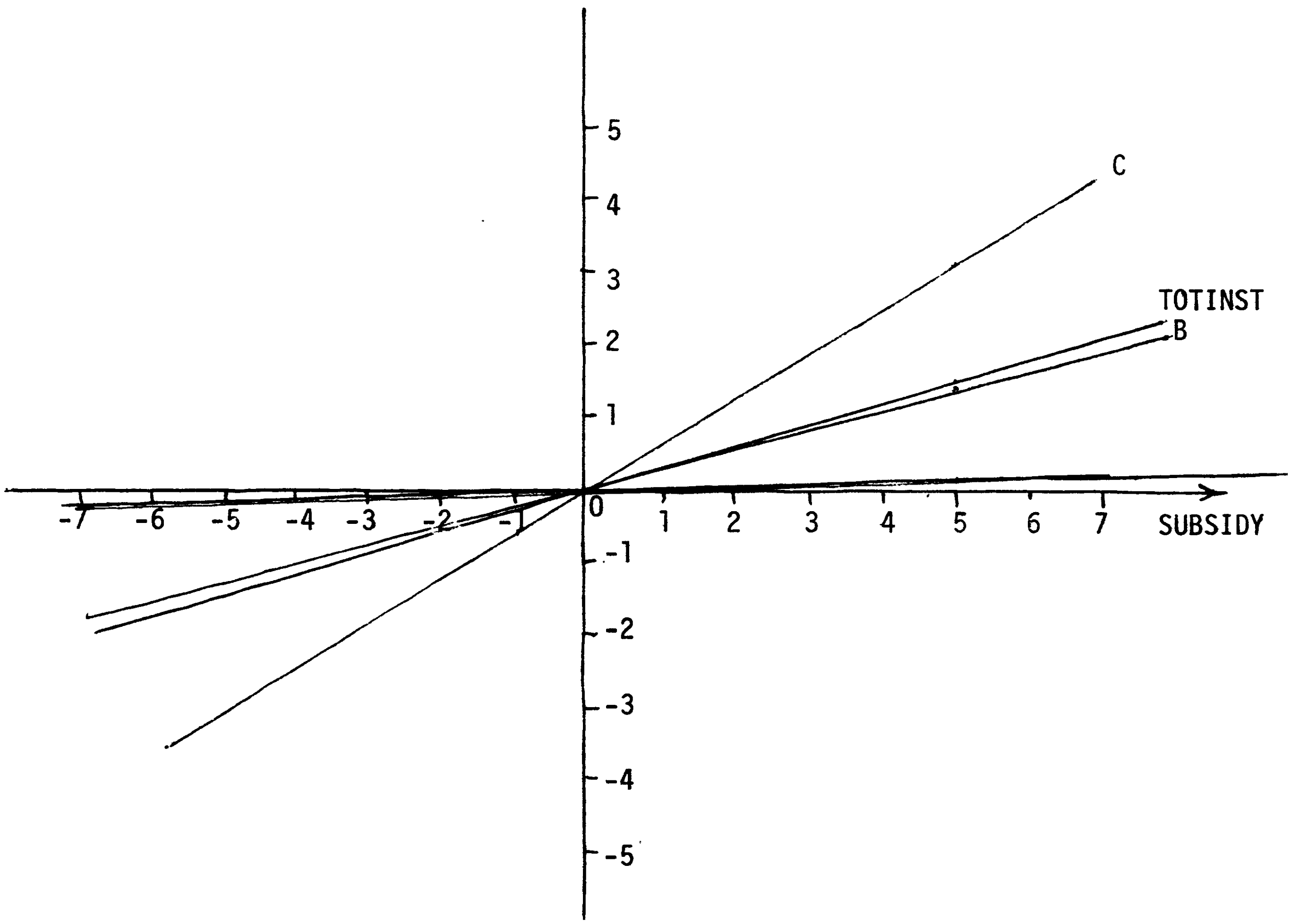
Market Development and Subsidy

These two policy options are the most important of the five, with magnitudes of their beta coefficients as high as .7007 for MD and .6365 for SUB. Increased expenditures for MD and SUB do not always contribute, in a desirable direction, to the policy criteria. Their beta coefficients are summarized in Figures IV-1 and IV-2.

From these two figures, it can be seen that an increase in SUB spending will improve C, B, and TOTINST, with a relatively small sacrifice in SPGPKW; an increase in MD will improve SPGPKW, B, and TOTINST, but at a substantial sacrifice in C. Both SUB and MD could be increased in equal amounts but that would result in a higher overall budget. If SUB is increased substantially, however, a modest reduction in MD will offset the increase in SPGPKW and return the other policy criteria to levels at or above their previous levels. The spending levels recommended in Chapter III, for example, represent a value for SUB that is 1-1/2 standard deviations above its mean, and MD 1/3 below its mean. These result in values for policy criteria that are better than the mean values (except for C) and better than the base case values (for all criteria).

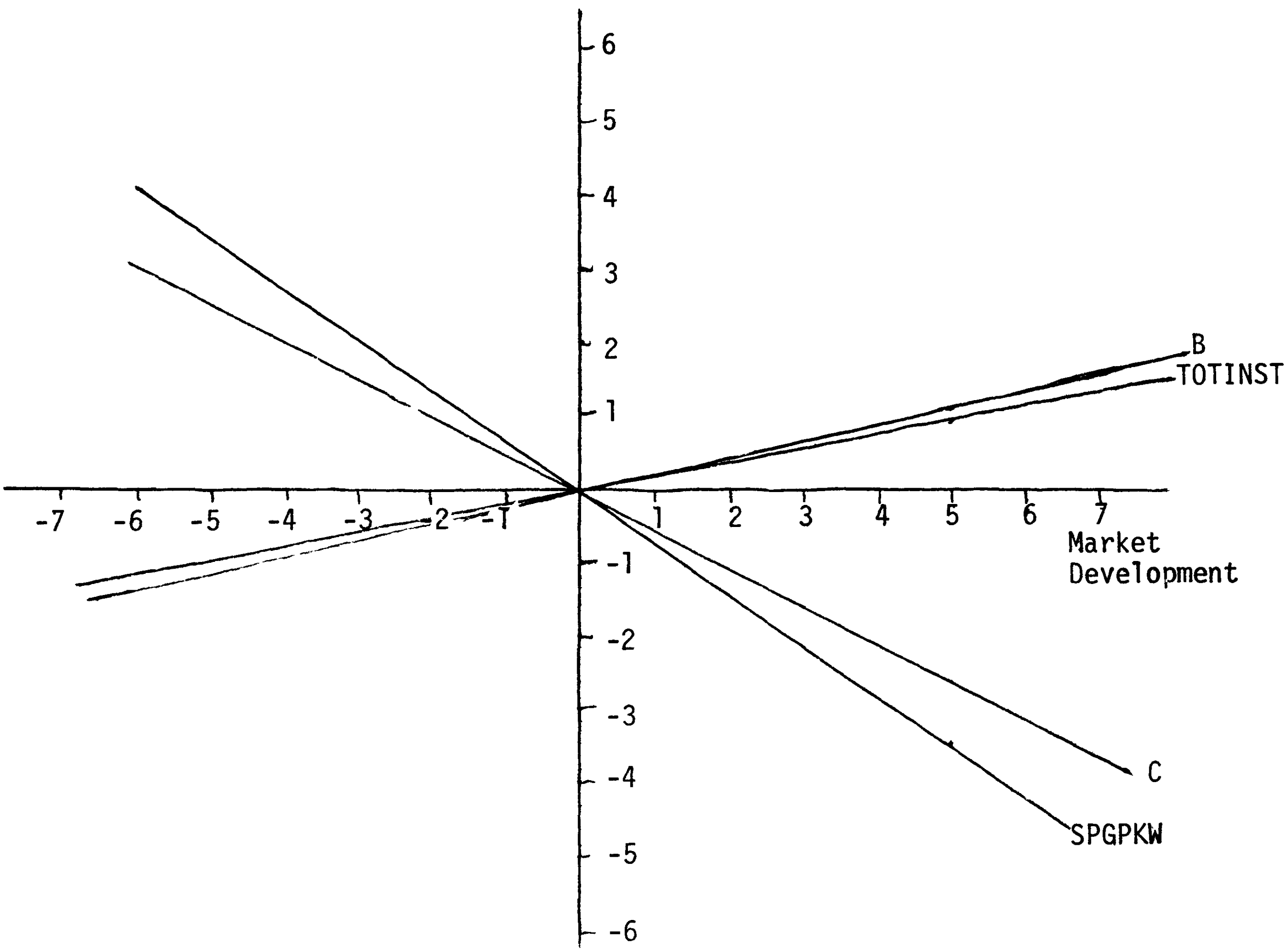
Subsidy rates substantially highr than those currently in use by DOE were shown to be very effective in accelerating commercialization, especially if ceilings were removed. It is, however, advantageous to

FIGURE IV-1: SENSITIVITY OF POLICY CRITERIA TO SUBSIDY SPENDING AS STANDARD DEVIATIONS FROM MEANS



* from BETA Coefficients in Multiple Regression Equations that include LIFE, RR, PVEF, WARR, NSC, and all 5 Policy Options (Tables III.A.1-4)

FIGURE IV-2: SENSITIVITY OF POLICY CRITERIA TO MARKET DEVELOPMENT SPENDING AS STANDARD DEVIATIONS FROM MEANS*



* from BETA Coefficients in Multiple Regression Equations the include LIFE, RR, PVEF, WARR, NSC, and all 5 Policy Options

(Tables III.A.I-4)

postpone these higher subsidies until the PV gross system cost has declined sharply. The best subsidy timing appeared to be one in which the subsidy rate increased steadily over time to a maximum level, and remained there (as in case SUB-5, Table II.A.1).

One of the limitations of PV1 is illustrated here: there is no provision in PV1 for the anticipation of PV price reductions that are predictable. If it is government policy to increase subsidy over time, many potential buyers may postpone their decision to purchase PV until the maximum subsidy is offered.

Similar to SUB, it appears beneficial to postpone MD spending, since this spending will purchase more PV when the price is lower, in later years. A carefully managed program to install MD PV units in the most advantageous regions of the country does not seem to be a worthwhile endeavor.

(Another limitation of PV1 is apparent here. While the positive effects of successful MD units are amply documented, there is no provision for the negative effects of failures.)

A policy that waits lower net system costs (NSC) before making MD and SUB expenditures represents a possible paradox: without MD and SUB expenditures, NSC may decline very slowly. The results of these 50 cases indicate that this paradox is only partly true. A multiple regression equation was constructed using NSC as the dependent variable, and the policy options as independent variables (See Table IV.1.).

The four policy options that can be included in this equation explain only 25 percent of the variance of the NSC at the end of the 8-Oyear model. The large magnitude of beta for ARD is the result of the changeover to Stage 3 just before the 8th year of the model due to ARD

Table IV.1

Dependent Variable: NSC

MEAN: 175.0 STANDARD DEVIATION: 57.0

Independent Variable*	b	Beta	Mean	Standard Deviation
ARD	-.3419	-.5117	336.0	85.3
SUB	-.2372	-.2720	53.9	65.3
MD	-.1250	-.1880	425.4	85.7
TD	.0247	.0478	511.9	110.2

Constant: 343.26

R^2 = .2513

Number of Cases: 50

---

*F-level or Tolerance-level insufficient to include SUB spending; ARD will not affect NSC values in earlier years. The low magnitudes of the betas for MD and SUB indicate that these policy options have little effect on NSC in the 8th year, and in earlier years as well.

There may be interactions, however, between MD and SUB that could affect NSC in early years. Therefore, it is recommended that both MD and SUB begin in early years at a low level, but above zero, and slowly build over time to a maximum level. The maximum subsidy rate could be as high as 80 percent, should have no ceiling associated with it, and could be the same for all sectors.

Other Policy Options

Two of the exogenous parameters have high beta valus: RR (the real annual rate of increase in the price of electricity) and WARR (the PV warranty period). While it would be inappropriate to suggest that capacity rates should be raised intentionally simply to accelerate the commercialization of PV, it is apparent that the real price of electricity has a powerful impact on the policy criteria. However, this impact occurs only when the real price of electricity increases by at least 20 percent per year over the 8-year period of the model.

Extending the warranty period seems to be a more realistic alternative policy option. The increased cost to the manufacturer of an extended warranty period could be directly subsidized by the government. This would increase the acceptance of PV among potential buyers, and thereby accelerate the commercialization of PV. As indicated in Secton II.5, an extended warranty period would enhance all of the policy criteria substantially. The cost of such a policy is unclear at this time.

One counterintuitive conclusion of this analysis is that the reduction of net system costs should not be a primary policy goal. A reduced NSC in the eighth year of the model will actually reduce the private involvement in the market (Table III.A.4) and reduce the total market penetration and its rate (Tables III.A.2 and 3), although a reduced NSC will increase the overall policy efficiency (Table III.A.1).

<u>Conclusion</u>

PV1 has been used in the writing of this report to demonstrate its use as a policy analysis device. The results, as summarized in this chapter, indicate that PV1 could be used to determine the interactions among policy options and to obtain guidelines for the relative levels of spending in each of these options. It would be inappropriate to use PV exclusively to arrive at absolute spending levels for any of the policy options.

The conclusions arrived at in this paper reflect conditions at or near the base case, as defined in Section I.4. It is entirely possible that different conclusions may be drawn given a substantially different base case. If the policy maker feels that this base case is inappropriate, a new one should be constructed, and this paper would then serve as a guide to an extensive analysis using this new base case.

Further work is needed using PV1 to more clearly establish the relationships among subsidy spending, market development spending, and the next system cost during the intermediate years of the model. This could help to define the increases and decreases of these options over time, that would most efficiently accelerate the commercialization of PV. Other work is needed to establish threshold spending amounts in each of the policy options, in order to establish optimal spending levels in absolute terms.

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