ANALYSIS OF FEDERAL OPTIONS TO SUPPORT PHOTOVOLTAIC INDUSTRY GROWTH

DO NOT MICROFILM
THIS PAGE

MASTER

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

The MITRE Corporation

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

Analysis of Federal Options to Support Photovoltaic Industry Growth

AC01-780335147

G. Bennington
A. Cherdak
F. Williams

MTR--79W00020

DE83 016951

May 1979

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

Contract Sponsor: The Department of Energy
Conservation and Solar Applications

Contract No.: EM-78-C-01-5147
Project No.: 1619K
Dept.: W-52

The MITRE Corporation
Metrek Division
1820 Dolley Madison Boulevard
McLean, Virginia 22102

NOTICE

PORTIONS OF THIS REPORT ARE ILLEGIBLE.

**It has been reproduced from the best
available copy to permit the broadest
possible availability.**

MTR-79W00020

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

leg

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

ABSTRACT

This report presents the methodology and results of an analysis to determine the impact and leverage of Federal options for supporting the growth of the photovoltaic industry. Results were projected for combinations of the following: an aggressive Federal research and development program, achievement of a technological breakthrough, and immediate or breakthrough-dependent incentives including direct price reductions, keyed-to-breakeven subsidies, and Federal purchases. The modeling methodology and market assumptions were also tested to determine their effect on analysis results.

TABLE OF CONTENTS

	<u>Page</u>
LIST OF ILLUSTRATIONS	vii
LIST OF TABLES	vii
EXECUTIVE SUMMARY	ix
1.0 INTRODUCTION	1
2.0 SCOPE	3
2.1 Markets	3
2.2 Incentive Cases	4
2.3 Technology Development	5
3.0 METHODOLOGY	6
3.1 Composition of Transition Markets	7
3.2 Composition of Mass Markets	7
3.3 Market Response	9
3.4 Photovoltaic System Assumptions	15
3.5 System Size	15
3.6 System Price	17
3.7 Collector Price	17
3.8 Balance of System Prices	21
3.9 General Economic Assumptions	24
4.0 PHASE 1 ANALYSIS	26
4.1 Approach	26
4.2 Results and Conclusions	28

	<u>Page</u>
5.0 PHASE 2 ANALYSIS	31
5.1 Approach	31
5.2 Results	31
6.0 PHASE 3 - TESTING OF ASSUMPTIONS	37
6.1 Modeling Methodology	37
6.2 Market Assumptions	39
APPENDIX A: ANALYSIS RESULTS	A-1
APPENDIX B: MARKET DATA BASE	B-1
APPENDIX C: INCENTIVE MECHANISMS	C-1

LIST OF ILLUSTRATIONS

<u>Figure Number</u>		<u>Page</u>
1	Metrek Market Share Function	13
2	Components of a Photovoltaic System	16
3	No Technology Breakthrough, Agressive Federal R&D Program (Phase 1 Analysis, Cases 2A and B)	18
4	No Technology Breakthrough, No Federal R&D Program (Phase 1 Analysis Cases 4A and B)	18
5	Technology Breakthrough, Agressive Federal R&D (Phase 1 Analysis, Cases 1A, B and C)	19
6	Technology Breakthrough, No Federal R&D Program (Phase 1 Analysis Cases 3A, B and C)	19
7	Phase 1 Incentive Cases and Options	27

LIST OF TABLES

<u>Table Number</u>		<u>Page</u>
I	Transition Market Data and System Price	8
II	Market Potential and Suitability of Residential and Commercial Buildings--New Construction	10
III	Potential Photovoltaic Central Utility Market	11
IV	Figure of Merit by Market Sector	14
V	Balance of System Price Assumptions	22
VI	Assumptions: Balance of Systems for Transition Markets	23
VII	Economic Parameters	25
VIII	Summary of Phase 1 Analysis	29
IX	Summary of Phase 2 Analysis--Breakthrough Cases	32
X	Summary of Phase 2 Analysis--Non-Breakthrough Cases	34
XI	Qualitative Assessment of Options	36
XII	Test of Assumptions--Price Reduction Methods	38

<u>Table Number</u>		<u>Page</u>
XIII	Test of Assumptions--Commercial and Utility Market Impact, No Incentives	40
XIV	Test of Assumptions--Commercial and Utility Market Impact, No Breakthrough, with Immediate Incentives	41
XV	Test of Assumptions--SERI Markets, Aggressive Federal R&D, No Incentives, No Breakthrough	43

EXECUTIVE SUMMARY

Photovoltaic systems provide a clean, simple method for the conversion of sunlight into electrical energy. The systems are silent and require no complex machinery, heat engine cycle, or intermediate conversion to heat.

However, the current costs of photovoltaic systems are high. As a result, photovoltaic sales are limited, and the existing industry for production of such systems is small.

This report presents the methodology and results of MITRE's analysis to determine the relative merit of various Federal options for supporting the growth of the photovoltaic industry.

The analysis was performed in three phases:

- Phase 1 consisted of a preliminary screening to identify the incentive cases with the greatest potential impact and leverage of Federal funds.
- Phase 2 consisted of a more detailed analysis of the three cases with the greatest potential.
- Phase 3 consisted of an analysis to determine how alternative assumptions would affect the results from Phases 1 and 2.

MITRE's photovoltaic market response model was used in each phase of the analysis. The model utilizes a market share function to estimate the fraction of a potential market that may be captured by the photovoltaic industry. It is assumed that reductions in photovoltaic prices will result from increased cumulative production experience rather than price/time relationships.*

*An exception is found in Phase 3 where the model was altered to examine industry production, assuming the achievement of DOE price goals.

Input to the model included estimates of size and breakeven prices for transition and residential markets.

The residential market was used as an index for determining the beginning of mass market penetration because the residential user can typically be expected to pay slightly more for electricity than commercial users and much more than industrial users.*

Although the residential market is an adequate mechanism for determining the relative impact of various incentives, the commercial/industrial and utility markets must be considered in quantifying the full extent of an incentive's impact.

Results were projected for various combinations of the following:

- continuation of an aggressive Federal research and development program
- achievement of a technological breakthrough (identification, by the mid-1980's of photovoltaic collector technology that could achieve a FOB factory price of 10 to 30 cents per peak watt)
- immediate (1980-1990) or breakthrough-dependent incentives (incentives withheld until 1990 through 2000--after a breakthrough has occurred) including:
 - direct price reductions (e.g., tax credits),
 - keyed-to-breakeven subsidies (reduction in the price of a photovoltaic system in proportion to the difference between the market price of the system and the breakeven price of the application)
 - Federal purchases

The effectiveness of each incentive was determined by its market impact and the leverage of Federal funds.

*National Electrical Rate Book, Federal Power Commission, 1976.

Market impact was measured by cumulative and annual collector sales and sales of systems in energy-saving mass markets. Leverage of Federal funds was determined by the Federal cost, collectors sold per Federal dollar invested, and systems sold in the mass market per Federal dollar.

This analysis resulted in the identification of the most promising of many broadly defined types of incentives. Conclusions which can be derived intuitively have been quantified and confirmed.

The findings based on this analysis represent only one step in a planning process to identify the "best" incentive. An investigation of delivery mechanisms and costs associated with promoting rapid achievement of a breakthrough and/or providing an immediate 50 percent keyed-to-breakeven subsidy would be a logical follow-up. The impact of commercial, industrial, utility and foreign markets must also be considered.

There are numerous mechanisms for each of the most promising types of incentives. Promoting a breakthrough, for example, could involve Federal laboratories, Federal grants to non-Federal sources, tax credits for private research, or guaranteed production support for breakthrough technology. A keyed-to-breakeven subsidy could be delivered as, for example, tax incentives for manufacturers or tax refunds to purchasers.

MAJOR FINDINGS

- o DOE price goals of 50¢ per Watt peak by 1986 are probably achievable without incentives if a technological break-

through occurs. Achievement of the goals would require markets that would be large enough to justify large-scale production of the breakthrough technology, once it is identified.

- A technological breakthrough by the 1980s would have a greater impact than any reasonable program of Federal incentives offered in 1980-1990 or 1990-2000. This emphasizes the need to continue and possibly improve or expand the Federal R and D program, thus increasing the probability of a breakthrough.
- If a technological breakthrough occurs, immediate or breakthrough-dependent incentives would have similar impact and leverage.
- If a breakthrough does not occur, immediate incentives would increase the impact and leverage of Federal expenditures.
- A 50 percent keyed-to-breakeven subsidy appears to be the most promising incentive for assuring high impact and leverage, with or without a breakthrough. However,
- A firm identification of the best incentive option will require additional analysis of incentive delivery mechanisms and associated administrative costs.

1.0 INTRODUCTION

Photovoltaic systems provide a clean, simple method for the conversion of sunlight into electrical energy. The systems are silent and require no complex machinery, heat engine cycle, or intermediate conversion to heat.

However, the existing photovoltaic industry is small--it presently consists of about 10 manufacturers and vendors of collectors or arrays.*

The current costs of photovoltaic systems are the greatest barrier to extensive market penetration and industry growth. The current capital cost of photovoltaic collectors ranges from \$12 to \$30 per peak watt for silicon flat plate arrays. The electricity they produce is 25 to 100 times more expensive than electricity generated by conventional energy sources.** As a result, current applications of photovoltaic systems are small-scale--i.e., generally less than one peak kilowatt--and most are located in remote areas where utility grid inter-ties would be very expensive. A total of approximately 700 peak kilowatts (kWp) were delivered in 1977.*

Federal action could be a major factor in promoting the development of a commercially viable, competitive photovoltaic industry. In recognition of this potential, MITRE/Metrek has analyzed alternative

*Photovoltaic Incentives Option--Preliminary Report to Congress, the BDM Corporation, Sponsored by DOE, August 1978.

**Based upon a 10 percent fixed charge rate, a 20 percent capacity factor for flat-plate photovoltaic collectors, and a balance-of-system price that is comparable to the collector price.

Federal options to determine their relative merits in providing for adequate growth of the photovoltaic industry. The most promising of many broadly defined types of incentives have been identified. These findings may be used to help focus the detailed analysis of delivery mechanisms and costs that would be needed to identify "the best incentive."

Although quantitative methods have been used in this analysis, MITRE recognizes that the numeric results are highly sensitive to cost and market assumptions that are fraught with uncertainty. For this reason, the numeric results in this report are presented only as indices of relative merit.

2.0 SCOPE OF THE STUDY

2.1 Markets

There are three potential markets for photovoltaic systems: current markets, intermediate/transition markets, and energy-saving/mass markets. The current market includes the relatively high-priced remote applications (such as microwave and radio repeaters, and cathodic protection equipment) which are now being sold by private industry.

Intermediate/transition markets include those applications that would require a sales price that is lower than current prices to be competitive against other available energy sources. These applications, which may include, for example, irrigation and remote village power, generally have no economical access to electric grid power.

Energy-saving/mass markets are comprised of applications that would require sales prices that are competitive with grid-supplied energy generated with conventional fuels. Major uses could include systems for residential, commercial, and industrial buildings and utilities for central power generation.

This analysis focused on identifying options that would promote industry growth through the transition markets and either stimulate or initiate penetration of the mass markets.

2.2 Incentive Cases

The following three types of incentive cases were analyzed. Possible mechanisms for administering each option are discussed in Appendix D:

- o continuation of an aggressive, Federally sponsored research and development (R&D) program
- o immediate incentives consisting of:
 - direct price reductions of 10, 20, and 30 percent in the years 1980 to 2000
 - keyed-to-breakeven subsidies of 25, 50, 75, and 100 percent in 1980 to 1990
 - Federal purchases of 50-1000 MWp in the years 1981-1990
- o Breakthrough-dependent incentives (offered if breakthrough technology is identified) consisting of:
 - keyed-to-breakeven subsidies of 25, 50, 75, and 100 percent in the years 1990 to 2000
 - Federal purchases of 50-1000 MWp in the years 1990 to 2000

The direct price reduction could be implemented as, for example, a consumer tax credit or producer subsidy. In this analysis, the incentive was applied to all photovoltaic sales, regardless of the breakeven costs of application.

The keyed-to-breakeven subsidies would be applied only to applications where photovoltaic technology is not economically competitive. The subsidy would reduce the price of a photovoltaic system in proportion to the difference between the market price of the system and the breakeven price of the application.

The Federal purchase incentive could increase industry production, thus reducing single-unit production costs through economies-of-scale. The purchase would not necessarily require that the photovoltaic application be economically competitive with other energy sources.

2.3 Technology Development

The impact of each incentive option was projected for both breakthrough and non-breakthrough technology development.

Breakthrough technology development has been defined as the near- to mid-term (mid-1980's) identification of photovoltaic collector technology that could achieve a FOB factory price of 20 cents per peak watt. This is consistent with the DOE goal of 10 cents to 30 cents per peak watt around the year 1990. It is assumed that the breakthrough will result from the development of low cost types of advanced collectors (e.g., thin films or compound cell concentrators) and/or advanced production processes (e.g. ribbon growth of silicon). The experience accumulated in the production of existing technology will not necessarily be applicable to the new cell types or production processes.

Non-breakthrough technology development has been defined as the evolutionary (gradual) reduction of collector price. This reduction is assumed to result from cumulative production experience and the gradual introduction of new technology.

3.0 METHODOLOGY

The photovoltaic incentive analysis was performed in three phases:

- Phase 1 consisted of a preliminary screening to identify the incentive cases with the greatest potential impact and leverage of Federal funds
- Phase 2 consisted of a more detailed analysis of the three cases with the greatest potential
- Phase 3 consisted of an analysis to determine how alternative assumptions would affect the results from Phases 1 and 2

MITRE's photovoltaic market response model was used in each phase of the analysis. The model utilizes a market share function to estimate the fraction of a potential market that will be captured by the photovoltaic industry. Reductions in photovoltaic prices result from cumulative production experience rather than price/time relationships.

In Phases 1 and 2, input to the model included estimates of size and breakeven prices for transition and residential markets.

The residential market was used as an index for determining the beginning of mass market penetration. This is because the residential user can typically be expected to pay slightly more for electricity than commercial users and much more than industrial users.*

*National Electrical Rate Book, Federal Power Commission, 1976.

Although the residential market is adequate for determining the relative impact of various incentives, the commercial/industrial and utility markets must be considered in quantifying the full extent of an incentive's impact. The potential impact of these markets and foreign markets was estimated in Phase 3.

3.1 Composition of Transition Markets

There is a large degree of diversity and fragmentation among the various domestic transition markets. As a result, estimates of the transition market size and composition vary greatly.*

In this study, MITRE has adopted a modified version of the markets described by BDM.** Market sectors contained in the BDM estimates include:

agriculture	forestry	military
commerce and service	household/consumer	mining
communication	industry	transportation
construction	leisure/recreation	utilities (auxiliaries)

The size of the total transition market is summarized in Table I. Appendix B gives a listing of the approximately 140 applications in this market.

3.2 Composition of Mass Markets

The residential and commercial market estimates were derived from the SPURR*** data base. The total market potential was assumed

*BDM Corporation, Draft Final Report-Photovoltaic Power Systems Market Identification and Analysis, BDM/W-77-049-TR, Nov. 1977, Vol. II.

Intertechnology Corp., Photovoltaic Power Systems Market Identification and Analysis, 1977.

SERI, Venture Analysis.

**BDM Op. cit.

***System for Projecting Utilization of Renewable Resources.

TABLE I

TRANSITION MARKET DATA AND SYSTEM PRICE

BREAK-EVEN LIFE-CYCLE SYSTEM PRICE (1986 prices in 1975 dollars per Watt peak)		POTENTIAL MARKET SIZE MW PEAK/YR*
>20		3
10-20		5
5-9.9		5
1-4.9		330
1 OR LESS		<u>6,050</u>
TOTAL		<u>6,393</u>

*This is a composite--not all applications are available in all years of the market penetration analysis.

(SOURCE: BDM/MITRE)

to encompass all new building construction. However, only a fraction of all new buildings was estimated to be suitable for solar (including photovoltaic) systems. This suitability fraction was assumed to increase with time as a result of, for example, increased solar awareness on the part of construction contractors and consumers. Estimates of the residential and commercial market potential and suitability fractions assumed in this analysis are summarized in Table II. Estimates of the potential markets for central utility systems were based upon the National Energy Plan scenario for electrical energy demand through the year 2000. For photovoltaic systems, the potential market penetration was limited to supplying 10 percent of this demand.*

Photovoltaic central utility systems may provide energy at a capacity factor of about 25 percent for fuel savers (photovoltaic systems with no dedicated energy storage) in the southwestern United States.** Based upon this and the demand scenario stated above, Table III shows total potential central utility markets through 2000.

3.3 Market Response

Market allocation among competing conventional and solar technologies is determined by first computing a Figure of Merit (FOM)

*EPRI states 5 percent as a reasonable national value, with a range approaching 20 percent in some regions of the U.S. See Requirements Assessment of Photovoltaic Power Plants in Electric Utility Systems, Electric Power Research Institute, EPRI ER-685-SY, Vols. 1-3, June, 1978.

**Systems Description and Engineering Costs for Solar-Related Technologies--Photovoltaic Central Power Systems, MITRE Corp., MTR-7485, Vol. VIII, June, 1977.

TABLE II

MARKET POTENTIAL AND SUITABILITY OF RESIDENTIAL AND
COMMERCIAL BUILDINGS--NEW CONSTRUCTION

BUILDING TYPE	YEARS	TOTAL MARKET POTENTIAL: NEW CONSTRUCTION (thousands of bldgs/yr)	SUITABILITY FRACTION FOR SOLAR ENERGY SYSTEMS
1- & 2-Family Residences (sunbelt)	1979	920	0.05
	1980	920	0.2
	1981-1985	920	0.5
	1986-1990	920	0.6
	1991-1995	950	0.7
	1996-2000	980	0.8
1- & 2-Family Residences (non-sunbelt)	1979	122	0.05
	1980	1,220	0.2
	1981-1985	1,220	0.5
	1986-1990	1,220	0.6
	1991-1995	1,260	0.7
	1996-2000	1,310	0.8
Commercial (sunbelt)	1983-1985	113	0.6
	1986-1990	113	0.7
	1991-1995	120	0.8
	1996-2000	127	0.8
Commercial (non-sunbelt)	1983-1985	150	0.6
	1986-1990	150	0.7
	1991-1995	161	0.8
	1996-2000	170	0.8

TABLE III
POTENTIAL PHOTOVOLTAIC CENTRAL UTILITY MARKET

YEAR	TOTAL U.S. DEMAND FOR ELECTRIC ENERGY (terawatt-hours/yr*)	POTENTIAL PHOTOVOLTAIC CENTRAL SYSTEM MARKETS (in MWp of collectors/yr at 10% penetration of total demand)
1990	11.8	5630.
1991-2000	14.6	6970.

*One Terawatt-hour equals 10^9 KWH.

which represents the decision maker's risk-free preference for the solar technology. Then, an appropriate share of the market is inferred for the new technology as a function of time.

Early in the life of a new product, sales will increase as the product is introduced to the marketplace. Sales may occur even if the new product is not economically competitive with the product or products already serving the market. Ultimately, economic criteria will predominate and non-economically viable products will disappear from the market. Products which are economically competitive will remain, eventually gaining a substantial share of the market.

In this analysis, the dynamics of increasing market acceptance and/or product failure are simulated by a substitution model similar to the "logit" or "S-shaped" curve presented by Fisher and Pry.* This model allows explicit specification of the value of the new technology relative to its conventional competitor by means of the FOM. Figure 1 shows the model plotted parametrically for various constant values of FOM.

Table IV shows the FOM used in this analysis. The FOM for residential markets was derived from a study which determined the attitudes of prospective home buyers toward solar energy.**

*Fisher, J. C. and Pry, R. H., "A Simple Substitution Model of Technological Change," Technological Forecasting and Social Change, Vol. 3, 1971, pp 75-88.

**Scott, Jerome E., Consumer Demand Analysis of Solar Heating and Cooling of Buildings--Final Report, COO-2598-1, University of Delaware, 1976.

Source: A System for Projecting the Utilization of Renewable Resources--SPURK Methodology, The MITRE Corporation, MTR-7570, September, 1977.

**FIGURE 1
METREK MARKET SHARE
FUNCTION**

TABLE IV
FIGURE OF MERIT BY MARKET SECTOR

MARKET SECTOR	FIGURE OF MERIT
Transition Markets	$FOM = \frac{SLCP}{\text{Solarsystem Price}}$ <p>Where: "SLCP" is the breakeven price for the application</p>
Residential Mass Markets	$FOM = 10.13 \left(\frac{\text{Annual Savings}}{\text{Solarsystem Price}} \right) + 0.12 \left(\frac{\text{Annual Savings} - \text{Solarsystem Price}}{360.} \frac{6000.}{6000.} \right)$ <p>Where: "Annual Savings" is the value of the energy displaced per year by the solar system.</p>
Commercial Mass Markets	$FOM = \frac{\text{Desired Payback Period}}{\text{Achieved Payback Period}}$ <p>Where: "Desired Payback Period" = 5 years.</p> <p>"Achieved Payback Period" is ratio of initial system price to annual savings of grid electricity charges.</p>
Utility Mass Markets	$FOM = \frac{SLCP}{\text{Solarsystem Price}}$

Transition and utility market Figures of Merit consisted of the ratio of breakeven price for each application to the current price of a photovoltaic system. Commercial applications employed a Figure of Merit consisting of the ratio of a desired payback period to a payback period which would be achieved by the photovoltaic system purchased at the current price.

3.4 Photovoltaic System Assumptions

Photovoltaic systems include collectors and the remaining portions of the systems which are referred to as the Balance of System (BOS). Figure 2 shows the various components and options for photovoltaic systems.

3.5 System Size

System sizes for transition market systems were determined by BDM* and range from less than a watt through 40 MWp. These are listed in Appendix B.

Residential systems are all sized with 3.4 KWp (rated) of collector. This is consistent with the residential photovoltaic system defined for the SERI Photovoltaic Venture Analysis.**

Commercial systems range in size from 50 KWp through 500 KWp. The variation occurs in time with smaller system applications appearing initially and the larger systems applications becoming available as the technology evolves through the year 2000.

*BDM, Op. Cit.

**Solar Energy Research Institute, Final Report--Photovoltaic Venture Analysis, SERI/TR-52-040, July 1978, Vols. I-III.

FIGURE 2
COMPONENTS OF A PHOTOVOLTAIC SYSTEM

Utility systems range in size from 10 MWp through 100 MWp. Again, the larger applications become available at the end of the 1979-2000 time frame.

3.6 System Price

In this analysis, the price of the photovoltaic system is taken as the sum of collector and BOS prices. Installation, structure, shipping, markups and credits are assumed to be contained in the BOS prices.

Prices (in constant year dollars) for collectors and BOS are assumed to reduce independent of each other, in response to the industry's cumulative production experience. Collector prices reduce more rapidly because BOS technology is assumed to be more conventional or better established.

Throughout this report, system, collector and BOS prices are given in terms of rated, peak collector power in constant 1975 dollars.

3.7 Collector Price

Industry response, or reduction in photovoltaic collector price, is assumed to result from cumulative production experience.* The modeling assumptions used in this analysis are summarized on Figures 3 through 6.

Figures 3 and 4 show the market responses for evolutionary (nonbreakthrough) technology development.

*Prices F.O.B. factory.

FIGURE 3
NO TECHNOLOGY BREAKTHROUGH, AGGRESSIVE FEDERAL R&D PROGRAM
(PHASE 1 ANALYSIS CASES 2A AND B)

FIGURE 4
NO TECHNOLOGY BREAKTHROUGH, NO FEDERAL R&D PROGRAM
(PHASE 1 ANALYSIS CASES 4A AND B)

FIGURE 5
TECHNOLOGY BREAKTHROUGH, AGGRESSIVE FEDERAL R&D
(PHASE 1 ANALYSIS CASES 1A, B AND C)

FIGURE 6
TECHNOLOGY BREAKTHROUGH, NO FEDERAL R&D PROGRAM
(PHASE 1 ANALYSIS CASES 3A, B AND C)

As shown in Figure 3, a rapid downward price trend for photovoltaic collectors was assumed to result from an aggressive, Federal R and D program. This Federal program would support development of both existing and new technology.

The rapid downward price trend is represented by a 75 percent experience curve slope through a price level of 50 cents per peak watt.* At 50 cents, it is assumed that new technology is required to serve the market. Below 50 cents, the experience curve slope changes to 90 percent and price reductions continue to 20 cents per peak watt (assumed to be the ultimate price for new technology).**

There is greater uncertainty in predicting the experience curves for low-cost technology whose characteristics are not yet known. This uncertainty about the technology and the rapidity with which it can be brought to its ultimate price is reflected in the 90 percent slope.

In Figure 4, the 90 percent slope reflects the assumption that, without an aggressive Federal R and D program, reduction in prices and growth in experience would be slow.

Figures 5 and 6 show the impacts assumed for a technology breakthrough. It is assumed that new "breakthrough" technology will differ substantially from existing technology*** and that the

*Prices F.O.B. factory.

**This is consistent with Federal program goals of 10-30 cents per peak watt.

***As different, say, as Cd-S photovoltaic cells deposited on glass by spray techniques are from current Czochralski silicon cells fabricated by largely manual techniques.

experience accumulated in production of existing technology is not necessarily applicable to the new technology. The new technology will enter the market at current prices and will share the market until low market price effectively drives out existing technology. This is modeled as an average 50 percent market share from the time of new technology introduction to the time at which market price falls below 50 cents per peak watt.

With an aggressive Federal program supporting technology development (Figure 5), breakthrough technology is assumed to decrease in price at a 75 percent rate to 20 cents per watt. Without the Federal program (Figure 6), the price decline is assumed to be slower.

In all cases, the initial conditions for collector price and cumulative production experience are taken as \$12/Wp and 2MWp, respectively.

3.8 Balance of System Prices

The Balance of System (BOS) prices that were used in this analysis are shown on Tables V and VI.

A single estimate of BOS prices derived from 13 applications was assumed for the transition markets. Initial BOS costs of \$15/Wp were allowed to reach an ultimate level of \$0.80/Wp. This reflects improvements in BOS design and a trend in the transition market from initial installation of small systems in small quantities, to numerous larger systems.

TABLE V
BALANCE OF SYSTEMS PRICE ASSUMPTIONS

MARKET SECTOR	BOS PRICE*	REMARKS
Transition	\$15.04/Wp decreasing with experience at an 80% slope to \$0.80/Wp.	See Table VI for a break-down of Transition BOS price.
Residential	\$0.91/Wp up to 1000 systems decreasing with experience to \$0.59/Wp at 10,000 systems (approximately, an 80% slope).	Comprised of \$0.32/Wp, fixed, plus power conditioner price of \$0.59/Wp reducing to \$0.27/Wp. Source: <u>SERI Venture Analysis--Final Report</u> , Vol. 1, pg. 126, July, 1978. Prices used are averages of ranges presented.
Commercial/ Industrial	\$0.93/Wp up to 1000 systems decreasing with experience to \$0.35/Wp at approximately an 80% slope.	Ultimate price of \$0.35/Wp from the <u>Long Term Demand Estimation</u> , MIT Energy Laboratory, for the SERI Photovoltaic Venture Analysis. Initial price of \$0.93/Wp is the average of the range of 1986 BOS prices expressed in Volume I (Table 26) of the SERI Venture Analysis.
Utility	\$0.38/Wp	Source: <u>SERI Venture Analysis</u> , Vol. I, Table 26.

*Prices are in terms of 1975 dollars per rated, peak collector power.

TABLE VI

ASSUMPTIONS: BALANCE OF SYSTEMS FOR TRANSITION MARKETS

ITEM	TRANSITION PRICE (\$/Wp)*
Balance of Systems (BOS)	
Battery Storage	3.00
Power Conditioning	0.82
Structure	1.59
Installation	6.34
O&M	2.13
Replacement	1.16
TOTAL BOS	15.04

*Average prices for 13 selected domestic applications based upon 1978 technology. Prices are expressed in 1975 dollars. From the Solar Energy Research Institute, Photovoltaic Venture Analysis--Interim Report, SERI-33, Vol. II, Appendix B, May, 1978.

3.9 General Economic Assumptions

Table VII shows the general economic parameters assumed for this analysis. The table shows a moderate general inflation rate of 6 percent with all conventionally generated electrical energy prices escalating 2 percent faster regardless of source.

A 10 percent general discount rate was originally intended to be a compromise among residential mortgage rates, commercial/industrial interest rates and electric utility average cost of money. With recent trends in home mortgage rates, this may be slightly low--a 12 to 14 percent rate might be more appropriate.

The financial life of a photovoltaic system was taken as 20 years. This reflects the estimates made by DOE of the design life of the photovoltaic system although the actual physical life could be well in excess of this period.

Simple payback is a criterion frequently used in commercial and industrial ventures. Although payback periods of 12-24 months are common criteria, for financial investments, a large capital investment with a long life could warrant a five year payback period. This may be particularly so in the case of solar technology since there is a good deal of uncertainty about the price of non-solar alternatives in the future.

TABLE VII
ECONOMIC PARAMETERS

PARAMETER	VALUE	REMARKS
Conventional Energy Source Price Escalation Rate	8%/yr.	Assumed
General Inflation Rate	6%/yr.	Assumed
General Discount Rate	10%/yr.	Assumed. May be slightly low.
Photovoltaic System Financial Life	20 yr.	Federal Program goal for residential and commercial systems.
Commercial Payback Period	5 yr.	Derived from <u>Technical and Economical Feasibility of Solar Augmented Process Steam Generation</u> , Thermo Electron Corp., 1976.

4.0 PHASE 1 ANALYSIS

4.1 Approach

Phase 1 of the analysis consisted of a preliminary screening of 10 incentive cases. The incentive cases and the options they include are described in Figure 7.

The effectiveness of each incentive was determined by its market impact and leverage of Federal funds.

Market impact was measured by cumulative and annual collector sales, and sales of systems in energy saving mass markets. Leverage of Federal funds was determined by Federal cost, collectors sold per Federal dollar invested, and residential systems sold per Federal dollar.

These effectiveness criteria were chosen because they are believed by MITRE to be of similar importance.

All of the options in this analysis were ranked for each effectiveness criterion. A value of "good" was assigned to approximately one-third of the options that had the highest numerical results, "moderate" for results in the middle range, and "poor" for approximately one-third of the options with the lowest results. Case values for each criteria were established by the average rating of the options within the case. This method was chosen to minimize the dependence upon actual numbers generated in the analysis.*

*An alternative method would have been to establish thresholds for success based on definitions of healthy industry growth. Numerical results produced in the analysis would be compared to the established thresholds. The "good," "moderate" or "poor" value of each option would then be critically dependent upon market assumptions used in the model and upon definitions of an economically viable industry.

OPTIONS FOR INCENTIVE CASES

Immediate Incentives Include:

- Direct price reductions of 10, 20 and 30% (1980-2000)
- Breakeven subsidies of 25, 50, 75 and 100% (1980-1990)
- Federal purchases of 50 to 1000 MWp (1981-1990)

Breakthrough-Dependent Incentives Include:

- Breakeven subsidies of 25, 50, 75 and 100% (1990-2000)
- Federal purchases of 50 to 1000 MWp (1990-2000)

FIGURE 7
PHASE 1 INCENTIVE CASES AND OPTIONS

4.2 Results and Conclusions

The results of the Phase 1 analysis are summarized in Table VIII. (The original data are contained in Appendix A.) The following conclusions may be derived from these results:

1. An aggressive, Federally-sponsored research and development program should be continued. Incentives could not compensate for the detrimental effect of withdrawing the Federally-sponsored R and D program.
 - Each of the cases with Federally-sponsored R and D (Cases 1A, 1B, 1C and 2B) had greater impact than the cases without Federal R and D (Cases 3 and 4).
 - Huge Federal incentives and expense would be required to achieve results comparable to those of an aggressive R and D program. For instance, the achievement of a moderate residential market penetration in the year 2000, with a Federal R and D program, would require greater than \$21 billion through an immediate or breakthrough-dependent 100 percent subsidy (see Appendix A, Cases 3B and 3C).

For these reasons, cases without an aggressive, Federally-sponsored R and D program (Cases 3 and 4) were excluded from further analysis.

2. A technology breakthrough without additional incentives would have a greater impact than immediate incentives without a breakthrough. This emphasizes the need to continue (and possibly improve or expand) the Federal R and D program to increase the probability of a breakthrough.
 - A breakthrough with no incentives (Case 1A) has greater impact and leverage than no breakthrough with immediate incentives (Case 2B). This result is based on the assumption that price is a major barrier to market penetration and that if technology can achieve a competitive price, no further incentive is needed to stimulate market penetration.
3. If a breakthrough occurs, immediate or breakthrough-dependent incentives provide only a slight increase in impact and leverage.

TABLE VIII
SUMMARY OF PHASE 1 ANALYSIS

29

CRITERIA FOR SUCCESS

IMPACT ON INDUSTRY

Cumulative Sales by Year 2000
Good = 3,590 - 7,600 MW
Moderate = 1,200 - 3,420
Poor = 240 - 1,170

Annual Production in Year 2000
Good = 641 - 1400 MW
Moderate = 154 - 635
Poor = 27 - 137

Cumulative Residential Market Penetration
Good = 263,000 - 359,000 systems
Moderate = 16,600 - 152,000
Poor = 0 - 6,620

SUBTOTAL

LEVERAGE OF FEDERAL DOLLAR

Federal Cost
Good = \$0 - 1,550 million
Moderate = \$1,640 - 3,390
Poor = \$3,602 - 9,434

Cumulative Sales/\$ Federal
Good = 1.08 - 1.90 MW/\$Federal
Moderate = .65 - 1.05
Poor = .07 - .64

Residential Penetration/\$Federal
Good = 50 - 168 systems/\$million
Moderate = 9.0 - 49
Poor = .35 - 4.4

SUBTOTAL

TOTAL

Score: Good = 4
Moderate = 2
Poor = 0

AGGRESSIVE FEDERALLY-SPONSORED R&D					NO FEDERALLY-SPONSORED R&D				
BREAKTHROUGH			NO BREAKTHROUGH		BREAKTHROUGH			NO BREAKTHROUGH	
NO INCENTIVE 1A	IMMEDIATE INCENTIVE 1B	DELAYED INCENTIVE 1C	NO INCENTIVE 2A	IMMEDIATE INCENTIVE 2B	NO INCENTIVE 3A	IMMEDIATE INCENTIVE 3B	DELAYED INCENTIVE 3C	NO INCENTIVE 4A	IMMEDIATE INCENTIVE 4B
moderate	good	good	poor	moderate-good	poor	poor	poor	poor	poor
2	4	4	0	3	0	0	0	0	0
moderate	good	good	poor	moderate	poor	poor	poor	poor	poor
2	4	4	0	2	0	0	0	0	0
good	good	good	poor	moderate	poor	poor	poor	poor	poor
4	4	4	0	2	0	0	0	0	0
—	—	—	—	—	—	—	—	—	—
8	12	12	0	7	0	0	0	0	0
good	poor-moderate	poor-moderate	good	poor-moderate	good	good	moderate	good	good
4	1	1	4	1	4	4	2	4	4
good	good	good	poor	moderate	undefined*	moderate	moderate	undefined	undefined
4	4	4	0	2	0	2	2	0	0
good	good	good	poor	moderate	undefined	poor	poor	undefined	undefined
4	4	4	0	2	0	0	0	0	0
—	—	—	—	—	—	—	—	—	—
12	9	9	4	5	4	6	4	4	4
20	21	21	4	12	4	6	4	4	4

*denominator = 0

- Immediate incentives with a breakthrough (Case 1B) and breakthrough-dependent incentives (Case 1C) have higher impact and lower leverage than a breakthrough without incentives (Case 1A). The total impact and leverage for Cases 1B or 1C is only slightly larger than the total for 1A. As in the preceding conclusion, these results are based on the assumption that price is the major barrier to market penetration. Without a breakthrough, extremely expensive incentives would be required to achieve the large price reduction that is assumed to result from a technology breakthrough.

4. If a breakthrough does not occur, immediate incentives would increase the impact and leverage of Federal funds.

- Immediate incentives (Case 2B) scored higher than no incentives (Case 2A) for all criteria except Federal cost.

In summary, the cases with the greatest potential impact and leverage are:

- o 1A--breakthrough without incentives
- o 1B--immediate incentives with a breakthrough
- o 1C--breakthrough followed by incentives
- o 2B--immediate incentives; no breakthrough

5.0 PHASE 2 ANALYSIS

5.1 Approach

The same 6 criteria for success that were used in Phase 1 of this analysis were used in Phase 2 to establish a relative ranking of options for the breakthrough cases (1A, no incentives, 1B, immediate incentives and 1C, breakthrough-dependent incentives) and for the non-breakthrough case (2B, immediate incentives).

5.2 Results

The results of the Phase 2 analysis are summarized in Tables IX and X. These results indicate that:

- If a breakthrough occurs, the options with the best impact and leverage are, in descending order:
 - an immediate 25 percent keyed-to-breakeven subsidy
 - an immediate 50 percent keyed-to-breakeven subsidy or a breakthrough-dependent Federal purchase of 50 MWp
 - an immediate 30 percent uniform price reduction or an immediate Federal purchase of 50 MWp
- If a breakthrough does not occur, the immediate incentives with the best potential are, in descending order:
 - a 75 percent keyed-to-breakeven subsidy
 - a 50 percent keyed-to-breakeven subsidy
 - a Federal purchase of 1000 MWp
- An immediate 50 percent keyed-to-breakeven subsidy would have high impact and leverage, with or without a breakthrough.

As indicated in Tables II and III, the range of results from the Phase 2 analysis is relatively small. This suggests that:

- The relative impact and leverage of the Federal options may be dependent upon the assumptions used in the model.

TABLE IX
SUMMARY OF PHASE 2 ANALYSIS - BREAKTHROUGH CASES

NO INCENTIVES - CASE 1A	IMMEDIATE INCENTIVES - CASE 1B							
	UNIFORM PRICE REDUCTION			KEYED-TO-BREAKDOWN			FEDERAL PURCHASES	
	10%	20%	30%	25%	50%	75%	50MW	1000MW
Cumulative Sales by Year 2000								
Good = 6,210 - 7,310 Mwp	poor	poor	moderate-good	poor	poor-moderate	good	poor	moderate-good
Moderate = 4,580 - 5,380	1	1	2	1	2	5	1	4
Poor = 2,840 - 3,750								
Annual Production in Year 2000								
Good = 1,240 - 1,480 Mwp	poor	poor	poor-moderate	poor	poor	poor-moderate	poor	poor-moderate
Moderate = 930 - 1,090	1	1	2	1	1	2	1	2
Poor = 610 - 770								
Cumulative Residential Market Penetration								
Good = 321,000 - 335,000 (systems)	poor	poor	poor-moderate	poor	poor-moderate	moderate	poor	moderate-good
Moderate = 292,000 - 305,000	1	1	2	1	2	3	1	4
Poor = 261,000 - 277,000								
SUBTOTAL	3	3	5	3	5	10	3	10
LEVERAGE OF FEDERAL DOLLAR								
Federal Cost								
Good = \$1,500 - 2,720 (million)	good	moderate-good	moderate-good	poor-good	good	good	poor	good
Moderate = \$3,810 - 4,890	5	4	4	2	5	5	1	5
Poor = \$5,980 - 7,060								
Cumulative Sales/\$ Federal								
Good = 1.70 - 1.90 (MW/\$million)	good	poor-moderate	poor-moderate	poor-moderate	good	moderate-good	poor-moderate	moderate-good
Moderate = 1.3 - 1.5	5	2	2	2	5	4	2	4
Poor = .83 - 1.0								
Residential Penetration/\$Federal								
Good = 140 - 168 (Systems/\$million)	poor	moderate	poor-moderate	poor-moderate	good	moderate	poor	moderate-good
Moderate = 80 - 110	1	3	2	2	5	3	1	4
Poor = .60 - .50								
SUBTOTAL	11	9	8	6	15	12	4	13
TOTAL	14	12	13	16	18	17	15	16

CRITERIA FOR SUCCESS

IMPACT ON INDUSTRY

Cumulative Sales by Year 2000
Good = 6,210 - 7,310 Mwp
Moderate = 4,580 - 5,380
Poor = 2,840 - 3,750

Annual Production in Year 2000
Good = 1,240 - 1,480 Mwp
Moderate = 930 - 1,090
Poor = 610 - 770

Cumulative Residential Market Penetration
Good = 321,000 - 335,000 (systems)
Moderate = 292,000 - 305,000
Poor = 261,000 - 277,000

SUBTOTAL

LEVERAGE OF FEDERAL DOLLAR

Federal Cost
Good = \$1,500 - 2,720 (million)
Moderate = \$3,810 - 4,890
Poor = \$5,980 - 7,060

Cumulative Sales/\$ Federal
Good = 1.70 - 1.90 (MW/\$million)
Moderate = 1.3 - 1.5
Poor = .83 - 1.0

Residential Penetration/\$Federal
Good = 140 - 168 (Systems/\$million)
Moderate = 80 - 110
Poor = .60 - .50

SUBTOTAL

TOTAL

Score: Good = 5
Moderate = 3
Poor = 1

TABLE IX, concluded
SUMMARY OF PHASE 2 ANALYSIS-BREAKTHROUGH CASES

CRITERIA FOR SUCCESS

IMPACT ON INDUSTRY

Cumulative Sales by Year 2000
Good = 6,210 - 7,010 MWp
Moderate = 4,580 - 5,380
Poor = 2,840 - 3,750

Annual Production in Year 2000
Good = 1,240 - 1,400 MWp
Moderate = 931 - 1,090
Poor = 610 - 770

Cumulative Residential
Market Penetration
Good = 321,000 - 335,000
(systems)
Moderate = 292,000 - 306,000
Poor = 261,000 - 277,000

SUBTOTAL

LEVERAGE OF FEDERAL DOLLAR

Federal Cost
Good = \$1,500 - 2,730
(million)
Moderate = \$3,810 - 4,890
Poor = \$5,980 - 7,060

Cumulative Sales/\$ Federal
Good = 1.7 - 1.9
(MW/\$million)
Moderate = 1.3 - 1.5
Poor = .8 - 1.0

Residential Penetration/\$Federal
Good = 140 - 168
(Systems/\$million)
Moderate = 81 - 109
Poor = .60 - .50

SUBTOTAL

TOTAL

Score:
Good = 5
Moderate = 3
Poor = 1

BREAKTHROUGH-DEPENDENT INCENTIVES - CASE 1C				
KEYED-TO-BREAKEVEN			FEDERAL PURCHASES	
25%	50%	75%	50MW	1000MW
poor	poor-moderate	good	poor	poor-moderate
1	3	5	1	2
poor	moderate	good	poor	poor
1	3	5	1	1
poor	poor	poor	poor	poor
1	1	1	1	1
--	--	--	--	--
3	7	11	3	4
good	moderate	poor	good	moderate
5	3	1	5	3
moderate	poor-moderate	poor	moderate-good	poor
3	2	1	4	1
moderate	poor-moderate	poor	good	poor-moderate
3	2	1	5	2
--	--	--	--	--
11	7	3	14	6
14	14	14	17	10

TABLE I
SUMMARY OF PHASE 2 ANALYSIS - NON-BREAKTHROUGH CASE

IMMEDIATE INCENTIVES - CASE 2B										
UNIFORM PRICE REDUCTION			KEYED-TO-BREAK-EVEN			FEDERAL PURCHASES				
10%	20%	30%	25%	50%	75%	50MW	250MW	500MW	1000MW	
poor	poor	moderate	poor	poor-moderate	good	poor	poor-moderate	moderate	moderate-good	
1	1	3	1	2	5	1	2	3	4	
poor	poor-moderate	good	poor	poor-moderate	moderate-good	poor	poor	poor-moderate	moderate	
1	2	5	1	2	4	1	1	2	3	
poor	poor	poor-moderate	poor	moderate	good	poor	poor-moderate	moderate	good	
1	1	2	1	3	5	1	2	3	5	
—	—	—	—	—	—	—	—	—	—	
3	4	10	3	7	14	3	5	8	12	
good	moderate-good	poor-moderate	good	good	poor	good	moderate-good	moderate	poor	
5	4	2	5	5	1	5	4	3	1	
moderate	moderate	moderate-good	moderate	good	good	moderate	moderate-good	moderate-good	moderate-good	
3	3	4	3	5	5	3	4	4	4	
poor	poor	poor-moderate	poor	good	good	poor	moderate	good	moderate-good	
1	1	2	1	5	5	1	3	5	4	
—	—	—	—	—	—	—	—	—	—	
9	8	8	9	15	11	9	11	11	9	
12	12	18	12	22	25	12	16	19	21	

CRITERIA FOR SUCCESS

IMPACT ON INDUSTRY

Cumulative Sales by Year 2000
Good = 6,310 - 7,610 MWp
Moderate = 3,710 - 5,000
Poor = 1,100 - 2,400

Annual Production in Year 2000
Good = 773 - 1,26 MWp
Moderate = 455 - 618
Poor = 155 - 210

Cumulative Residential Market Penetration
Good = 290,000 - 359,000 (systems)
Moderate = 150,000 - 222,000
Poor = 10,600 - 85,000

SUBTOTAL

LEVERAGE OF FEDERAL DOLLAR

Federal Cost
Good = \$1,720 - 2,900 (million)
Moderate = \$4,080 - 5,250
Poor = \$6,430 - 7,600

Cumulative Sales/\$ Federal
Good = .91 - 1.1 (MW/\$ million)
Moderate = .50 - .67
Poor = .07 - .21

Residential Penetration/\$ Federal
Good = 32.3 - 37.6 (Systems/\$ Federal)
Moderate = 20.5 - 26.2
Poor = 9.0 - 14.7

SUBTOTAL

Score: Good = 5
Moderate = 3
Poor = 1

TOTAL

- Qualitative and quantitative analyses are necessary to identify the best of the more promising options.

MITRE recognizes that Federal cost assumptions must be improved to provide a more accurate estimate of Federal leverage. However, administrative costs are a major uncertainty. These costs could vary greatly, depending upon the mechanism chosen to deliver each option. For this reason, estimates of Federal costs were limited to forgone revenues in the direct price reduction and keyed-to-breakeven subsidies, and were limited to the price of equipment in the Federal purchase options.* If administrative costs had been included, the relative leverage of the options could be different.

Administrative costs are closely related to qualitative aspects, such as ease of implementing an incentive, or industrial decision processes. The administrative costs and qualitative aspects associated with the three types of incentive options are summarized in Table XI. However, each option must be analyzed further before a conclusion on "best incentive" can be made.

*The cost of the existing Federal program was assumed to be \$1.5 billion for the years 1980 to 1990. (Federal costs were derived from the "Solar Photovoltaic Energy Research, Development and Demonstration Act of 1978.") These costs were added to the cost of direct price reductions and keyed-to-breakeven subsidies in Cases 1B, 1C and 2B.

TABLE XI
QUALITATIVE ASSESSMENT OF OPTIONS

INCENTIVE OPTION	RELATIVE ADMINISTRATIVE COST	EASE OF IMPLEMENTATION
Uniform Price Reduction	Moderate	<ul style="list-style-type: none"> + Relatively simple to administer (i.e., tax credit or deduction) + Would encourage industry to achieve lowest possible prices. (Incentive could be applied even if breakeven costs have been achieved.)
Keyed-to-Breakeven Subsidy	High	<ul style="list-style-type: none"> - Difficult to administer. Would require expensive, continuous assessment to establish breakeven prices. + Foregone Federal revenues would decrease as technology improves. Incentive can be gradually "phased-out." - May not encourage industry to achieve better-than-breakeven prices.
Federal Purchase	Low	<ul style="list-style-type: none"> + Near-term impact would be substantial because purchases would represent a large portion of the total market. - Large impact may require focusing incentive on a limited number of manufacturers. May reduce competition. - Uncertain long-range impact. System design and cost would be geared to government requirements rather than private market demand.

6.0 PHASE 3 ANALYSIS: TESTING OF ASSUMPTIONS

Comments on earlier drafts of this report indicate that the most controversial MITRE assumptions concerned market estimates and methods for modeling reductions in the price of photovoltaic technology. Phase 3 of this analysis was performed to determine how alternative assumptions in each of these areas would impact results from Phases 1 and 2.

6.1 Modeling Methodology

In Phases 1 and 2 of this analysis, experience curves were used to generate the price of technology as a function of cumulative production experience. In Phase 3, the model was altered so that market and industry response could be calculated, assuming that the following DOE price goals are achieved:

Year	FOB Factory Price (1975 Dollars per Wp)
1982	2.00
1983	1.00
1986	.50
1990	.10 - .30

As shown on Table XII, the results from the use of DOE price goals are very similar to results from the use of experience curves, assuming a breakthrough and no incentives. This indicates that:

- DOE price goals are probably achievable, without incentives, if a technological breakthrough occurs. Achievement of the goals would require markets, such as those used in this analysis, that are large enough to justify large-scale production of breakthrough technology.

TABLE XII

TEST OF ASSUMPTIONS - PRICE REDUCTION METHODS*

IMPACT								LEVERAGE		
Price (\$/M _p)			Cumulative Collector Sales Thru Yr 2000 (MM _p)	Industry Production MM _p /Yr Collector	Residential Sales		Commercial MM _p Sold Thru Yr 2000	Federal Cost Cumulative To 2000 (\$ Millions)	Cumulative MM _p Per Million \$ Federal	Residential MM _p Per Federal \$ Million
Collector	Systems				Year of Initial Sales	MM _p Sold Thru Yr 2000				
	Transition Market	Residential Market								
.20	1.00	.79	47,200	11,600	1982	1890	37,500	1,500	31.5	1.26
(.40)	(1.20)	(.99)	(26,600)	(7,410)	(1989)	(669)	(21,600)	(1,500)	(17.7)	(.45)
(.20)	(1.00)	(.79)	(46,000)	(11,600)	(1989)	(1560)	(37,200)	(1,500)	(30.7)	(1.04)

*Includes residential, commercial, and utility mass markets.

Price/YearPrice/Experience

- o no breakthrough,
no incentives
- o breakthrough,
no incentives

6.2 Market Assumptions

6.2.1 Commercial and Utility Mass Markets

In Phase 3 of the analysis, commercial and utility mass markets were added to the photovoltaic incentive model. (Only transition markets and residential mass markets were modeled in Phases 1 and 2.) Estimates of the commercial and utility markets, summarized in Section 3, were derived from the SPURR* market penetration model.

Results from the Phase 3 analysis are summarized in Tables XIII and XIV. These results indicate that with an aggressive Federal R and D program, and without incentives:

- Increased markets yielded an increase in impact and leverage of Federal expenditures;
- The results from a breakthrough remain substantially larger than nonbreakthrough results;
- The inclusion of additional markets has the greatest effect if there is no breakthrough. This is because price reductions in the nonbreakthrough case occur solely as a function of production experience and market pull. Price reductions in a breakthrough case are less market dependent. Prices will be reduced, regardless of the market size.

With an aggressive Federal R and D program, incentives and no breakthrough:

- A 30 percent uniform price reduction has a much larger impact than the other incentives. However, the Federal cost of the incentive is prohibitive. These results occur because the 30 percent uniform price reduction is the only incentive tested in Phase 3 that remains in effect after 1990 and because a large portion of the Federal expenditure was used to subsidize systems that were already economically competitive.

*System for Projecting Utilization of Renewable Resources (SPURR), The MITRE Corporation, Metrek Division, 1978.

TABLE XIII

TEST OF ASSUMPTIONS-COMMERCIAL AND UTILITY MARKET IMPACT, NO INCENTIVES

IMPACT								LEVERAGE		
Price (\$/M _p)			Cumulative Collector Sales Thru Yr 2000 (M _p)	Industry Production M _p /Yr Collector	Residential Sales		Commercial M _p Sold Thru Yr 2000	Federal Cost Cumulative Thru 2000 (\$ Millions)	Cumulative M _p Per Million \$ Federal	Residential M _p Per Federal \$ Million
Collector	Systems				Year of Initial Sales	M _p Sold Thru Yr 2000				
	Transition Market	Residential Market								
.40	1.20	.99	26,600	7,410	1989	669	21,690	1,500	17.7	.45
(1.06)	(3.34)	(1.74)	(817)	(124)	(1992)	(23)	—	(1,500)	(.54)	(.02)
.20	1.00	.79	46,300	11,600	1989	1560	37,280	2,500	30.7	1.0
(.20)	(1.77)	(.79)	(2,840)	(610)	(1990)	(889)	—	(1,500)	(1.9)	(.59)

TABLE KIV
TEST OF ASSUMPTIONS-COMMERCIAL AND UTILITY MARKET IMPACT,
NO BREAKTHROUGH, WITH IMMEDIATE INCENTIVES

IMPACT								LEVERAGE			
Price (\$/M _p)			Cumulative Collector Sales Thru Yr 2000 (M _p)	Industry Production M _p /Yr Collector	Residential Sales		Commercial M _p Sold Thru Yr 2000	Federal Cost Cumulative To 2000 (\$ Millions)	Cumulative M _p Per Million \$ Federal	Residential M _p Per Federal \$ Million	
Collector	Systems				Year of Initial Sales	M _p Sold Thru Yr 2000					
	Transition Market	Residential Market									
50% Keyed-To Breakeven Subsidy											
• with commercial and utility mass markets	.39	1.19	.58	30,800	7,480	1981	1200	23,800	5,540	5.56	.22
• without commercial and utility mass markets (Case 2B)	(.64)	(2.19)	(1.23)	(2,620)	(316)	(1998)	(313)	—	(2,760)	(.95)	(.11)
50 M _p Federal Purchase											
• with commercial and utility mass markets	.39	1.19	.58	27,400	3,780	1988	727	22,000	2,000	13.7	.36
• without commercial and utility mass markets (Case 2B)	(.89)	(2.89)	(1.48)	(1,220)	(171)	(1989)	(80)	—	(2,030)	(.60)	(.04)
500 M _p Federal Purchase											
• with commercial and utility mass markets	.39	1.19	.98	30,000	7,460	1984	902	23,200	4,440	6.76	.20
• without commercial and utility mass markets (Case 2B)	(.55)	(1.92)	(1.14)	(3,830)	(432)	(1984)	(518)	—	4,750	(.81)	.11
30% Uniform Price Reduction											
• with commercial and utility mass markets	.35	1.15	.94	61,900	16,100	1987	1900	50,400	27,000	2.29	.07
• without commercial and utility mass markets (Case 2B)	(.53)	(1.86)	(1.12)	(4,650)	(926)	(1989)	(333)	—	(5,530)	(.84)	.06

41
50% Keyed-To- Breakeven Subsidy

- with commercial and utility mass markets
- without commercial and utility mass markets (Case 2B)

50 M_p Federal Purchase

- with commercial and utility mass markets
- without commercial and utility mass markets (Case 2B)

500 M_p Federal Purchase

- with commercial and utility mass markets
- without commercial and utility mass markets (Case 2B)

30% Uniform Price Reduction

- with commercial and utility mass markets
- without commercial and utility mass markets (Case 2B)

- The tested incentives were not able to reduce photovoltaic prices sufficiently to achieve utility mass market penetration in these simulations by the year 2000.

6.2.2 SERI Market Impact

MITRE estimates of transition and residential markets were replaced by SERI's estimates of small and very large markets.* As shown below, MITRE's total market estimate is more than twice as large as the SERI very large market. However, a much larger proportion of the SERI markets have high breakeven prices.

SERI AND MITRE MARKET SIZE

BREAKEVEN LIFE-CYCLE SYSTEM PRICE (1986 prices in 1975 dollars per Wp)	SERI SMALL MARKETS (MWp/Yr)	SERI VERY LARGE MARKETS (MWp/Yr)	MARKETS ESTI- MATED BY MITRE (MWp/Yr)
20	0	19	3
10 - 20	6	10	5
5 - 9.9	6	206	5
1 - 4.9	27	451	330
1 or less	2535	2986	7315**
Total	2574	3672	7658

The Phase 3 results in Table XV indicate that the impact and leverage would be greater for the SERI Very Large Market than for the MITRE market estimate. This occurs because most of the market penetration is in the higher-priced transition markets which are much

*Solar Energy Research Institute, Final Report--Photovoltaic Venture Analysis, SERI/TR-52-040, July 1978.

**Includes a residential market of 1265 MWp per year.

TABLE XV

TEST OF ASSUMPTIONS - SERI MARKETS, AGGRESSIVE FEDERAL R&D, NO INCENTIVES, NO BREAKTHROUGH

IMPACT							LEVERAGE		
Price (\$/W _p)			Cumulative Collector Sales Thru Yr 2000 (MW _p)	Industry Production MW _p /Yr Collector	Residential Sales		Federal Cost Cumulative To 2000 (\$ Millions)	Cumulative MW _p Per Million \$ Federal	Residential MW _p Per Federal \$ Million
Collector	Systems				Year of Initial Sales	MW _p Sold Thru Yr 2000			
	Transition Market	Residential Market							
2.73	7.49	3.64	80	11		0	1,500	.053	0
.46	1.51	1.05	8,610	812	1984	1650	1,500	5.74	1.10
(1.06)	(3.34)	(1.74)	(817)	(124)	(1992)	(23)	(1,500)	(.54)	(4.41)

*No commercial or utility mass markets

larger in the SERI Very Large Market estimates. If the simulation had been extended beyond the year 2000, the analysis results would reflect increased penetration of the mass market, and it would be likely that the impact and leverage using MITRE's market estimate would be larger than the results using SERI markets.

APPENDIX A
ANALYSIS RESULTS

ANALYSIS RESULTS - CASE 1A (AGGRESSIVE FEDERAL R&D, BREAKTHROUGH, NO INCENTIVES)

IMPACT						LEVERAGE			
Price (\$/W _p)			Cumulative Collector Sales Thru Year 2000 (MW _p)	Industry Production MW _p /Year Collector	Residential Systems		Federal Cost Cumulative to Year 2000 (\$ Millions)	Cumulative MW _p per Million \$ Federal	Residential Systems per Federal \$ Million
Collector	Systems				Year of Initial Sales	Number Sold Thru Year 2000			
	Transition Market	Residential Market							
.20	1.77	.79	2,840	610	1990	261,000	1,500	1.9	.60

ANALYSIS RESULTS - CASE 1B (AGGRESSIVE FEDERAL R&D, BREAKTHROUGH, IMMEDIATE INCENTIVES)

	IMPACT							LEVERAGE		
	Price (\$/W _p)			Cumulative Collector Sales Thru Year 2000 (MW _p)	Industry Production MW _p /Year Collector	Residential Systems		Federal Cost Cumulative to Year 2000 (\$ Millions)	Cumulative MW _p per Million \$ Federal	Residential Systems per Federal \$ Million
	Collector	Systems				Year of Initial Sales	Number Sold Thru Year 2000			
		Transition Market	Residential Market							
<u>INCENTIVE OPTION</u>										
Uniform Price Reduction										
10%	.20	1.67	.79	3,440	727	1989	271,000	2,940	1.2	92.1
20%	.20	1.58	.79	4,250	918	1989	277,000	3,600	1.2	76.8
30%	.20	1.47	.79	5,420	1,120	1988	280,000	5,160	1.0	54.2
Keyed-to-Breakeven										
25%	.20	1.70	.79	3,180	635	1989	276,000	1,640	1.9	168.5
50%	.20	1.57	.79	4,060	694	1987	289,000	2,690	1.5	107.5
75%	.20	1.35	.79	6,570	813	1986	306,000	6,110	1.1	50.0
100%	.20	1.13	.79	12,300	1,030	1983	335,000	14,740	.83	22.7
Federal Purchase										
50 MW _p	.20	1.69	.79	3,260	641	1988	276,000	2,100	1.6	131.8
250 MW _p										
500 MW _p										
1000 MW _p	.20	1.40	.79	5,840	783	1983	312,000	7,060	.83	44.1

ANALYSIS RESULTS - CASE 1C (AGGRESSIVE FEDERAL R&D, BREAKTHROUGH-DEPENDENT INCENTIVES)

	IMPACT							LEVERAGE		
	Price (\$/W _p)			Cumulative Collector Sales Thru Year 2000 (MW _p)	Industry Production MW _p /Year Collector	Residential Systems		Federal Cost Cumulative to Year 2000 (\$ Millions)	Cumulative MW _p per Million \$ Federal	Residential Systems per Federal \$ Million
	Collector	Systems				Year of Initial Sales	Number Sold Thru Year 2000			
		Transition Market	Residential Market							
<u>INCENTIVE OPTION</u>										
Uniform Price Reduction										
10%										
20%										
30%										
Keyed-to-Breakeven										
25%	.20	1.65	.79	3,590	770	1990	265,000	2,446	1.5	108.7
50%	.20	1.51	.79	4,900	1,040	1990	270,000	3,990	1.2	67.5
75%	.20	1.36	.79	7,010	1,400	1990	275,000	5,700	1.0	41.2
100%	.20	1.22	.79	10,700	1,820	1990	280,000	11,500	.93	24.3
Federal Purchase										
50 MW _p	.20	1.75	.79	2,940	617	1990	263,000	1,770	1.7	148.8
250 MW _p										
500 MW _p										
1000 MW _p	.20	1.52	.79	4,540	720	1990	277,000	4,580	.99	60.4

ANALYSIS RESULTS - CASE 2A (AGGRESSIVE FEDERAL R&D, NO BREAKTHROUGH, NO INCENTIVES)

IMPACT						LEVERAGE			
Price (\$/W _p)			Cumulative Collector Sales Thru Year 2000 (MW _p)	Industry Production MW _p /Year Collector	Residential Systems		Federal Cost Cumulative to Year 2000 (\$ Millions)	Cumulative MW _p per Million \$ Federal	Residential Systems per Federal \$ Million
Collector	Systems				Year of Initial Sales	Number Sold Thru Year 2000			
	Transition Market	Residential Market							
1.06	3.34	1.74	817	124	1992	6,620	1500	.54	4.4

ANALYSIS RESULTS - CASE 2B (AGGRESSIVE FEDERAL R&D, NO BREAKTHROUGH, IMMEDIATE INCENTIVES)

	IMPACT						LEVERAGE			
	Price (\$/M _p)			Cumulative Collector Sales Thru Year 2000 (M _p)	Industry Production M _p /Year Collector	Residential Systems		Federal Cost Cumulative to Year 2000 (\$ Millions)	Cumulative M _p per Million \$ Federal	Residential Systems per Federal \$ Million
	Collector	Systems				Year of Initial Sales	Number Sold Thru Year 2000			
		Transition Market	Residential Market							
INCENTIVE OPTION										
Uniform Price Reduction										
10%	.91	2.93	1.50	1,200	198	1991	18,700	2,060	.58	9.1
20%	.72	2.42	1.31	2,120	388	1990	40,900	3,100	.68	13.2
30%	.53	1.86	1.12	4,650	926	1989	97,900	5,550	.84	17.7
Keyed-to-Breakeven										
25%	.93	3.00	1.53	1,100	156	1990	16,600	1,720	.64	9.6
50%	.64	2.19	1.23	2,620	316	1988	92,100	2,760	.95	33.4
75%	.46	1.55	1.05	7,600	677	1986	257,900	6,870	1.10	37.6
100%	.41	1.26	1.00	15,000	1,020	1983	358,800	16,200	.98	22.2
Federal Purchase										
50 M _p	.39	2.89	1.48	1,220	171	1989	23,300	2,030	.60	11.5
250 M _p	.55	2.22	1.24	2,520	307	1985	90,600	3,390	.74	26.7
500 M _p	.55	1.92	1.14	3,330	432	1984	152,400	4,750	.81	32.1
1000 M _p	.48	1.67	1.07	5,840	581	1983	232,100	7,600	.77	30.5

ANALYSIS RESULTS - CASE 3A (NO FEDERAL R&D, BREAKTHROUGH, NO INCENTIVES)

IMPACT						LEVERAGE			
Price (\$/W _p)			Cumulative Collector Sales Thru Year 2000 (MW _p)	Industry Production MW _p /Year Collector	Residential Systems		Federal Cost Cumulative to Year 2000 (\$ Millions)	Cumulative MW _p per Million \$ Federal	Residential Systems per Federal \$ Million
Collector	Systems				Year of Initial Sales	Number Sold Thru Year 2000			
	Transition Market	Residential Market							
2.45	5.46	3.36	350	55	2000	7	0	Undefined*	Undefined*

*Denominator = 0

ANALYSIS RESULTS - CASE 3B (NO FEDERAL R&D, BREAKTHROUGH, IMMEDIATE INCENTIVES)

	IMPACT							LEVERAGE		
	Price (\$/W ₂)			Cumulative Collector Sales Thru Year 2000 (MW _p)	Industry Production MW _p /Year Collector	Residential Systems		Federal Cost Cumulative to Year 2000 (\$ Millions)	Cumulative MW _p per Million \$ Federal	Residential Systems per Federal \$ Million
	Collector	Systems				Year of Initial Sales	Number Sold Thru Year 2000			
		Transmission Market	Residential Market							
<u>INCENTIVE OPTION</u>										
Uniform Price Reduction										
10%	2.19	4.89	3.10	500	85	1998	123	855	1.40	.35
20%	1.94	4.32	2.85	740	137	1996	624	940	.79	.66
30%	1.68	3.75	2.50	1,170	230	1995	1,880	1,920	.61	.98
Keyed-to-Breakeven										
25%	1.86	4.31	2.77	540	89	1995	1,100	596	1.10	1.85
50%										
75%										
100%	.61	1.66	1.20	9,830	589	1990	126,000	35,100	.28	3.60
Federal Purchase										
50 MW _p	1.96	4.53	2.78	550	79	1996	632	701	.78	.90
250 MW _p										
500 MW _p										
1000 MW _p	1.01	2.55	1.60	2,610	272	1990	40,900	9,150	.29	44.70

ANALYSIS RESULTS - CASE 3C (NO FEDERAL R&D, BREAKTHROUGH-DEPENDENT INCENTIVES)

	IMPACT						LEVERAGE			
	Price (\$/W _p)			Cumulative Collector Sales Thru Year 2000 (MW _p)	Industry Production MW _p /Year Collector	Residential Systems		Federal Cost Cumulative to Year 2000 (\$ Millions)	Cumulative MW _p per Million \$ Federal	Residential Systems per Federal \$ Million
	Collector	Systems				Year of Initial Sales	Number Sold Thru Year 2000			
		Transition Market	Residential Market							
<u>INCENTIVE OPTION</u>										
Uniform Price Reduction										
10%										
20%										
30%										
Keyed-to-Breakeven										
25%										
50%	1.76	3.75	2.67	1,360	282	1996	1,300	2,270	.60	.57
75%										
100%	1.10	2.14	1.69	9,600	1,650	1992	22,200	21,700	.44	1.10
Federal Purchase										
50 MW _p	2.29	5.05	3.20	440	63	1998	58	367	1.20	48.30
250 MW _p										
500 MW _p										
1000 MW _p	1.58	3.29	2.30	1,850	154	1992	4,180	5,140	.36	.81

ANALYSIS RESULTS - CASE 4A (NO FEDERAL R&D, NO BREAKTHROUGH, NO INCENTIVES)

IMPACT							LEVERAGE		
Price (\$/W _p)			Cumulative Collector Sales Thru Year 2000 (MW _p)	Industry Production MW _p /Year Collector	Residential Systems		Federal Cost Cumulative to Year 2000 (\$ Millions)	Cumulative MW _p per Million \$ Federal	Residential Systems per Federal \$ Million
Collector	Systems				Year of Initial Sales	Number Sold Thru Year 2000			
	Transition Market	Residential Market							
5.88	9.20	6.79	240	27	-	0	0	Undefined*	Undefined*

*Denominator = 0

ANALYSIS RESULTS - CASE 4B (NO FEDERAL R&D, NO BREAKTHROUGH, IMMEDIATE INCENTIVES)

	IMPACT							LEVERAGE		
	Price (\$/W _p)			Cumulative Collector Sales Thru Year 2000 (MW _p)	Industry Production MW _p /Year Collector	Residential Systems		Federal Cost Cumulative to Year 2000 (\$ Millions)	Cumulative MW _p per Million \$ Federal	Residential Systems per Federal \$ Million
	Collector	Systems				Year of Initial Sales	Number Sold Thru Year 2000			
		Transition Market	Residential Market							
<u>INCENTIVE OPTION</u>										
Uniform Price Reduction										
10%	5.47	8.31	6.38	400	46	-	0	830	.48	0
20%										
30%										
5.24	7.84	6.38	520	60	-	0	1,550	.34	0	
Keyed-to-Break-even										
25%	5.44	8.25	6.35	400	32	-	0	619	.65	0
50%										
75%										
3.37	4.38	4.28	8,640	80	-	0	41,200	.21	0	
Federal Purchase										
50 MW _p	5.55	8.48	6.46	350	31	-	0	714	.49	0
250 MW _p										
500 MW _p										
4.38	6.16	5.29	1,560	51	-	0	9,430	.17	0	
1000 MW _p										

APPENDIX B
MARKET DATA BASE

ANNUAL MARKET

MARKET SECTOR	APPLICATION	NUMBER OF SYSTEMS	1986 BREAK-EVEN LIFE CYCLE PRICE (1975\$/WATT)	TOTAL KW PEAK	MARKET INTRODUC- TION YEAR	END OF MARKET YEAR	1986 ANNUAL SAVINGS (1975\$)
GOVTBUYS	DEPT OF ENGI BUYS	500000	99999.00	500.	1974	1986	0.0
OTHERGCV	DEPT OF ENGI BUYS	0	0.0	.0	0	0	0.0
CONSTRUC	PORTABLE CB RADIOS	15000	17000.00	30.0	1979	0	0.0
RSID/COM	GARAGE DOOR OPENER	0	32.00	32.0	1977	0	0.0
TRANSPOT	FLASHING LIGHTS	300000	500.00	.120E+04	1977	0	0.0
TRANSPOT	TRAFFIC COUNTERS	1000	200.00	9.00	1977	0	0.0
INDUSTRY	GAS DETECTORS	4500	168.00	2.25	1977	0	0.0
UTILITIES	MICROWAVE REPEATERS	1000	163.55	30.0	1979	0	0.0
TRANSPOT	REMOTE RAILROAD CROSSING	2500	73.00	125.	1977	0	0.0
COMSESERV	NUCLEAR MONITOR INSTRUME	110000	72.54	33.0	1977	0	0.0
MILITARY	INDIVIDUAL LIGHTING UNIT	100	67.25	6.00	1977	0	0.0
MILITARY	FIXED CAMERA	10	58.38	32.0	1977	0	0.0
UTILITIES	REMOTE RADIO RECEIVER SI	2000	58.16	280.	1977	0	0.0
TRANSPOT	RAILROAD SWITCHING	1000	39.00	3.00	1977	0	0.0
COMMUNIC	FIBER OPTIC REPEATER	1100	33.00	102.	1980	0	0.0
COMMUNIC	ANTENNA ROTATION FOR HOM	0	29.00	605.	1978	0	0.0
COMMUNIC	FIBER OPTIC RECEIVER	2200	27.00	308.	1980	0	0.0
COMMUNIC	FIBER OPTIC TRANSMITTER	2200	27.00	308.	1980	0	0.0
TRANSPOT	SEASONAL SIGNS	1000	27.00	20.2	1979	0	0.0
MINING	OIL TANKER TRANSPONDER	72	22.76	2.88	1977	0	0.0
MINING	OIL LEAK DETECTOR	1500	20.92	30.0	1977	0	0.0
TRANSPOT	RAILWAY SIGNALING	1000	20.00	140.	1977	0	0.0
MILITARY	CLOSED CIRCUIT TV	10	19.64	97.0	1973	0	0.0
MILITARY	TELESCOPE STATION	5	17.03	96.9	1979	0	0.0
MILITARY	MESS & ADMINISTRATION LI	26	15.46	15.1	1979	0	0.0
COMMUNIC	TV TRANSLATOR	140	14.00	81.2	1977	0	0.0
COMMUNIC	FM TRANSLATOR	350	14.00	203.	1977	0	0.0
MILITARY	AREA LIGHTING	80	13.65	.128E+04	1978	0	0.0
LEIS&REC	BATTERY OPERATED TOYS	1000000	13.18	.300E+04	1979	0	0.0
MILITARY	COMMAND POST LIGHTING	26	12.20	31.2	1979	0	0.0
TRANSPOT	FLASHING CHEVRON	100	10.00	120.	1979	0	0.0
TRANSPOT	FLASHING ARROWS	100	9.50	230.	1979	0	0.0
RSID/COM	RESIDENTIAL BURGULAR ALR	50000	8.58	650.	1977	0	0.0
MILITARY	AIRPORT/HLIPORT RUNWY LGH	13	8.40	377.	1979	0	0.0
TRANSPOT	RV UTILITY POWER (LIGHT)	5000	6.31	.195E+04	1979	0	0.0
FORESTRY	EARTH COREING DRILLS	100	5.83	260.	1979	0	0.0
TRANSPOT	VISITOR CONTROL	200	5.70	520.	1978	0	0.0
MILITARY	CLOSED CIRCUIT TV	10	5.37	97.0	1979	0	0.0
MILITARY	FIXED CAMERA	25	5.06	80.0	1979	0	0.0
TRANSPOT	RUNWAY LIGHTS (SHALL)	1800	5.00	216.	1979	0	0.0
MILITARY	CINETHODOLITES	30	5.00	390.	1979	0	0.0
TRANSPOT	RV UTILITY POWER (HEAVY)	100	4.90	78.0	1980	0	0.0
RSID/COM	PORTY WATT POLE YARD LGT	5000	4.70	385.	1980	0	0.0
MILITARY	TELESCOPE STATION	5	4.53	96.9	1979	0	0.0
MILITARY	HYPERSE OSMOSIS WTR PURIF	200	4.51	.900E+04	1979	0	0.0
MILITARY	BALLISTIC CAMERAS	25	4.41	325.	1979	0	0.0
COMSESERV	GENERATOR (1.5KW)	3700	4.41	.666E+04	1980	0	0.0
COMMUNIC	PORTABLE TRANSCIVERS	1000000	4.00	.170E+05	1979	0	0.0
TRANSPOT	OILBARGE PUMPS	200	3.70	.780E+05	1981	0	0.0
COMSESERV	GENERATOR (5KW)	1000	3.22	.600E+04	1981	0	0.0

ANNUAL MARKET

MARKET SECTOR	APPLICATION	NUMBER OF SYSTEMS	1986 BREAK-EVEN LIFE CYCLE PRICE (1975\$/WATT)	TOTAL KW PEAK	MARKET INTRODUC- TION YEAR	END OF MARKET YEAR	1986 ANNUAL SAVINGS (1975\$)
COMESERV	GENERATOR (4KW)	1500	3.06	.720E+04	1983	0	0.0
COMESERV	GENERATOR (3KW)	2000	3.02	.720E+04	1982	0	0.0
TRANSPOT	HIGHWAY LIGHTING	15000	2.62	.210E+04	1982	0	0.0
FORESTRY	REMOTE RANGER STATION PW	15	2.36	153.	1979	0	0.0
MILITARY	CINETHODOLITES	30	1.91	390.	1979	0	0.0
AGRICULT	ELECTRIC FENCE	9300	1.90	465.	1977	0	0.0
LEISEREC	CAMPGROUND LIGHTING	450	1.71	.109E+04	1980	0	0.0
COMMUNIC	TELEPHONE BOOTH LIGHTING	5000	1.50	485.	1980	0	0.0
COMMUNIC	COMMUNITY ANTENNA RELAY	400	1.46	.480E+04	1977	0	0.0
COMMUNIC	CABLE TV RECEIVER	110	1.46	.132E+04	1977	0	0.0
COMESERV	HIGH INTENSITY LGHT EH/D	8000	1.45	960.	1979	0	0.0
RSID/COM	SMOKE DETECTORS	0	1.35	.138E+05	1979	0	0.0
FORESTRY	CROP SPRAYER	0	1.35	.228E+05	1979	0	0.0
LEISEREC	PLAYGROUND LIGHTING	1000	1.34	409.	1979	0	0.0
AGRICULT	IRRIGATION TEXAS	42	1.30	.504E+04	1979	0	0.0
RSID/COM	RESIDENTIAL ATTIC FAN	8000	1.15	.160E+04	1980	0	0.0
AGRICULT	IRRIGATION NEBRASKA	100	1.10	.470E+05	1979	0	0.0
COMESERV	HIGH INTENSITY LGT 12H/D	1000	1.02	.170E+05	1980	0	0.0
COMESERV	OUTDOOR INCAND LGHT 12H/D	15000	0.99	465.	1980	0	0.0
CONSTRUC	SUBMERSIBLE PUMPS	1000	0.96	970.	1981	0	0.0
COMMUNIC	TELEVISION TRANSMITTER	13	0.94	7.54	1979	0	0.0
COMMUNIC	AM RADIO TRANSMITTER	36	0.94	.209E+04	1979	0	0.0
COMMUNIC	FM RADIO TRANSMITTER	430	0.94	.249E+05	1979	0	0.0
LEISEREC	OUTDOOR CLUBHOUSE LIGET	100	0.93	102.	1980	0	0.0
AGRICULT	IRRIGATION TEXAS	150	0.90	.600E+04	1979	0	0.0
MILITARY	PWR FOR REMOTE CAMERA SI	15	0.85	960.	1979	0	0.0
TRANSPOT	ELECTRIC VEHICLE CHARGER	4000	0.84	.140E+05	1980	0	0.0
MINING	OIL WELL PUMPS	100	0.83	.190E+05	1979	0	0.0
COMESERV	CUSTOMS BORDER STATION	10	0.83	84.0	1977	0	0.0
RSID/COM	POOL FILTERS	1100	0.81	528.	1980	0	0.0
COMESERV	AIR COMPRESSORS	1000	0.80	.390E+04	2001	0	0.0
COMESERV	OUTDOOR INCAND LIGHT 12H/D	1500	0.79	930.	1980	0	0.0
COMESERV	REMOTE RESORT HOTEL	3	0.73	.390E+04	1980	0	0.0
AGRICULT	LAYER POULTRY HOUSE	1000	0.68	.450E+04	1982	0	0.0
UTILITIES	BATTERY CHARGERS SUBSTAT	2000	0.68	.520E+05	1979	0	0.0
UTILITIES	BATTERY CHARGERS	2400	0.68	.264E+06	1979	0	0.0
CONSTRUC	WARNING ALARMS	5000	0.65	38.5	1977	0	0.0
AGRICULT	DAIRY BARN	2000	0.65	.480E+05	1980	0	0.0
AGRICULT	IRRIGATION NEBRASKA	100	0.65	.820E+05	1979	0	0.0
AGRICULT	IRRIGATION TEXAS	42	0.65	.882E+04	1979	0	0.0
LEISEREC	GOLF COURSE CARTS	1000	0.63	.383E+04	1977	0	0.0
AGRICULT	IRRIGATION NEBRASKA	150	0.62	.160E+05	1979	0	0.0
TRANSPOT	VISITOR CONTROL	800	0.61	680.	1977	0	0.0
AGRICULT	IRRIGATION ARIZONA	120	0.60	.384E+05	1979	0	0.0
AGRICULT	IRRIGATION TEXAS	370	0.60	.740E+05	1979	0	0.0
AGRICULT	IRRIGATION TEXAS	0	0.60	.840E+04	1979	0	0.0
AGRICULT	BROILER POULTRY HOUSE	1000	0.59	.140E+05	1979	0	0.0
FORESTRY	TEMPERATURE RECORDERS	4000	0.59	.308	1977	0	0.0
MINING	CONVEYORS	180	0.59	.342E+05	1983	0	0.0
AGRICULT	IRRIGATION ARIZONA	100	0.59	.670E+05	1979	0	0.0

ANNUAL MARKET

MARKET SECTOR	APPLICATION	NUMBER OF SYSTEMS	1986 BREAK-EVEN LIFE CYCLE PRICE (1975\$/WATT)	TOTAL KW PEAK	MARKET INTRODUC- TION YEAR	END OF MARKET YEAR	1986 ANNUAL SAVINGS (1975\$)
AGRICULT	IRRIGATION NEBRASKA	100	0.58	.630E+05	1979	0	0.0
TRANSPORT	VISITOR CONTROL	16	0.57	8.48	1977	0	0.0
MINING	LOCOMOTIVES	0	0.57	.299E+06	1983	0	0.0
LEISEREC	ELECTRIC MOPEDS	0	0.56	.550E+05	2001	0	0.0
LEISEREC	ELECTRONIC SPRINKLER CNT	430	0.56	256.	1977	0	0.0
CONSTRUC	PORTABLE LOUDSPEAKERS	10030	0.55	32.0	1977	0	0.0
CONSERV	WAREHOUSE POWER	7830	0.53	.601E+05	1980	0	0.0
AGRICULT	BROILER POULTRY HEATING	1830	0.53	.198E+06	1983	0	0.0
AGRICULT	LAYER POULTRY HEATING	18030	0.50	.576E+05	1983	0	0.0
MINING	OIL WELL PUMPS	30030	0.50	.300E+07	1982	0	0.0
CONSERV	EDUCATIONAL BUILDING	1030	0.48	.410E+04	1980	0	0.0
CONSERV	TOTAL BUSINESS POWER	5030	0.48	.230E+05	1984	0	0.0
INDUSTRY	TEMPERATURE CHANGE ALARM	2030	0.47	16.0	1977	0	0.0
INDUSTRY	COMMERCIAL BURGULAR ALARM	500030	0.47	.105E+06	1977	0	0.0
INDUSTRY	OUTDOOR TV SECURITY SYST	20040	0.47	.116E+05	1977	0	0.0
INDUSTRY	INTRUSION DETECTORS	1000040	0.47	.100E+05	1977	0	0.0
UTILITIES	ODORANT PUMP	1040	0.47	730.	1977	0	0.0
UTILITIES	TELEHEATING	10040	0.47	80.0	1977	0	0.0
MINING	HYDRAULIC PUMPS	1740	0.47	.663E+05	1982	0	0.0
MINING	NONFERROUS PROCESS PUMPS	2460	0.47	.936E+05	1982	0	0.0
MINING	LOCOMOTIVES	0	0.47	.299E+06	1983	0	0.0
MINING	ELECTROLYTIC SEPARATOR	5	0.47	.195E+06	1983	0	0.0
MINING	FLOTATION MACHINES	110	0.47	.390E+05	1983	0	0.0
AGRICULT	IRRIGATION NEBRASKA	110	0.47	.210E+05	1979	0	0.0
CONSTRUC	ELECTRONIC DISTANCE MEAS	2200	0.45	50.6	1977	0	0.0
CONSTRUC	PORTABLE ELECTRIC WINCH	1060	0.45	.130E+04	1979	0	0.0
RSID/CON	POWER TOOL BATTERY CHARGER	500010	0.42	.195E+06	1979	0	0.0
MINING	GRINDING MACHINES	200	0.40	.240E+06	1983	0	0.0
LEISEREC	MARINE EILGE PUMPS	150000	0.36	.480E+04	1980	0	0.0
LEISEREC	SHOWER SUMP PUMP	1000	0.36	355.	1980	0	0.0
LEISEREC	VHF FM MARINE RADIOS	9000	0.36	90.0	1979	0	0.0
LEISEREC	DEPTH/FISH FINDERS	17000	0.36	357.	1979	0	0.0
RSID/CON	NICAD BATTERY CHARGER	10000	0.33	770.	1978	0	0.0
MILITARY	INSTALLATION POWER	20	0.33	.800E+06	1984	0	0.0
INDUSTRY	WORK SIRENS & HORNS	3000	0.32	.780	1977	0	0.0
INDUSTRY	ELECTRIC SECURITY VEHICLE	1000	0.32	.120E+05	1980	0	0.0
INDUSTRY	ELECTRIC FORK LIFTS	1100	0.32	.154E+05	1983	0	0.0
INDUSTRY	MAINTENANCE TRACTORS&CARTS	3500	0.32	.137E+04	1980	0	0.0
UTILITIES	LEAK DETECTION DEVICES	5000	0.32	50.0	1977	0	0.0
MINING	MINING MACHINES(PACE EQ)	3	0.32	.108E+05	1983	0	0.0
AGRICULT	IRRIGATION CALIFORNIA	103	0.27	.130E+05	1980	0	0.0
RSID/CON	PORTABLE TV/RADIO	500000	0.20	500.	0	0	0.0
AGRICULT	DRYING PFW	1000	0.05	.290E+05	1980	2000	0.0
RESIDENC	SUNBELT - 3.4KW, 1979	57353	0.0	.195E+06	1979	3000	186.00
RESIDENC	NON-SUNBELT, 3.4KW, 1979	315441	0.0	.107E+07	1979	3000	109.00
COHL	SUNBELT, 1979	0	0.85	.520E+08	1979	1979	0.0
COHL	SUNBELT, 1980	0	0.85	.520E+08	1980	1980	0.0
COHL	SUNBELT, 1983-1985/50KW	113000	0.85	.565E+07	1983	1985	0.0
COHL	SUNBELT, 1986-1990/100KW	113000	0.85	.113E+08	1986	1990	0.0
COHL	SUNBELT, 1991-1995/250KW	120000	0.85	.300E+08	1991	1995	0.0

ANNUAL MARKET

MARKET SECTOR	APPLICATION	NUMBER OF SYSTEMS	1986 BREAK-EVEN LIFE CYCLE PRICE (1975\$/WATT)	TOTAL KW PEAK	MARKET INTRODUC- TION YEAR	END OF MARKET YEAR	1986 ANNUAL SAVINGS (1975\$)
COHL	SUNBELT, 1996-2000, 500KW	127000	0.85	.635E+08	1996	2000	0.0
COHL	NON-SUNBELT, 1979	0	0.74	.695E+08	1979	1979	0.0
COHL	NON-SUNBELT, 1980	0	0.74	.695E+08	1980	1980	0.0
COHL	NON-SUNBELT, 1983-1985	150000	0.74	.750E+07	1983	1985	0.0
COHL	NON-SUNBELT, 1986-1990	150000	0.74	.150E+08	1986	1990	0.0
COHL	NON-SUNBELT, 1991-1995	161000	0.74	.403E+08	1991	1995	0.0
COHL	NON-SUNBELT, 1996-2000	170000	0.74	.850E+08	1996	2000	0.0
UTLT	TOTAL US 100W 1990	520	0.47	.520E+07	1990	1990	0.0
UTLT	TOTAL US 500W 1991-1995	128	0.47	.640E+07	1991	1995	0.0
UTLT	TOTAL US 1000W 1996-2000	64	0.47	.640E+07	1996	2000	0.0

APPENDIX C
INCENTIVE MECHANISMS

APPENDIX C--INCENTIVE MECHANISMS

Table C-I provides examples of mechanisms for incentive options that were modeled in this analysis. This information has been extracted from Photovoltaic Incentives Options, the BDM Corporation, Report W-78-184-TR, August 1978.

TABLE C-1
EXAMPLES OF INCENTIVE MECHANISMS

INCENTIVE OPTIONS (Modeled in this analysis)	MECHANISMS TO IMPLEMENT INCENTIVE	IMPLEMENTATION METHODS	ADVANTAGES	DISADVANTAGES/PROBLEMS
DIRECT PRICE	• LOW INTEREST LOANS	<ul style="list-style-type: none"> - DIRECT LOANS FROM FEDERAL AGENCIES (SBA? DOE?) - LOANS THRU BANKS OR UTILITIES - 2-5% INTEREST RATES, 8-25 YEARS LOAN MATURITY, ONLY INTEREST IS SUBSIDIZED 	<ul style="list-style-type: none"> - REDUCE COST OF CAPITAL - VERY HIGH LEVERAGE IN SHORT TERM - ATTRACTIVE WHEN INTEREST RATES HIGH - EQUITABLE 	<ul style="list-style-type: none"> - EXPENSIVE TO GOVERNMENT OVER LIFETIME OF PROGRAM - HIGH ADMINISTRATIVE COSTS - AGENCY DIFFICULTIES WITH DIRECT LOANS--VERY EXPENSIVE, ENTIRE CAPITAL COST WOULD HAVE TO COME FROM FEDERAL BUDGET - MAY REQUIRE NEW ADMINISTRATIVE STRUCTURE
	• ACCELERATED DEPRECIATION/ RAPID AMORTIZATION TIED TO SALES	<ul style="list-style-type: none"> - 5 OR 10 YEAR AMORTIZATION - INCREASE VALUE OF DEPRECIATION BY SHORTENING TIME OR BY ALLOWING A MORE LIBERAL DEPRECIATION METHOD - ADMINISTERED BY IRS 	<ul style="list-style-type: none"> - ENCOURAGE INVESTMENT BY FIRMS WITH LARGE TAXABLE INCOMES 	<ul style="list-style-type: none"> - WOULD NOT HELP FIRMS WITH LOW TAXABLE INCOME - DIFFICULT TO CONTROL PROGRAM SIZE
	• GRANTS	<ul style="list-style-type: none"> - FOR ALL OR PART OF PLANT OR EQUIPMENT COSTS - ADMINISTERED BY DOE, SBA OR GSA - FOR SPECIFIC DEVELOPMENT WORK OR FOR CONSTRUCTION 	<ul style="list-style-type: none"> - DIRECT ECONOMIC BENEFITS TO MANUFACTURERS, INSTALLERS, DISTRIBUTORS, SERVICE COMPANIES - COMPARABLE TO TAX CREDIT, BUT MORE IMMEDIATE AND NO CHANGE REQUIRED IN TAX CODE 	<ul style="list-style-type: none"> - HIGH COSTS RELATIVE TO PROBABLE BENEFITS - LARGE ADMINISTRATIVE STRUCTURE - MAY NOT BE EQUITABLE
	• TAX ACTIONS <ul style="list-style-type: none"> - INVESTMENT TAX CREDITS o CONVENTIONAL o 5 YEAR CARRYFORWARD, 2 YEAR CARRYBACK TIED TO SALES 	<ul style="list-style-type: none"> - ADMINISTERED BY IRS - SPECIFY INVESTMENTS THAT WILL BE CREDITED, E.G., CAPITAL EQUIPMENT 	<ul style="list-style-type: none"> - EQUITABLE - RELATIVELY HIGH LEVERAGE - ADMINISTRATIVELY EFFICIENT - CAN BE PRECISELY TAILORED FOR SPECIFIC OBJECTIVES 	<ul style="list-style-type: none"> - WOULD NOT HELP FIRMS WITH LOW TAXABLE INCOMES - DIFFICULT TO CONTROL PROGRAM SIZE - INDISCRIMINATE - CREDIT WHETHER OBJECTIVES PROMOTED OR NOT AND MAY ASSUME A PERMANENT STATUS - REDUCE FEDERAL TAX REVENUES - REQUIRES AMENDMENT OF TAX CODE
KEYED-TO-BREAK-EVEN SUBSIDY	• PRICE SUPPORTS	<ul style="list-style-type: none"> - PAYMENT BY GOVERNMENT OF A DIFFERENTIAL WHEN MARKET PRICES FALL BELOW A PRE-DETERMINED SUPPORT LEVEL 	<ul style="list-style-type: none"> - SHIFT RISKS FROM INDUSTRY TO GOVERNMENT 	<ul style="list-style-type: none"> - MAY NOT REDUCE RISKS SUFFICIENTLY TO ATTRACT BROAD PARTICIPATION - COULD BE EXPENSIVE - MAY BE INEQUITABLE, FAVORING A FEW FIRMS - ADMINISTRATIVELY COMPLEX
FEDERAL PURCHASE	• FEDERAL PURCHASES	<ul style="list-style-type: none"> - GOVERNMENT PURCHASE FOR GOVERNMENT USE (E.G., FPUP) - GUARANTEED MARKET AT STATED PRICE - GOVERNMENT AS PURCHASER OF LAST RESORT 	<ul style="list-style-type: none"> - PUBLICLY VISIBLE/REASSURE POTENTIAL PRIVATE PURCHASERS - VERY HIGH ECONOMIC AND PSYCHOLOGICAL LEVERAGE - COST CAN BE SET AT ANY LEVEL - CAN EMPHASIZE EARLY DEVELOPMENT OF HIGHLY TRANSFERABLE PRODUCTS 	<ul style="list-style-type: none"> - MAY BE EXPENSIVE - ADMINISTRATION MAY BE COMPLEX - MAY RESULT IN PRODUCTS UNSUITABLE TO PRIVATE MARKETS
AGGRESSIVE FEDERAL RESEARCH AND DEVELOPMENT PROGRAM	• FUNDING FOR RESEARCH AND DEVELOPMENT	<ul style="list-style-type: none"> - GOVERNMENT GRANTS, CONTRACTS, LOANS, PRDA'S - ADMINISTERED BY DOE, NATIONAL LABS, SFRP 	<ul style="list-style-type: none"> - LOW COST, LOW RISK - GOVERNMENT CONTROL OF R&D FOCUS - GOVERNMENT CONTROL OF DISSEMINATION OF RESULTS 	<ul style="list-style-type: none"> - DIFFICULT TO ASSESS COST-EFFECTIVENESS