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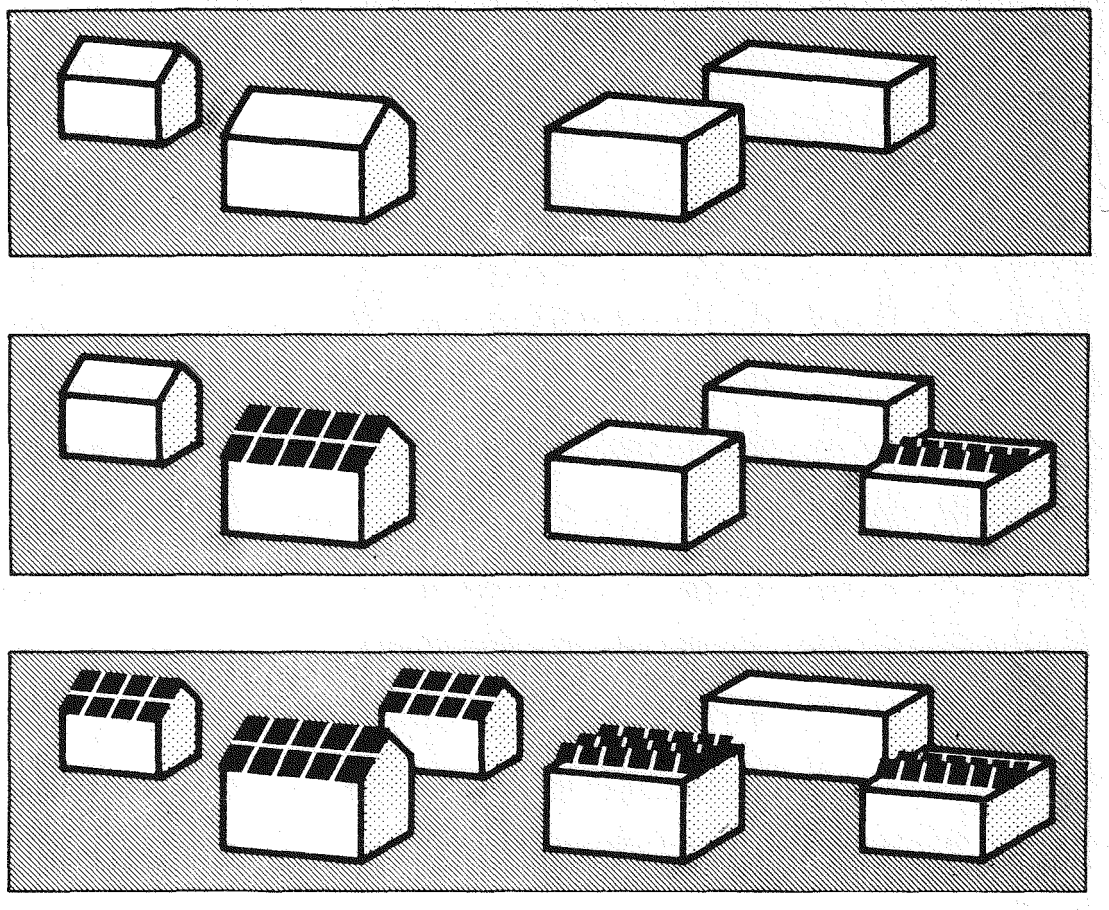
Solar Heating and Cooling of Buildings (SHACOB) Commercialization Report

Part B — Analysis of Market Development

Volume I — Executive Summary

September 1977



Prepared For
U.S. DEPARTMENT OF ENERGY
Assistant Secretary for Conservation
and Solar Applications
Task Force on Solar Energy
Commercialization (FEA)

Under Contract No. CR-05-70066-00

May 1978

FEDERAL ENERGY ADMINISTRATION ACTIVITIES

The Federal Energy Administration (FEA) is involved with the development and use of solar energy encompassing a broad range of interests including: the direction of the nation's solar-related endeavors as part of our national energy strategy; the policy, planning and overall coordination of solar energy commercialization; and certain regulatory and resource management functions which affect the use of solar energy.

FEA's legislative authority for solar-related activities is based on a number of laws including PL 93-275, PL 93-438, and PL 94-385. Of significance, the Energy Conservation and Production Act (PL 94-385) authorizes FEA to "provide overall coordination of federal solar energy commercialization activities" and "to carry out a program to develop the policies, plans, implementation strategies, and program definitions for promoting the accelerated utilization and widespread commercialization of solar energy." As part of PL 94-385, the Congress listed several solar energy commercialization activities which it expects FEA to carry out, a few of which include:

- Develop a national plan for the accelerated commercialization of solar energy to include workable options for achieving on the order of 1 million barrels per day of oil equivalency in energy savings by 1985 from a combined total of all solar technologies;
- Develop commercialization plans for each major solar technology;
- Conduct studies and analyses addressing mitigation of economic, legal, environmental, and institutional constraints;
- Develop state solar energy commercialization plans and programs and coordinate with state energy conservation programs; and
- Develop such major commercialization projects as, but not limited to, the "Southwest Project," the "Solar Energy Government Buildings Project," among others.

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UC-59, 59a, 59b, 59c

Solar Heating and Cooling of Buildings (SHACOB) Commercialization Report

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Prepared By
Arthur D. Little, Inc. 376 9800

Prepared For
U.S. DEPARTMENT OF ENERGY
Assistant Secretary for Conservation
and Solar Applications
Task Force on Solar Energy
Commercialization (FEA)
Washington, D.C. 20545

Under Contract No. CR-05-70066-00

May 1978

NOTE: This report was prepared for the Task Force on Solar Energy Commercialization, Federal Energy Administration (FEA) prior to the activation of the U.S. Department of Energy (DOE) by the Energy Reorganization Act. FEA'S functions have been transferred to DOE.

PREFACE

The Energy Conservation and Production Act (PL 94-385) authorizes the Federal Energy Administration (FEA) to "provide overall coordination of federal solar energy commercialization activities" and "to carry out a program to develop the policies, plans, implementation strategies, and program definitions for promoting the accelerated utilization and widespread commercialization of solar energy." The Congressional conference report listed several specific actions desired by the Congress including (among others):

- Develop a national plan for the accelerated commercialization of solar energy to include workable options for achieving on the order of 1 million barrels per day of oil equivalency in energy savings by 1985 from a combined total of *all* solar technologies;*
- Develop commercialization plans for *each* major solar technology;
- Conduct studies and analyses addressing mitigation of economic, legal, environmental, and institutional constraints.

In essence, the "National Plan . . . for *all* solar technologies" will be comprised of the combination of "commercialization plans for *each* major solar technology." Analyses of costs, benefits, and strategy options for each of the technologies can be placed in context, coordinated and optimized into an overall commercialization plan for solar energy.

The SHACOB Commercialization Report (PARTS A and B) is the first step toward development of a SHACOB Commercialization *Plan*. PART A, prepared by Midwest Research Institute under FEA Contract No. CR-05-70065-00, addresses *qualitatively* the potential barriers to and incentives for the accelerated commercialization of SHACOB in the residential and commercial sectors. It represents a summary and synthesis of a large amount of recently completed research on all aspects of the market development of solar heating and cooling. PART B, prepared by Arthur D. Little, Inc., contains *quantitative* analyses of the market penetration and the costs and benefits to the government associated with some of the incentives examined in PART A.

The SHACOB Commercialization Report relates closely to the President's proposed National Energy Plan (NEP) in that it analyzes a large number of incentives in terms of their impact on barriers to commercialization, their impact on income and interest groups, and possible administrative mechanisms. The impacts of incentives contained in the NEP are analyzed and compared to the present research, development and demonstration programs, an expanded NEP, and new initiatives.

PART B is divided into three volumes. Volume I contains the executive summary, while the technical report makes up Volume II. Volume III contains appendices which support the technical discussions in Volume II.

* Major solar technologies include: solar heating (including hot water) and cooling of buildings — SHACOB, agricultural and industrial process heat, wind energy conversion systems, photovoltaics, fuels from biomass, solar thermal, and ocean thermal energy conversion.

PART B was prepared by Arthur D. Little, Inc., under FEA Contract No. CR-05-70066-00 for the Federal Energy Administration's Task Force on Solar Energy Commercialization. Norman W. Lutkefedder is Director of the Task Force. Other Task Force members who contributed to this report are: Samuel J. Taylor, Howard L. Walton, Charles Allen, Richard D. Stoll, Howard Magnas, LaVerne P. Johnson, Robert Grubenmann, I-Ling Chow, Stanly Stephenson, Edward Downey, Mike Kutsch, Elaine Smith, Robert Jordan, Jeffrey Milstein, Margaret Sibley, Sally Mott, Ned Dearborn, James H. Berry, Mary Liebert, and Jack Koser.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

EXECUTIVE SUMMARY

OBJECTIVE AND SCOPE

Objective

The objective of this study is twofold:

- to construct a quantitative model capable of generating comprehensive market penetration figures for the solar heating and cooling of buildings under a wide range of assumptions; and
- to analyze and compare the results of the model as solar incentive scenarios and data base assumptions are changed.

Designed in support of the efforts of the Federal Energy Administration Task Force on Solar Energy Commercialization, the model allows broad consideration of socioeconomic and technical data, and has the flexibility to allow alterations and refinements as the need for them arises. This model for the solar heating and cooling of buildings — the SHACOB Commercialization Model — is being transferred to the Federal Energy Administration (FEA) for its continued use.

The original intent of this project was to refine a previous Arthur D. Little solar modeling effort entitled *An Analysis of the Market Development of Solar Systems: 1976-1990*. Instead, the assumptions of previous work have been used as a base for the construction of a more advanced computer approach to solar penetration analysis.

Scope

The scope of this study is defined by the parameters and limitations of the model. They are as follows:

- The model is concerned with the solar heating and cooling of buildings only. Agricultural and industrial process heating, photovoltaics and other energy producing techniques are subject for separate analysis.
- Residential and commercial/institutional construction, both new and retrofit, are analyzed on an annual and cumulative basis.
- Solar penetration is measured against the three major energy sources, natural gas, oil and electricity. Fuel prices and fuel shares have been supplied by the FEA.
- The period of analysis is from 1977 through 1990.
- Solar penetration is analyzed on a national level, and by each of the 10 FEA regions.
- A Reference Case has been developed, representing a "business-as-usual" scenario for solar heating and cooling. This Reference Case is used to compare the relative impacts on solar penetration of three primary incentives packages: the President's proposed National Energy Plan (NEP), an Expanded NEP, and New Initiatives scenarios.
- The model has been constructed as a FORTRAN program accessed via the SUPER WYLBUR data management program at FEA.

Over 130 scenarios were run on the model to test the sensitivity of such key assumptions as fuel prices and fuel shares, solar equipment costs, etc. As part of the model construction, assumptions on present and future solar market infrastructure were evaluated. A review of recent solar marketing efforts by public and private agencies was made to insure currency of both logic and data development.

QUANTITATIVE RESULTS

Principal Incentive Scenarios Analysis

Table I-1 summarizes the principal quantitative results of the SHACOB model. The figures reflect the comparative impacts of the Reference Case and various Federally sponsored incentive scenarios on the commercialization of solar heating and cooling equipment. For each of the major categories listed — solar equipment sold, dollar volume of sales, energy savings, and Btu's per dollar of government cost — the figures given are totals for new and retrofit applications and include all three system types (hot water systems; heating and hot water systems; and heating, hot water and air conditioning systems). Annual as well as cumulative results are given for the years 1977, 1985 and 1990.

Figure I-1 charts the growth of annual solar sales from 1977 through 1990 for the four basic scenarios, each of which is described below:

- *Reference Case* — The Reference Case is a "business-as-usual" base case with minimal government support activity (ongoing research, development and demonstration efforts only). The only direct incentive contained in the Reference Case is an investment tax credit amounting to 10% on qualified energy conservation expenditures from 1978 through 1980, decreasing to 7% for the period 1981-1990.

  Solar market development in the base case follows a pattern that is typical of new construction products in dispersed markets. As Figure I-1 illustrates, growth occurs in the early years, followed by stagnation and decline (1980-1985). As the market matures, moderate growth resumes (1985-1990). Under the assumptions of the Reference Case, sales of solar equipment will move from a unit volume of 47,000 in 1977 to 147,000 in 1990 (see Table I-1). By 1990, national annual energy savings will reach only 23 trillion Btu's.

  It is clear that solar penetration will be limited in the absence of incentives to industry development. Even when it is assumed that technological advance and rising energy prices will enhance public acceptance of solar energy systems, the market remains relatively static through 1990.

- *National Energy Plan* — The NEP scenario assumes three basic government incentives to solar development: an investment tax credit, a residential tax credit and a government buildings program. The investment tax credit is the same as the 10%/7% allowance of the Reference Case, with an additional 10% credit added for 1978-1982. The residential tax credit of the NEP allows a 40% tax credit on the first $1,000 invested in solar, and a 25% credit on expenditures in excess of $1,000 to a total of $7,400 (a maximum credit of $2,000). The residential tax credit percentages are scaled down to 35%/20% for 1980-1982, and drop to 25%/15% for 1982-1984. The government buildings program would involve an expenditure of $100 million for the purchase of solar systems for government buildings over the three year period 1979-1981.

TABLE I-1

SOLAR INCENTIVE COMPARISONS
SUMMARY TABLE

	Annual			Cumulative		
	1977	1985	1990	1977	1985	1990
1. Residential Units Sold (000)[1]						
- Reference Case	46	87	144	46	749	1,330
- NEP	46	577	774	46	3,465	6,951
- Expanded NEP	46	641	850	46	4,211	8,042
- New Initiatives	46	882	1,162	46	7,209	12,451
2. Non-residential Units Sold (000)[2]						
- Reference Case	1	2	3	1	14	26
- NEP	1	9	12	1	44	98
- Expanded NEP	1	9	13	1	52	111
- New Initiatives	1	12	16	1	77	149
3. Total Collector Area (MM Sq.Ft.)						
- Reference Case	4	7	10	4	62	103
- NEP	4	55	65	4	315	623
- Expanded NEP	4	61	72	4	389	731
- New Initiatives	4	86	102	4	697	1,177
4. Total Solar Equipment Sales (MM $)						
- Reference Case	153	236	352	153	2,197	3,684
- NEP	153	1,225	1,507	153	7,939	14,975
- Expanded NEP	153	1,355	1,648	153	9,422	17,120
- New Initiatives	153	1,863	2,270	153	15,822	26,429
5. Government Cost of Incentives (MM $)[3]						
- Reference Case	87	11	12	87	451	509
- NEP	87	17	18	87	1,831	1,919
- Expanded NEP	87	17	19	87	2,202	2,294
- New Initiatives	87	230	278	87	5,587	6,887
6. Total Energy Saved (10^{12} Btu)[4]				Cumulative Annual Savings		
- Reference Case	1	2	2	1	13	23
- NEP	1	12	15	1	67	138
- Expanded NEP	1	13	17	1	83	161
- New Initiatives	1	19	24	1	149	258
7. Btu's (000) Saved/$ Government Cost						
- Reference Case	N/A	N/A	N/A	11.5	28.8	45.2
- NEP	↓	↓	↓	11.5	36.6	71.9
- Expanded NEP	↓	↓	↓	11.5	37.7	70.2
- New Initiatives	↓	↓	↓	11.5	26.6	37.4

(1) Average Residential collector size (all devices) for the NEP case in 1985 is 80 square feet.

(2) Average Non-residential collector size (all devices) for the NEP in 1985 is 965 square feet.

(3) Governmental RD & D expenses for solar prior to 1977 were not included for comparative purposes. RD & D expenditures for 1979 are estimates and have been divided evenly among the three solar devices.

(4) Energy savings are measured at the point of entry to the building. In the case of electricity, these savings do not reflect power plant or distribution losses. Under the assumptions of the NEP, and taking energy savings in 1985 as an example, an energy saving of 67×10^{12} Btu at the wall is equivalent to 122.5×10^{12} Btu of primary energy (electric Btu's saved x 3 plus gas and oil Btu's saved, or: [27.5 x 3] + 20.7 + 19.3 = 122.5).

For conversion to oil equivalent, 2.1 quads = 1 million barrels of oil per day. Thus an energy saving of 122.4×10^{12} Btu annually is the equivalent of 58,300 barrels of oil per day.

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FIGURE I–1
TOTAL ANNUAL SOLAR SYSTEM SALES: 1977–1990
($ MM)

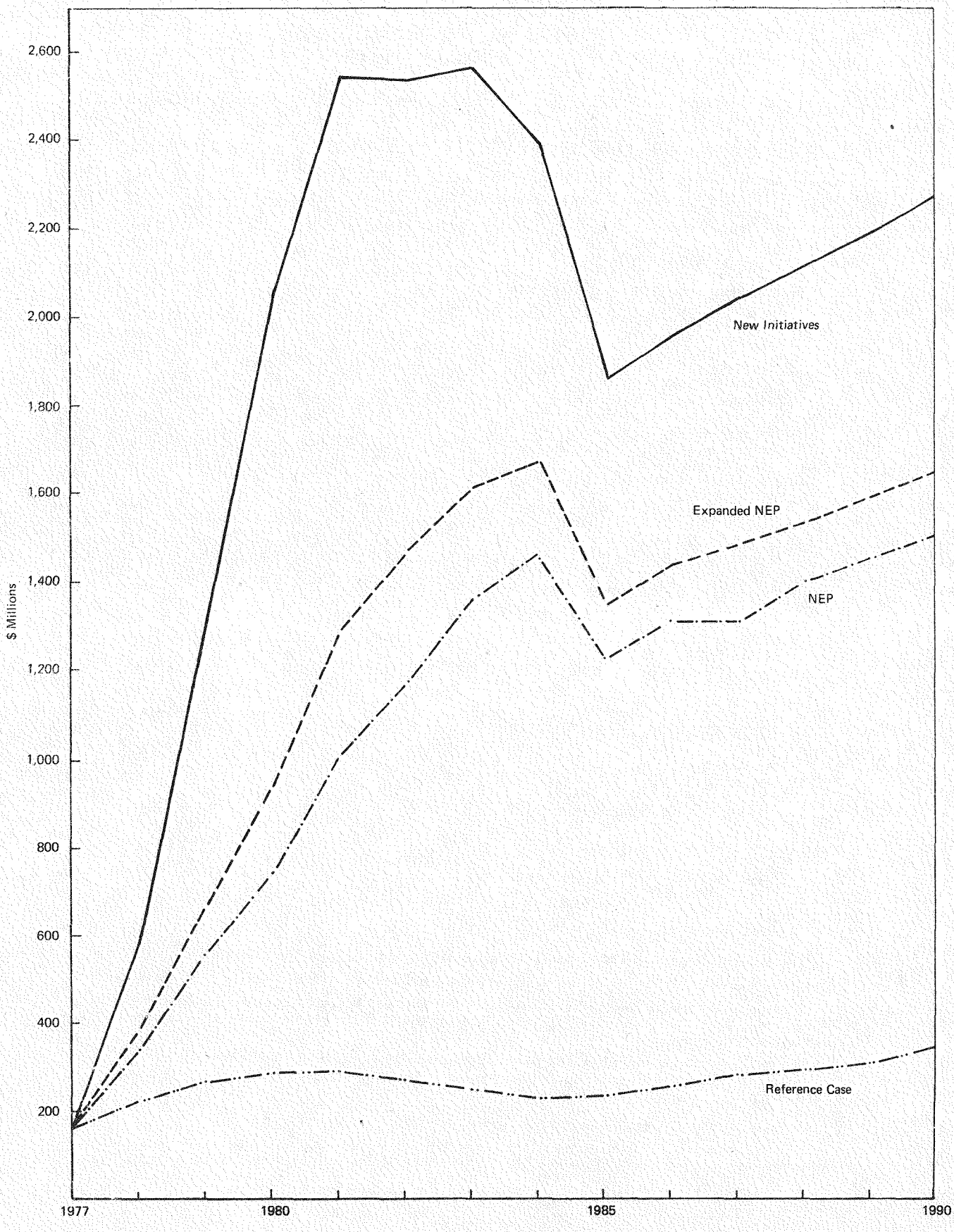


Table I-1 indicates that under the NEP, solar heating and cooling of buildings makes significant strides in both market penetration and national energy savings. This is due principally to the action of financial incentives in reducing first costs and improving solar paybacks. The NEP program would generate over 6.9 million units through 1990, annual industry sales would be in excess of $1.5 billion per year, and annual energy savings would be 138 trillion Btu's, or 500% greater energy savings than in the Reference Case. In April 1977, President Carter announced a national goal of 2.5 million residential solar units by 1985. Under the provisions of the NEP, this goal would be met and surpassed, with some 3.4 million residential units in use by 1985. The curve representing annual solar system sales under the assumptions of the NEP (see Figure I-1) shows a much steeper slope than the same curve for the Reference Case. The dip in the curve in 1984 indicates the phasing down of Federal incentives. Sales volume recovers and continues to rise in the year 1985-1990. See Tables I-2 and I-3 (which are examples of Report Format) for additional NEP data at the back of this volume.

Of the four basic scenarios, the NEP most closely approximates near-term expectations as to the probable structure of Federal incentives for solar development. The sensitivity of NEP results to changes in input assumptions has therefore been the subject of careful analysis. Model results for the NEP scenario have been compared to two additional runs of the model with altered assumptions as to rates of fuel price increases. Based on FEA/PIES[1] fuel figures, the model assumes annual fuel price increases from 1977-1990 as follows: for electricity, .7%; for gas, 4.5%; and for oil, 1.5%. If it is assumed that prices for gas and oil will increase at an annual rate of 4%, and electricity at an annual rate of 2% over 1977 levels, sales of residential solar units increase 62% over NEP levels. If a 25% increase in fuel prices is assumed for the year 1990, a cumulative total of 13.5 million residential units results — almost twice the NEP level of 6.9 million. Table I-4 highlights these three fuel pricing cases.

- *Expanded National Energy Plan* — The Expanded NEP scenario uses the NEP incentives as a base, then expands the government building program to $200 million and institutes utility and product certification activities. The Expanded NEP does not contain any new direct economic incentives. Implementation of the Expanded NEP would lead to dramatic solar penetration and energy savings relative to the Reference Case, but these market improvements would not be significantly greater than those achieved under the NEP scenario. This relationship among scenarios is clear in Figure I-1. The overall shape of the NEP and Expanded NEP curves is similar, and they are not widely separated.

  As is shown in Table I-1, residential and commercial penetrations approach 850,000 units and 13,000 units respectively on an annual basis for 1990. For the same year annual solar sales are $1.6 billion and annual energy savings total 161 trillion Btu's.

- *New Initiatives* — The New Initiatives scenario further expands the solar incentive programs, most notably through the addition of accelerated depreciation for solar devices, low interest loans and a larger government buildings effort (now

1. Project Independence Evaluation System.

TABLE I-4

NEP – EFFECT OF FUEL PRICE VARIATIONS ON
SOLAR SYSTEM SALES
CUMULATIVE THROUGH 1990

	FEA/PIES Prices	25% Over FEA/PIES Prices	Annual Increase Gas – 4%, Oil – 4%, Electricity – 2%
Residential Units (000)	6,951	13,494	11,278
Non-Residential Units (000)	98	174	150
Collector Area	623	1,302	1,088

1. Using FEA/PIES 1977 prices as base.

$500 million to be spent in equal amounts in 1979, 1980 and 1981). Again, Figure I-1 illustrates the impact of this scenario relative to the other three.

The results in Table I-1 show annual solar unit sales (residential and commercial) of 1.2 million by 1990, as opposed to 147,000 for the Reference Case and 786,000 for the NEP. Annual energy savings under the New Initiatives scenario reach 258 trillion Btu's by 1990. The significant increase in solar activity under the New Initiatives scenario is due to the direct impact of the additional economic incentives on solar equipment sales.

Additional Scenario Analysis

In addition to summary statistics of the type noted above, the SHACOB Model generates detailed reports on new versus retrofit markets. For these, and for the new/retrofit combined report, the model output shows the distribution of total values by system type. For example, the category "Residential Units Sold" will show the apportionment of total units for hot water systems, heating and hot water systems, and heating, cooling and hot water systems.

Figure I-2 plots the relationship of new versus retrofit solar installation under each of the four scenarios for the years 1977-1990. Beginning in 1977, the retrofit market shows a sales volume that is significantly larger than sales volume in the new construction market for all cases. The retrofit market also reacts more markedly to each scenario than does the new construction market.

Figure I-3 compares solar hot water and solar heating/hot water systems on an annual sales basis for all scenarios. The curves are roughly comparable in shape to those in Figure I-2, and the heating/hot water systems account for a larger percentage of solar equipment sales in all but the Reference Case. The results charted in Figures I-2 and I-3 suggest that financial incentives will encourage market acceptance of retrofit heating/hot water systems.

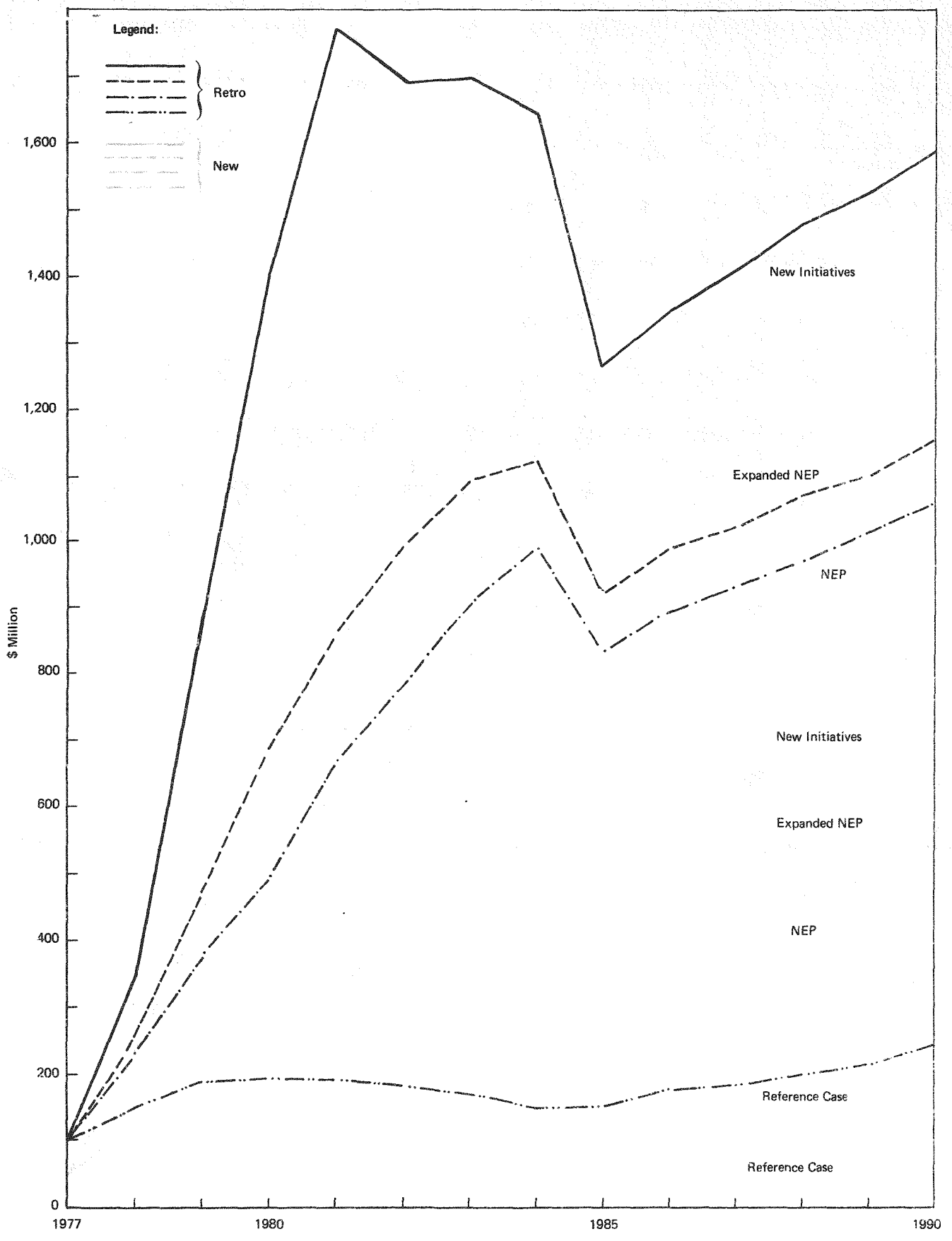


FIGURE I–2
ANNUAL SOLAR SYSTEM SALES BY MARKET: 1977–1990
($ MM)
NEW VS. RETROFIT

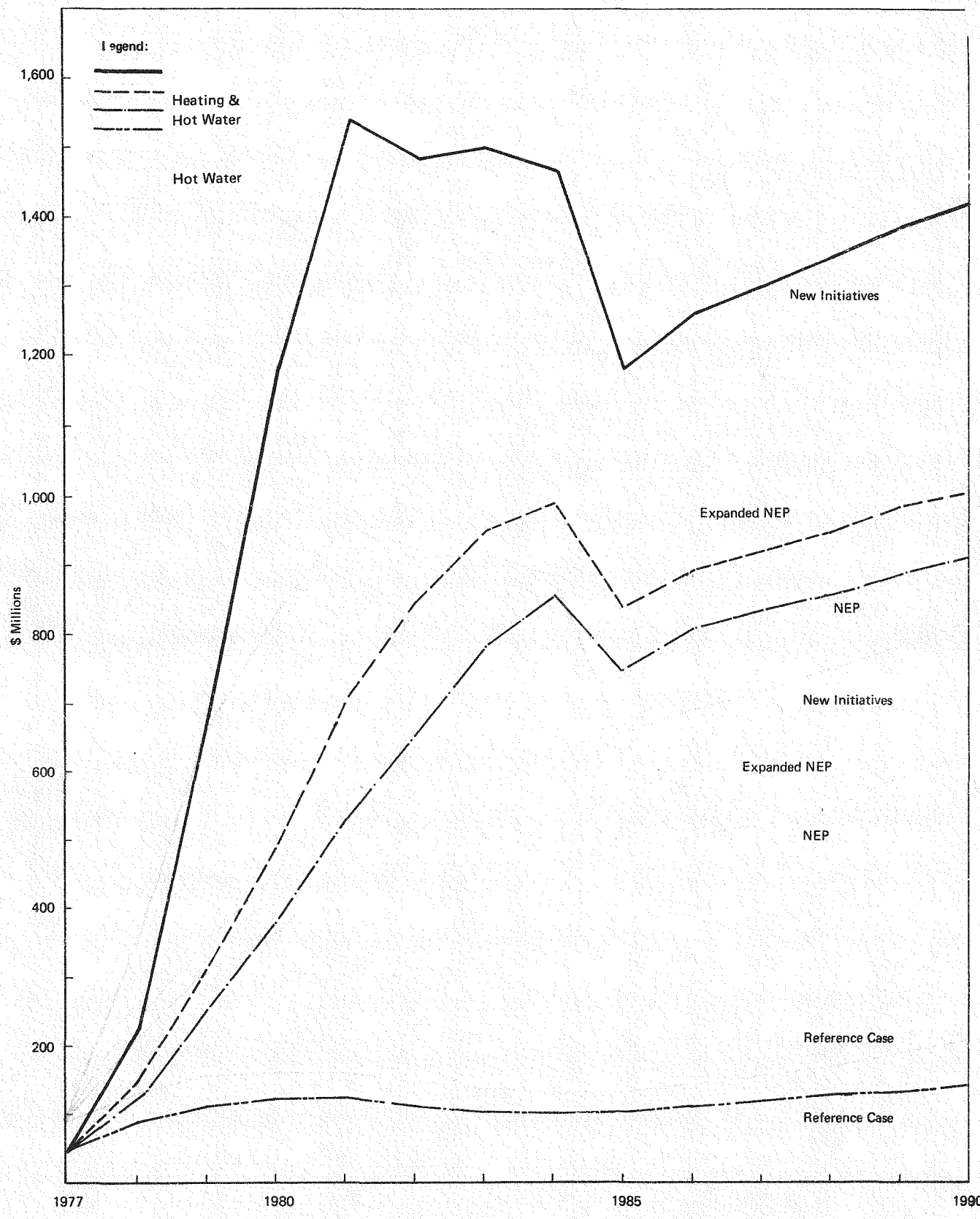


FIGURE I–3
ANNUAL SOLAR SYSTEM SALES BY DEVICE: 1977–1990
($ MM)
HOT WATER VS. HEATING & HOT WATER

Figure I-4 shows the effect of the basic scenarios on residential and commercial markets. For both markets, collector area rises over time and with added incentives. The relative proportion of residential to commercial penetration remains almost constant, however. This point is further illustrated in Figure I-5, which shows the relative market share of each of the 10 building categories under the assumptions of the NEP scenario.

Model Sensitivity Analysis

The sensitivity of the model to changes in major assumptions was tested by the independent alteration of key variables. The NEP scenario was used as a point of comparison. The variables that were altered included: fuel prices; solar equipment costs; penetration assumptions (high or low acceptance curves); and future availability of natural gas. Results of the sensitivity analysis indicated that changes in collector costs will have greater impact on solar market penetration than changes in fuel prices, and that the assumption of a high or low penetration curve is crucial in determining solar development. Table I-5 illustrates these results in terms of percent changes in residential units and total sales.

TABLE I-5

MODEL SENSITIVITY ANALYSIS
PERCENT DEVIATIONS FROM NEP – CUMULATIVE THROUGH 1990

	% Deviation Over (Under) NEP	
	Residential Units	Total Solar Sales
NEP – Fuel Cost Up 25%	94%	95%
NEP – Collector Costs Down 15%	78	52
NEP – Collector Costs Up 15%	(83)	(74)
NEP – Low Penetration Curve	(89)	(74)
NEP – High Penetration Curve	241	246

Single Incentive Impacts

Using the Reference Case as the base case, a number of single incentives were added to the scenario as a means of determining individual incentive impacts. Incentives tested included: the residential tax credit, the investment tax credit, the $100 million government buildings program, low interest loans (7%), and accelerated depreciation.

The residential tax credit is by far the most important single incentive in aiding commercialization of solar energy systems. The NEP version of the residential tax credit generates some 6,790,000 cumulative residential solar installations by 1990 — only 3% below the levels of the total NEP incentives package. (See Table I-6.)

NEP versus Compromise NEP

The National Energy Plan, originally proposed by President Carter in April 1977, has been used as one of the basic scenarios in this report. Since April, the U.S. House of Representatives has taken action on the NEP and passed what is referred to here as the Compromise NEP (incorporated in HR8444 of 5 August 1977). Action by the Senate has also been taken but the final form of the NEP awaits conference committee action and subsequent passage by both the House and Senate. Because the House version of the NEP contains a revised version of the residential tax credit, and because of the demonstrated importance of the residential tax credit to solar commercialization, the Compromise NEP has been analyzed as a separate scenario.

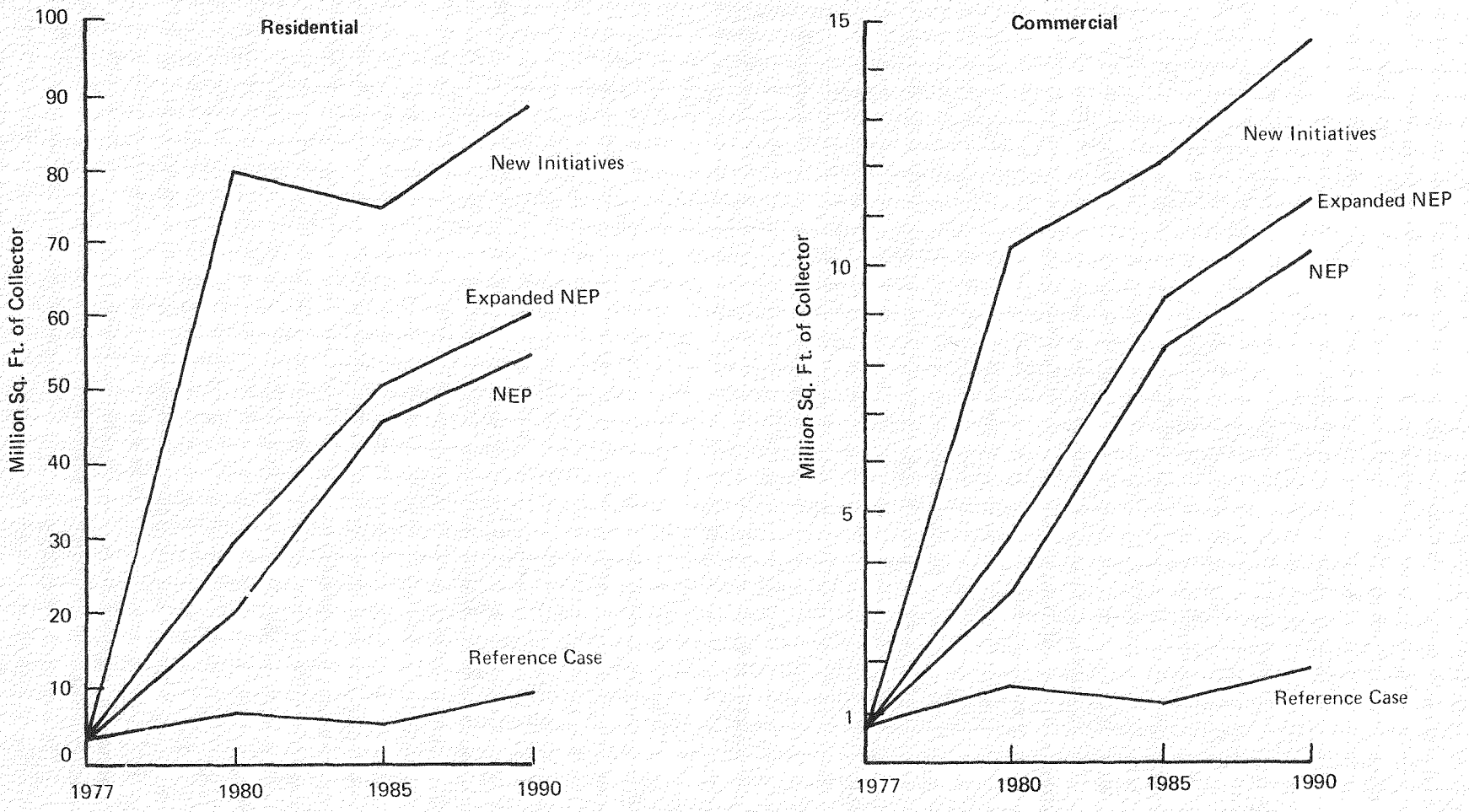


FIGURE I-4 ANNUAL SOLAR SYSTEM SALES BY MARKET (MILLION SQUARE FEET OF COLLECTOR)
RESIDENTIAL VS. COMMERCIAL

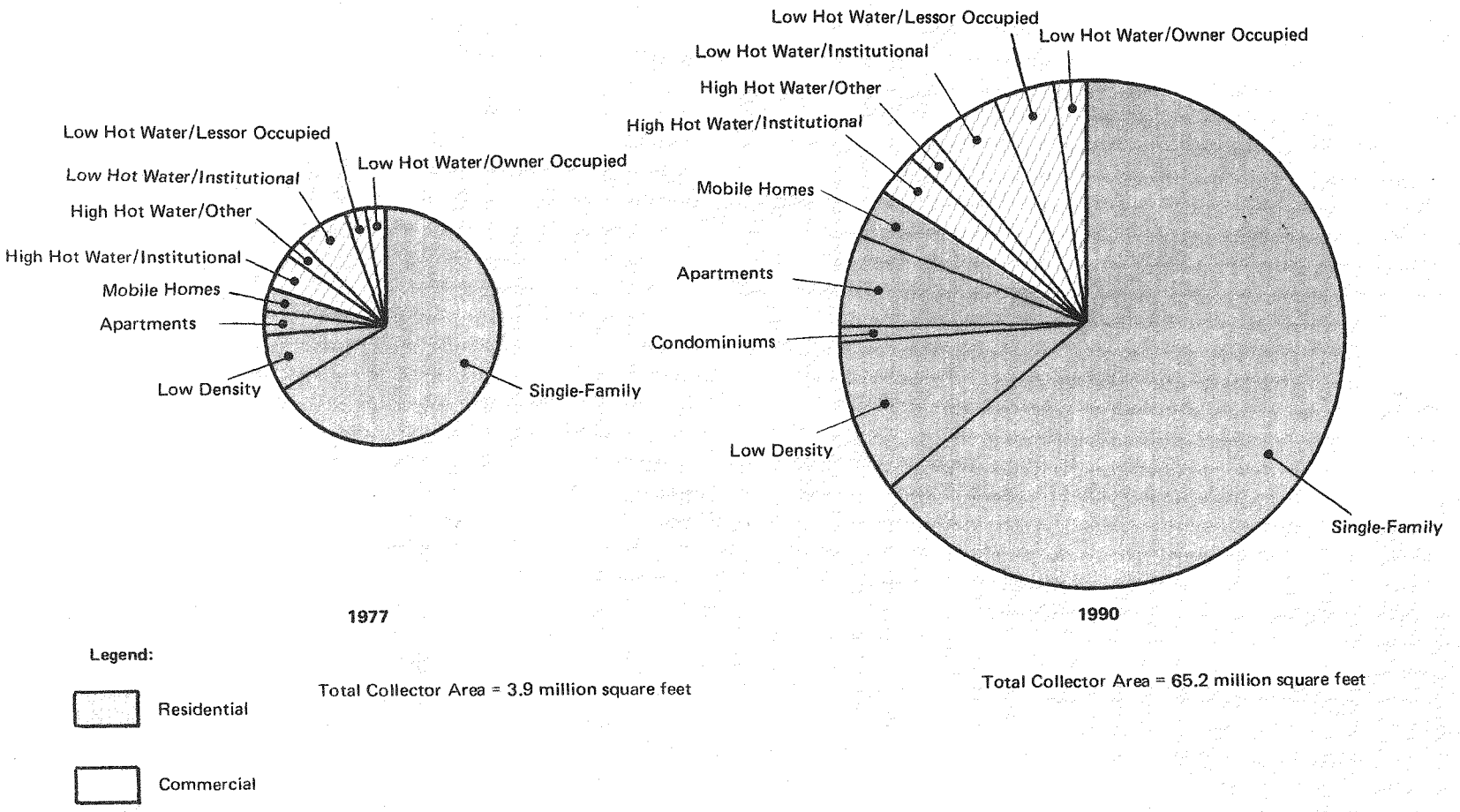


FIGURE I-5 ANNUAL SOLAR MARKET SIZE (MILLION SQUARE FEET OF COLLECTOR AREA) UNDER NEP: 1977 AND 1990, RESIDENTIAL & COMMERCIAL SYSTEMS

TABLE I-6

SINGLE INCENTIVE IMPACT –
REFERENCE CASE – CUMULATIVE THROUGH 1990

	Installations (000 Units)	
	Residential	Non-Residential
Reference Case	1,330	26
Reference Case with		
NEP Res. Tax Credit	6,790	89
Compromise Res. Tax Credit	6,956	89
Investment Tax Credit	1,482	29
$100 MM Gov. Bldg. Prog.	1,828	34
Low Interest Loan (7%)	2,690	43
Accelerated Deprec.	1,469	31

The basic difference between the NEP and the Compromise NEP (COMP/NEP) is that the residential tax credit in the latter takes the following form: a 30% tax credit on the first $1,500 of solar expenditure with a 20% tax credit on expenditures in excess of $1,500 up to a total of $10,000 (a maximum credit of $2150). Unlike the NEP tax credit, the House version does not decline, but remains at the 30%/20% level through 1984.

By 1980 the NEP generates some 16% more total solar units than the COMP/NEP. By 1985, however, the COMP/NEP shows cumulative solar units 2% higher than the NEP. This lead increases to 1990, where the COMP/NEP exceeds the NEP by 4%. In terms of dollar efficiencies, the NEP leads to greater Btu savings per dollar of government cost with 72,000 Btu's per dollar vs COMP/NEP's 67,000 Btu's.

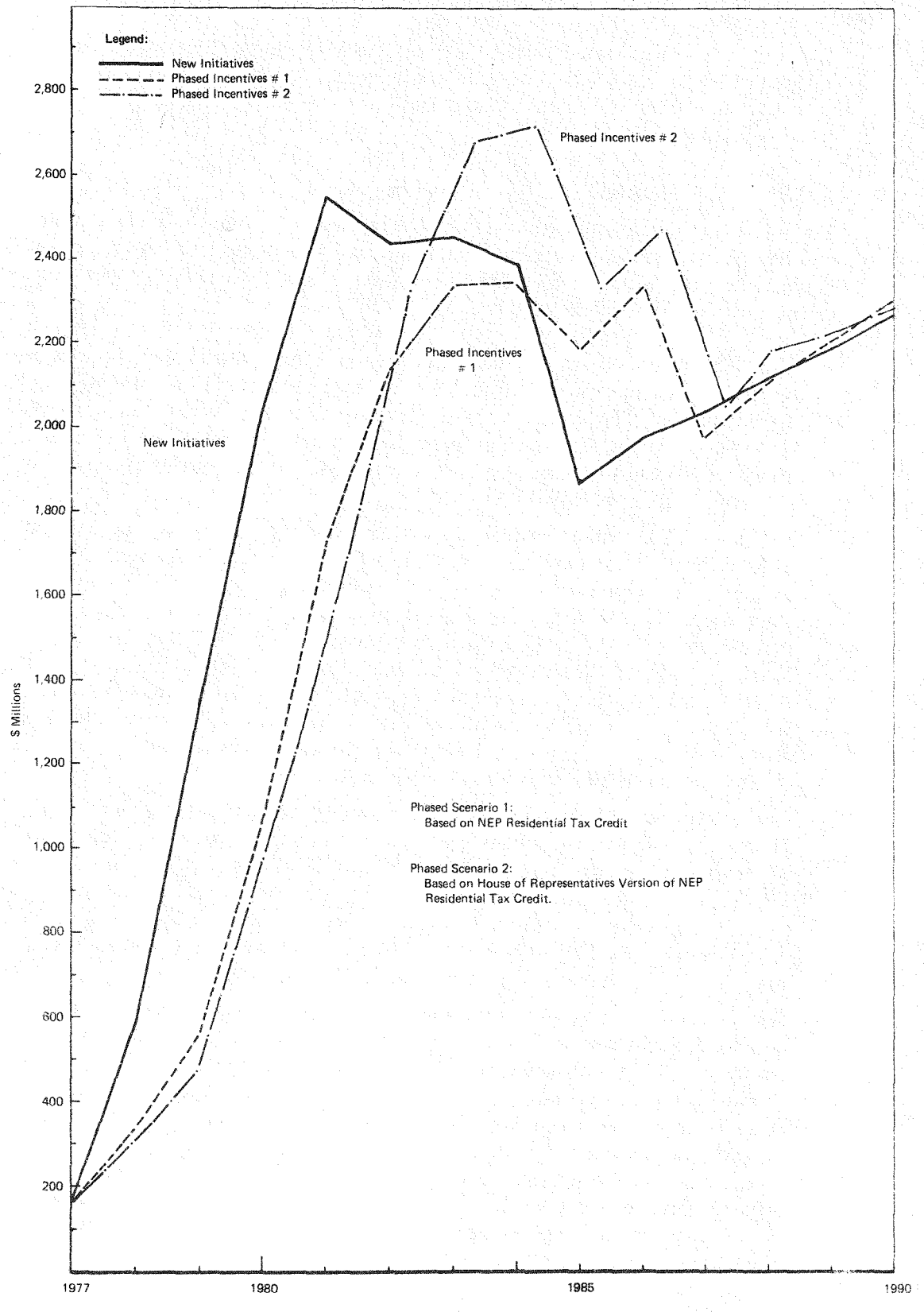
Phasing of Incentives

The results charted in Figures I-1 — I-3 show the comparative effects of the basic scenarios on solar market development. In the years where incentives are initiated, there are sharp increases in market activity; when incentives are dropped, there are notable market declines. If industry incentives can be phased so as to smooth these peaks and valleys, the long-term beneficial effect on solar commercialization can be optimized.

Alterations in the time-phasing of incentives can be incorporated into any model scenario. By introducing various incentive and timing combinations into the model it is possible to see how the transitions from incentive introduction to withdrawal might be moderated.

Figure I-6 compares the New Initiatives scenario (discussed above) with two phased-incentive scenarios, one utilizing the NEP version of the residential tax credit, and the other utilizing the COMP/NEP version. Both scenarios use programs from NEP, Expanded NEP, and New Initiatives, but phased in and out more gradually. The residential tax credits, for example, are phased through 1986 at 20%/10% credit levels, while the government buildings program is staged through six years (at $500 million level) rather than three. The result is more realistic growth rates and a softening of the inevitable drop in sales at the termination of incentives. While these scenarios are not optimum programs, they do portray the SHACOB Model's ability to anticipate incentive timing.

FIGURE I–6
ANNUAL SOLAR SYSTEM SALES
($MM)



SHACOB Model Flexibility

The number of scenarios analyzed by the SHACOB Model in this report are limited by time constraints. The Model has the flexibility to analyze a variety of solar stimulation approaches, most notably giving priority for new gas hookups to those individuals who incorporate or at least consider solar devices.

DISCUSSION OF FINANCIAL INCENTIVES

The quantitative analysis of the results obtained in measuring the impact of Federally sponsored incentives underscores the importance of the Federal role in accelerating the use of solar equipment in the heating and cooling of buildings. The following are the main qualitative conclusions drawn from the model analysis:

- Although Federal incentives range from research and development funding to project demonstrations, it is clear that the critical factor in encouraging rapid development of solar energy is the introduction of market oriented financial incentives. At present, the principal barrier to the purchase of solar energy systems is economic, system first costs are high and the performance of the devices is yet unproven as an offset to this barrier.
- The construction market is widely dispersed with many participants and decision-makers, most of whom are first-cost conscious. Because of the dispersed nature of residential and commercial solar heating and cooling, the introduction and substantial growth of solar devices becomes more difficult due to the wide range of individuals who must be persuaded to buy solar equipment. The lead time for building a successful market for a new construction device is normally 20-30 years. It is clear that it is not in the nation's interest to wait for market forces to react in the normal time frame on the acceptance of solar energy. Federally sponsored economic and non-economic incentives are methods to short-cut this lengthy market acceptance procedure for solar heating and cooling.
- Government actions, can provide only the catalyst for an expanding solar heating and cooling market. Free market forces are necessary to address the complex issues of growth and to handle the many conflicting pressures of the marketplace. A growing market for solar energy will encourage industry participation. It is this industry participation which will intensify technical developments, reduce first costs through competition and economies of manufacturing scale, and address the barriers and constraints which affect industry development.
- While the financial incentives provide the principal stimulation for an expanding market and provide the foundation for the creation of the solar industry infrastructure, other supportive governmental activities in the form of non-economic incentives are also necessary. Well directed educational programs aimed at the consumer and financial areas will add to an increased market by encouraging potential purchasers who might have little knowledge of solar equipment. Demonstrations of sustained and substantial Federal commitment to solar energy through such programs as the government buildings program indicate to the public that solar energy is a viable part of the National Energy Plan and not just an interesting technology for the future.

MODEL PHILOSOPHY AND DESCRIPTION

The SHACOB commercialization computer model represents an integrated approach to assessing the future development of solar heating and cooling devices in residential and commercial building markets. Its objective is to provide a best estimate of the extent to which solar energy devices will be used for heating and cooling in the residential and commercial building markets.

No one can predict with certainty the developments that will occur in solar energy during the next 10-15 years. A variety of unknown factors will affect solar penetration such as fuel prices, technology development, and consumer preference. The philosophy of the solar market computer model is to incorporate these important aspects of decision marking. Best estimates of the data associated with the decisions and various markets were used in the model. The model has the following features:

- The model considers all residential and commercial markets at once, but maintains a distinction among building types and markets.
- The model has been developed in a manner such that both financial and non-financial characteristics of the solar energy devices are considered in determining the degree of penetration into the building markets.
- The model is flexible enough to allow modification in basic data and assumptions to be made as new information or changes in policies occur.

Market forecasting is an inexact science, particularly for a product in the earliest stages of its development and for which market experience is extremely limited. The model is a tool to explore the relationships between the factors affecting solar energy development. It is the first step in the process; the need for additional information and further analysis became clear during the course of the project. Aspects of the model can and should be refined as further information becomes available.

The computer model has been designed in order to incorporate all of the features indicated by the above philosophies. The most important features of the model are:

- The model considers all factors of the solar energy market at a detailed aggregate level, specifically:
  - ten (10) regional areas (FEA regions)
  - ten (10) market and building types
  - retrofit and new construction
  - three solar devices (solar hot water, solar hot water and space heating, and solar hot water, space heating and space cooling)
  - seven conventional fuel-firing options (i.e. back-up systems)
  - fourteen individual years (1977-1990).

The above combination of factors leads up to 58,800 combinations of options that are individually considered by the model. The model has the flexibility to consider only subsets of these factors or to perform the calculations on an aggregated basis.

- The model examines both the financial and non-financial attractiveness of each solar device option. The financial attractiveness is measured by the value of undiscounted payback (in years) associated with each device in each building type and fuel-firing option. Penetration curves are developed which indicate the percentage of consumers who would choose the device(s) at each level of financial attractiveness. Non-financial characteristics of the devices (aesthetics, attitude toward solar energy, etc.) are reflected in the level set for the non-financial utility weighting and rating.
- The total experience associated with solar energy for use in buildings is calculated through each year of the model. The experience is developed at the level of annual solar device installation in terms of square feet. Both consumer response and solar device first cost installed are designed to change as a result of increasing experience. The model can thus display the dynamics associated with solar energy during infusion into the market.
- The model handles all of the accounting level details by arranging the data to be used in the penetration calculations and aggregating the results. The model results can be aggregated and displayed in any form under special computer control.
- Financial incentives are all handled as changes in the effective first costs of the solar devices. This approach allows multiple incentives to be instituted simultaneously and compared against each other. Incentives can be phased in and out in any year from 1977-1990.

INDUSTRY INFRASTRUCTURE

The market assessment model described above has been designed in response to an understanding of the solar industry infrastructure. The major considerations relative to status and trends in the industry are as follows:

- There are several primary groups of solar industry participants, including: designers and architects; materials suppliers; equipment manufacturers and distributors; builders and contractors; financial institutions; and the consumer. New participants who are beginning to exert market influence are the government, through its potential solar incentive programs, and the energy consultant, particularly in the commercial sector.
- The solar industry is largely comprised of small regional firms of an entrepreneurial type. Many of these firms will survive as the industry develops, with the expected role of providing regional assembly, distribution and installation of solar equipment.
- There are large companies involved in solar development. Their role will likely expand in the future, aided by broad technical and financial resources and market reputation and credibility.
- The industry rationalization process, accelerated by government incentives, will lead to major changes in the structure of the solar market. In the long run, it is expected that industry structure will parallel and be integrated with the manufacturer and distribution systems of the heating, ventilation and air conditioning industry.

- Economies of scale, consumer knowledge, and legislative response are expected to develop favorably as the industry pursues opportunities created by incentives to growth.

MARKET RESEARCH

The immature character of the solar industry makes comprehensive and timely market research difficult. In recent months, however, several major solar studies have been released. While the focus and scope of these studies is variable (ranging from a study of solar water heating only to a study of all potential applications of solar), a good deal of effort has been devoted to the determination of those factors affecting solar energy decisions. The results of studies based on surveys of industry participants have been closely considered in constructing the SHACOB Model.

There is a continuing need to monitor market processes and consumer acceptance of solar energy systems. The model presented in this study is a step toward rigorous analysis of the quantitative aspects of solar development. Continued use of this and other analytical models will provide decisionmakers with the tools necessary for informed response to a changing energy environment.

TABLE I-2

SOLAR IMPACT MODEL
NATIONAL ENERGY PLAN 28 SEPT 77
CUMULATIVE DATA – N/R

		1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
RESIDENTIAL	(HW)	38.1	129.9	281.4	488.7	787.0	1149.3	1590.4	2074.2	2450.4	2860.0	3290.6	3744.5	4218.8	4726.9
SOLAR UNITS	(HHW)	7.5	26.4	66.5	135.2	245.7	394.4	586.8	812.9	1013.1	1232.0	1461.7	1703.2	1956.2	2221.6
(000 UNITS)	(HC)	0.0	0.0	0.1	0.3	0.5	0.7	1.0	1.5	1.5	1.7	2.0	2.2	2.4	2.7
	(ALL)	45.6	156.3	348.0	624.2	1033.2	1544.4	2178.1	2888.4	3464.9	4093.7	4754.2	5450.0	6177.5	6951.2
COMMERCIAL	(HW)	0.7	2.1	4.1	7.1	11.1	16.1	21.4	27.2	33.6	40.6	48.0	56.0	64.5	73.8
SOLAR UNITS	(HHW)	0.2	0.4	0.9	1.7	2.8	4.3	6.1	8.1	10.3	12.8	15.4	18.1	21.0	24.1
(000 UNITS)	(HC)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	(ALL)	0.8	2.5	5.0	8.8	13.9	20.4	27.5	35.3	43.9	53.3	63.4	74.1	85.6	97.9
PENETRATION	(HW)	0.42	0.73	1.07	1.39	1.79	2.17	2.58	2.94	3.08	3.23	3.38	3.52	3.66	3.81
RESIDENTIAL	(HHW)	0.08	0.15	0.25	0.38	0.56	0.75	0.95	1.15	1.27	1.39	1.50	1.60	1.70	1.79
(PCT)	(HC)	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	(ALL)	0.50	0.88	1.32	1.77	2.35	2.92	3.53	4.09	4.36	4.63	4.88	5.13	5.36	5.60
PENETRATION	(HW)	0.62	0.94	1.23	1.61	2.02	2.44	2.79	3.11	3.41	3.71	3.99	4.26	4.54	4.81
COMMERCIAL	(HHW)	0.14	0.19	0.28	0.39	0.51	0.66	0.79	0.92	1.05	1.17	1.28	1.38	1.48	1.57
(PCT)	(HC)	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	(ALL)	0.76	1.13	1.51	2.00	2.53	3.10	3.59	4.04	4.46	4.88	5.26	5.64	6.01	6.39
COLLECTOR	(HW)	2.2	7.2	15.1	25.6	40.4	57.9	78.6	100.8	118.2	136.8	155.9	175.8	196.1	217.6
SOLD	(HHW)	1.8	5.9	14.8	29.2	51.5	80.9	117.5	159.2	196.4	236.1	276.7	318.4	361.0	404.7
(MIL SQ FT)	(HC)	0.0	0.0	0.0	0.1	0.1	0.2	0.3	0.4	0.4	0.5	0.5	0.6	0.7	0.7
	(ALL)	4.0	13.1	29.9	54.9	92.0	139.0	196.4	260.4	315.0	373.3	433.2	494.8	557.8	623.0
PVT DOLLARS	(HW)	96.3	249.3	464.5	745.8	1099.7	1509.3	1974.1	2458.6	2924.1	3425.1	3945.6	4487.6	5047.3	5640.8
INVESTED	(HHW)	56.6	160.0	357.7	662.0	1091.8	1638.6	2297.9	3028.7	3778.4	4582.7	5410.4	6263.5	7140.1	8041.4
(MIL $ S)	(HC)	0.0	0.4	1.8	4.3	7.4	11.1	15.1	19.3	22.9	26.6	30.4	34.2	38.2	42.2
	(ALL)	152.9	409.6	824.0	1410.1	2198.9	3159.0	4287.1	5506.6	6725.3	8034.4	9386.3	10785.4	12225.6	13724.5
TOT INDUSTRY	(HW)	96.3	306.8	606.5	965.1	1424.7	1929.8	2503.1	3102.6	3569.8	4072.5	4594.8	5138.8	5700.5	6296.2
SALES	(HHW)	56.6	187.7	440.4	811.2	1336.2	1975.4	2740.7	3590.5	4344.6	5153.9	5986.7	6845.2	7727.5	8634.2
(MIL $ S)	(HC)	0.0	0.4	2.1	4.9	8.4	12.4	16.7	21.3	24.8	28.6	32.4	36.3	40.3	44.3
	(ALL)	152.9	495.0	1049.0	1781.1	2769.2	3917.6	5260.5	6714.5	7939.3	9255.0	10614.0	12020.2	13468.0	14974.7
BTU S SAVED	(HW)	0.2	0.6	1.2	2.1	3.3	4.8	6.6	8.6	10.4	12.3	14.4	16.6	18.9	21.6
GAS	(HHW)	0.0	0.1	0.5	1.2	2.2	3.7	5.7	8.1	10.3	12.9	15.6	18.6	21.8	25.2
(TRL BTU)	(HC)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	(ALL)	0.2	0.7	1.7	3.2	5.5	8.5	12.3	16.6	20.7	25.2	30.0	35.2	40.7	46.7
BTU S SAVED	(HW)	0.2	0.5	1.0	1.7	2.7	4.0	5.5	7.1	8.4	9.8	11.2	12.8	14.4	16.1
OIL	(HHW)	0.0	0.2	0.6	1.4	2.6	4.2	6.3	8.7	10.9	13.2	15.6	18.1	20.6	23.2
(TRL BTU)	(HC)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	(ALL)	0.2	0.7	1.6	3.1	5.3	8.2	11.7	15.8	19.3	23.0	26.9	30.9	35.0	39.3
BTU S SAVED	(HW)	0.2	0.7	1.5	2.5	4.0	5.7	7.7	9.9	11.5	13.2	14.9	16.6	18.4	20.3
ELECTRIC	(HHW)	0.2	0.6	1.4	2.6	4.5	6.9	9.8	13.1	16.0	18.9	22.0	25.0	28.2	31.5
(TRL BTU)	(HC)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1
	(ALL)	0.4	1.3	2.9	5.1	8.5	12.6	17.6	23.1	27.5	32.2	36.9	41.8	46.7	51.7
BTU S SAVED	(HW)	0.5	1.8	3.7	6.3	10.0	14.5	19.8	25.6	30.2	35.3	40.5	46.1	51.8	57.9
TOTAL	(HHW)	0.3	1.0	2.5	5.2	9.3	14.8	21.8	29.8	37.1	45.0	53.2	61.7	70.5	79.7
(TRL BTU)	(HC)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1
	(ALL)	0.8	2.7	6.2	11.5	19.3	29.3	41.6	55.5	67.4	80.4	95.8	107.9	122.5	137.7

TABLE I-3

SOLAR IMPACT MODEL
NATIONAL ENERGY PLAN 28 SEPT 77
GOVERNMENT COST OF INCENTIVES, REGION 11 (MIL $)

INCENTIVE		1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
TAX CREDIT RESIDENT	(HH)	0.0	57.1	83.8	77.4	102.4	93.5	108.8	115.4	0.0	0.0	0.0	0.0	0.0	0.0
	(MHH)	0.0	25.3	51.2	60.8	88.9	84.2	102.8	115.4	0.0	0.0	0.0	0.0	0.0	0.0
	(MC)	0.0	0.0	0.2	0.2	0.3	0.3	0.3	0.3	0.0	0.0	0.0	0.0	0.0	0.0
	(ALL)	0.0	82.4	135.1	138.3	191.6	177.9	211.9	231.2	0.0	0.0	0.0	0.0	0.0	0.0
TAX CREDIT COMMERCIAL	(HH)	0.0	4.2	6.2	7.0	8.2	8.3	8.7	7.2	1.7	1.8	1.9	2.0	2.2	2.3
	(MHH)	0.0	4.3	7.4	10.2	12.5	14.2	10.1	11.2	4.9	5.3	5.5	5.7	5.8	6.0
	(MC)	0.0	0.0	0.0	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	(ALL)	0.0	8.5	13.6	17.2	20.7	22.6	18.8	18.4	6.6	7.2	7.4	7.7	8.0	8.3
DIR SUBSIDY	(HH)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	(MHH)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	(MC)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	(ALL)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
LOW LOAN PRESENT VAL	(HH)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	(MHH)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	(MC)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	(ALL)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
LOW LOAN CASH FLOW	(HH)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	(MHH)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	(MC)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	(ALL)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ACCEL DEPREC PRESENT VAL	(HH)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	(MHH)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	(MC)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	(ALL)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ACCEL DEPREC CASH FLOW	(HH)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	(MHH)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	(MC)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	(ALL)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
GOVERNMENT BUILDINGS	(HH)	0.0	0.0	12.0	11.0	11.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	(MHH)	0.0	0.0	11.0	11.0	11.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	(MC)	0.0	0.0	11.0	11.0	11.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	(ALL)	0.0	0.0	34.0	33.0	33.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
R D & D	(HH)	29.0	32.0	34.0	20.0	12.0	8.0	5.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
	(MHH)	29.0	32.0	33.0	20.0	12.0	8.0	5.0	4.0	3.0	3.0	3.0	3.0	3.0	3.0
	(MC)	29.0	32.0	33.0	20.0	11.0	7.0	5.0	4.0	3.0	3.0	3.0	3.0	3.0	3.0
	(ALL)	87.0	96.0	100.0	60.0	35.0	23.0	15.0	12.0	10.0	10.0	10.0	10.0	10.0	10.0
PRESENT VAL	(HH)	29.0	93.3	135.9	115.4	133.5	109.7	120.5	126.6	5.7	5.8	5.9	6.0	6.2	6.3
TOTAL	(MHH)	29.0	61.5	102.5	101.8	124.4	106.4	117.9	130.6	7.9	8.3	8.5	8.7	8.8	9.0
	(MC)	29.0	32.1	44.2	31.3	22.4	7.4	5.4	4.4	3.0	3.0	3.0	3.0	3.0	3.0
	(ALL)	87.0	186.9	282.7	248.5	280.3	223.5	243.7	261.5	16.6	17.2	17.4	17.7	18.0	18.3
CASH FLOW TOTAL	(HH)	29.0	93.3	135.9	115.4	133.5	109.7	120.5	126.6	5.7	5.8	5.9	6.0	6.2	6.3
	(MHH)	29.0	61.5	102.5	101.8	124.4	106.4	117.9	130.6	7.9	8.3	8.5	8.7	8.8	9.0
	(MC)	29.0	32.1	44.2	31.3	22.4	7.4	5.4	4.4	3.0	3.0	3.0	3.0	3.0	3.0
	(ALL)	87.0	186.9	282.7	248.5	280.3	223.5	243.7	261.5	16.6	17.2	17.4	17.7	18.0	18.3