Toward a National Plan for the Accelerated Commercialization of Solar Energy

The Implications of a National Commitment

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Toward a National Plan for the Accelerated Commercialization of Solar Energy:

The Implications of a National Commitment

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Abstract

This report analyzes the expected benefits, costs, and implications of three levels of federal commitment and subsidy for the accelerated commercialization of solar energy. It includes estimates of potential solar use representing 16 to 23 percent of the nation's energy supply in the year 2000. Projections are based on data available as of early 1979.

Preface

This report is one of a series designed to support program planning for the accelerated commercialization of solar technologies. This work was performed for the Conservation and Solar Applications Branch of the Department of Energy (DOE). Much of this analysis was in support of the Solar Energy Domestic Policy Review or was performed subsequently to expand upon the issues raised in the latter stages of that review. However, the analysis and conclusions contained herein are wholly the responsibility of The MITRE Corporation. No acceptance or endorsement by the Department of Energy is implied.

The intention of this report and the other reports in this series is to expand upon President Carter's national goal for solar energy use by:

- providing detailed technology utilization goals on a regional basis
- assessing physical, institutional, financial, and research requirements to achieve the stated goals
- providing "growth trajectories" which may be used as check-points to assess the progression towards the stated goals

This report presents a national overview of the benefits and costs expected to result from various levels of government commitment and subsidies for solar. It provides a context for understanding how the development and implementation of solar technologies might contribute to the total U.S. energy balance, employment, national security, pollution reduction and other issues of national consequence.

Another report in this series, *Price/Demand Scenarios and Projections of Solar Utilization Under the National Energy Act,* MTR-8057, describes the macroeconomic assumptions of each of the three levels of accelerated commercialization. A third, *Guidelines for Regional Planning,* MTR-79W00385, addresses the regionally-specific benefits, costs and implications of solar technology implementation. It includes detailed data to support the Regional Solar Energy Centers in their formulation of required commercialization implementation plans.

Acknowledgments

Special thanks are due to Roger Bezdek, our Department of Energy project manager, and Jerome Rosenberg for continued daily guidance and support; Ronald Scott, DOE-Director of Solar Applications,[1] for excellent insights offered in numerous project reviews; and Conservation and Solar Applications and Energy Technology members of the DOE Commercialization working groups.

This study also benefited greatly from the assistance of other DOE contractors and MITRE subcontractors. Planning Research Corporation provided suggestions and comments in the areas of financial analysis, existing solar programs, and environmental control costs. The staff at Battelle Pacific Northwest Laboratory provided the analysis of historic incentives for conventional fuels. Dave Feasby of the Solar Energy Research Institute provided helpful suggestions. Substantive contributions were also provided by the more than 50 participants in our market sector working groups.

The MITRE project team was led by Gerald E. Bennington and Peter Spewak. Market sector analyses were performed by Marcia Bohannon, James Taul, Carol Moncrief, and Cynthia Payne (Residential and Commercial), Narasimhan Kannan, Michael Shulman, and Gena Hughitt (Industrial), Grant Miller and Marie Coluzzi (Utility), and Abu Talib and David Salo (Fuels and Biomass). Significant technical support was provided by David Boyd, John Caskey, Frank Eldridge, Gerald Price, and Felicia Williams. Dispersed electric applications were analyzed by Ruth Hartzler and Robert Gerstein with engineering support from Arnold Cherdak, Willis Jacobsen, and Richard Manley. Andrew Lawrence, Susan Rifkin, and Shyang-Lai Kung provided technical analysis in assessing environmental impacts. Kathy Rebibo coordinated the development of the macroeconomic scenarios and the integration of results across market sectors. Dyanne de Jong was responsible for administrative coordination and editorial assistance.

The authors greatly appreciate the efforts of our editor, Shirley True, and our secretarial staff, expecially Peggy Frazier, Denise McCoy, and Janeth Rowe. We are also grateful to Mary Blackwell and the staff of the Metrek Word Processing Center for their efforts in helping to produce this document.

[1]Now Chief of Solar Terrestrial Applications, Energy Systems Division, National Aeronautics and Space Administration, Washington, D.C.

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The federal government has responded to the nation's growing need for renewable energy resources with an increasing commitment to the commercialization of solar energy. The solar research, development, demonstration, and information programs and the solar subsidies encompassed by the National Energy Act (NEA) aim to ensure the availability of a broad range of commercially viable products. The National Plan for the Accelerated Commercialization of Solar Energy (NPAC) is an attempt to develop a coordinated plan for the commercialization of solar technologies.

This report analyzes the expected benefits, costs, and implications of three levels of federal commitment and subsidy for accelerated solar commercialization.[1] A Reference Case containing the current levels of financial incentives (federal and state, including those of the NEA) and nonfinancial commercialization programs (information exchange and dissemination and removal of legal and institutional barriers) was used as a basis against which to measure the effects of alternate strategies for accelerating commercialization. The three accelerated levels would result in solar contributions of about 19, 22, and 26 quads by 2000.[2]

Although this analysis preceded President Carter's setting a goal of solar's providing 20 percent of the nation's energy requirements by the year 2000, the 22-quad level of commercialization corresponds approximately to the president's goal. However, the underlying assumptions differ considerably. Most notably, the projected national gross energy demand used in this study is 115 quads, while the president's goal is based on a 95-quad energy demand.[3]

MITRE estimates were derived from analyses of solar energy technology costs and performance, market development, health and environmental impacts, and the economic costs and benefits expected from the use of solar technologies. These analyses were provided by The MITRE Corporation, Booz-Allen & Hamilton, Battelle Pacific Northwest Laboratory, Planning Research Corporation, the Solar Energy Research Institute, and a variety of support contractors.

Guides for Accelerated Solar Commercialization Planning

1. Accelerated solar commercialization will require extensive federal programs to remove economic and institutional barriers.

Economic incentives are essential to the commercialization of solar energy. R&D, institutional, and information programs alone are not sufficient to result in early commercialization. To maximize the impacts of the financial incentives, these programs should be expanded to an appropriate level. Their expansion would promote public awareness; expedite industry infrastructure development; identify labor, material, and capital resources; determine appropriate solar/utility interface alternatives; and resolve legal code, standard, and zoning issues.

2. Federal and private RD&D programs must provide commercially competitive solar technologies.

Of the solar capacity expected to be installed between 1980 and 2000, 30 to 40 percent will be provided by technologies that are not now commercially available and must be developed. Those solar technologies now commercially available also need RD&D support to reduce costs and increase reliability.

3. Establishing a solar industry and promoting a rapid transition to solar energy will require a major investment by the nation.

To triple the current solar capacity (from 4.9 quads to 14.6 quads by 2000 under the Reference Case), over $500 billion (1976 $) will be required. To achieve an annual production of about 22 quads of solar energy, an estimated cumulative public and private expenditure of over $800 billion ($1 trillion in 1978 dollars) will be required (see pages 23-25).[4] This could represent as much as 20 percent of the nation's investment capital over the next twenty years.

4. A significant solar energy contribution by the year 2000 will have major implications.

— A large and vigorous domestic industry would be established. Under the Reference Case, annual sales of solar systems in the year 2000 would amount to approximately $35 billion[5]—a greater than 150-fold increase over current solar sales. Over 50 million solar systems in residential and commercial buildings and industrial plants would supply space heat, hot water, process heat, and electricity.

— If solar energy were to supply 20 percent of the nation's energy needs in 2000, 50 percent of the homes in this country would have a solar system in one form or another. They would provide over 3.6

[1] This analysis was conducted during the fall of 1978 and completed in the spring of 1979. Unless otherwise noted, all costs are in 1976 dollars.

[2] Throughout this report, energy savings means primary fuel displaced.

[3] The 115-quad figure was derived from a scenario based on mid-priced oil ($25/bbl). The scenario was confirmed by a DOE-funded analysis by Brookhaven National Laboratory.

[4] Accounting for conventional capacity displaced and certain quantifiable benefits, the net cost would be as low as $400 billion (1976 $).

[5] Current annual sales for General Motors are approximately $63 billion.

quads of energy savings. Electric utilities would use over 4,000 large-scale systems including hydroelectric, wind, solar thermal, photovoltaic, biomass electric, and ocean thermal systems.

Numbers of solar systems for the principle solar contributors expected to be installed by the year 2000 are shown in Table S-1.

— Under the Reference Case, over 1 million persons would be employed by the turn of the century in the production of steel, glass, aluminum, copper, and concrete and the manufacture, installation, and maintenance of the solar systems. This would constitute roughly 1 percent of the labor force in the year 2000.

— Greater flexibility in energy choices would result in less risk of debilitating embargoes and improve national security (see pages 29-32). As solar energy displaces the use of imported oil, the country will be less vulnerable to the disastrous economic effects of an oil embargo. Commercialization of solar energy within the U.S. will result in the probable acceptance of the technology overseas, further decreasing the potential instabilities of an oil embargo. This should lead to improved national security, allowing the nation to enjoy greater flexibility in the design of foreign policies.

5. Significant solar energy savings by the year 2000 are expected from residential and commercial thermal systems, thermal and biomass process heat systems, thermal and wind electric systems, and hydroelectric generators (see Table S-II).

Initially, energy savings would be provided by solar hot water and space heating in buildings, wood stoves, solar- and biomass-generated industrial process heat, and hydroelectric generators. These technologies are expected to save up to 5.8 quads per year by 1985 under the Reference Case.

6. The utilization of solar technologies will vary greatly from region to region due to variations in regional demands, resource availability, and the price of conventional fuels.

Energy saved by solar technologies is generally expected to be greatest in southern and western regions. Projections of the regional use of solar energy (based on the nine U.S. Census Regions of Figure S-1) are shown in Table S-III.

7. Subsidies for conventional energy sources, government regulations, and energy pricing policies have made it difficult for solar energy technologies to compete in the marketplace.

Average historical subsidies for all energy technologies amount to $.15 per MMBTU (1976 $).[1] Average historical subsidies for nuclear energy amount to about $1.90 per MMBTU. The net effect of these energy subsidies has been to reduce the prices of the conventional fuels against which solar energy must compete. In addition, the consumer faces average rather than marginal prices for other energy sources but must pay the marginal price for solar energy. Since solar costs are primarily capital costs, they cannot be expensed in the same manner as conventional fuels which, therefore, enjoy a lower effective price than solar.

8. The mix of solar technologies and the proportion of solar in each market sector are expected to change little with increased equivalent subsidies for all technologies.

If across-the-board subsidies for all technologies are increased, the proportion and mix of technologies will remain about the same as long as the marketplace is free to select the most appropriate and cost-effective solar technology for an application.

[1] B. Cone et al., "Long Term Solar Parity Considerations Based on an Analysis of Incentives to Energy Production," Battelle Pacific Northwest Laboratory, Nov. 1978.

Table S-I
Number of Solar Systems Installed by the Year 2000

Market Sector/Application	Average Size	Number of Systems: Reference Case	19 Quads	22 Quads	20 Quads
Residential					
Hot Water	50 Sq. Ft.	25,600,000	31,600,000	33,600,000	35,700,000
Water, Heating & Cooling	240 Sq. Ft.	7,700,000	10,300,000	13,300,000	18,400,000
Passive	300 Sq. Ft.	4,900,000	6,800,000	7,600,000	9,900,000
Commercial					
Hot Water	175 Sq. Ft.	810,000	870,000	880,000	880,000
Water, Heating & Cooling	1,900 Sq. Ft.	980,000	1,110,000	1,230,000	1,330,000
Passive	18,000 Sq. Ft.	130,000	140,000	144,000	150,000
Industrial					
Thermal	100,000 Sq. Ft.	41,000	50,600	63,300	99,100
Biomass	1,000 Tons per Day	410	600	700	750
Utilities					
Wind	100 MWe Array	360	540	670	730
Hydroelectric	50 MWe	1,740	1,780	1,820	1,890
Solar Thermal	100 MWe	280	550	710	810

Table S-II
Annual Energy Savings by Market Sector and Technology in the Year 2000
(Quads of Primary Fuel Displaced)

			Level of Commercialization							
			Reference Case		19 Quads/Yr Scenario		22 Quads/Yr Scenario		26 Quads/Yr Scenario	
Sector	Sector Demand (Quads/Year[1])	Technology	Quads	Percent of Total Solar	Quads	Percent of Total Solar	Quads	Percent of Total Solar	Quads	Percent of Total Solar
Residential	20.3	Thermal	1.1	7.5	1.5	8.0	1.8	8.0	2.3	8.8
		Passive	0.2	1.4	0.3	1.6	0.3	1.3	0.4	1.5
		Wind	0.3	2.0	0.4	2.1	0.5	2.2	0.6	2.3
		Photovoltaics	0.2	1.4	0.3	1.6	0.3	1.3	0.4	1.5
		Wood Stoves[2]	0.6	4.1	0.7	3.7	0.8	3.6	0.9	3.5
Commercial	18.0	Thermal	0.7	4.8	0.8	4.3	0.9	4.0	1.0	3.8
		Passive	*	—	*	—	*	—	*	—
		Wind	*	—	*	—	*	—	*	—
		Photovoltaics	*	—	*	—	*	—	0.1	0.4
Industrial	55.0	Solar Thermal	2.2	15.0	2.5	13.3	3.2	14.2	4.0	15.4
		Biomass[2]	2.2	15.0	3.2	17.0	3.7	16.4	4.0	15.4
		Photovoltaics	*	—	*	—	*	—	*	—
		Wind	0.1	0.7	0.1	0.5	0.1	0.4	0.1	0.4
		Solar Thermal Electric	*	—	*	—	*	—	*	—
		Solar Total Energy Systems	*	—	0.1	0.5	0.1	0.4	0.2	0.8
		Small-Scale Hydroelectric	0.2	1.4	0.2	1.1	0.3	1.3	0.4	1.5
Electric Utility	49.0	Wind	1.3	8.8	2.0	10.6	2.5	11.1	2.8	10.8
		Solar Thermal	1.0	6.8	1.6	8.5	2.0	8.9	2.2	8.5
		Photovoltaics	*	—	0.3	1.6	0.5	2.2	0.6	2.3
		Ocean Thermal	0.1	0.7	0.2	1.1	0.3	1.3	0.4	1.5
		Biomass Electric	*	—	0.1	0.5	0.2	0.9	0.3	1.2
		Hydroelectric[3]	3.8	25.9	3.9	20.7	4.0	17.8	4.2	16.2
Synthetic Fuels and Chemicals	4.4	Wood	0.5	3.4	0.4	2.1	0.7	3.1	0.8	3.8
		Animal Waste	0.2	1.4	0.2	1.1	0.3	1.3	0.3	1.2
		Total**	14.7	(13)	18.8	(16)	22.5	(20)	26.0	(23)
		Incremental Over Reference Case	0		4.2		7.9		11.4	
		Incremental Over Current Level	9.8		13.9		17.6		21.1	

[1]Includes fossil fuel equivalent of end use electricity demand as well as demand of energy for generation. Thus, there is double accounting of intermediate fuels and energy produced from those fuels. Actual gross demand is 115 quads.
[2]Includes current use of 0.3 quads of biomass in the residential sector and 1.6 quads in the industrial sector.
[3]Includes 3.0 quads current use.
*Less than 0.1 quads.
**Numbers in parenthesis represent percent of projected national gross energy demand.

Figure S-1
U.S. Census Regions

9. In some cases, solar development will result in short-term increases in environmental pollution.

The production of energy from solar technologies is generally an environmentally benign process. However, solar technologies tend to be capital- and materials-intensive. The mining and manufacturing activities to support the manufacturing of solar systems can actually lead to short-term increases in environmental pollutants. By the year 2000, solar savings from increased wood burning, biomass farming, and mining and manufacturing activities are expected to result in slight increases of total suspended particles (TSP) in air and total suspended solids (TSS) in water. However, significant decreases are expected to result in carbon dioxide (CO_2), industrial sludge, sulphur oxides (SO_x), and nitrous oxides (NO_x) due to solar displacement of the use of fossil fuels (see pages 30-32). These trends continue as energy savings grow beyond the Reference Case.

10. Subsidizing solar energy may cost the federal government—primarily in revenues lost to tax credits—at least $10 billion to $180 billion (1976 $) by the year 2000,[1] depending on the level of solar commercialization achieved.

The primary federal costs will be to: (a) offset the higher capital costs for solar compared to conventional fuels and (b) reflect potential economic benefits and the subsidy levels of conventional fuels on a continuing basis (parity). If the federal government takes a more active role in solar energy production and purchase due to lags in solar technology developments, economic competitiveness, and public commitment, federal costs may be higher (see page 23).

Energy Savings Under the Reference Case

Under the NEA—and assuming that the current commitments to market-ready solar technologies will be extended to other solar technologies as they become available—it may be possible to almost triple the current level of solar energy use within twenty years (see Figure S-2). This would increase the energy saved by the solar contribution from the present level of 4.9 quads to 14.6 quads by 2000.

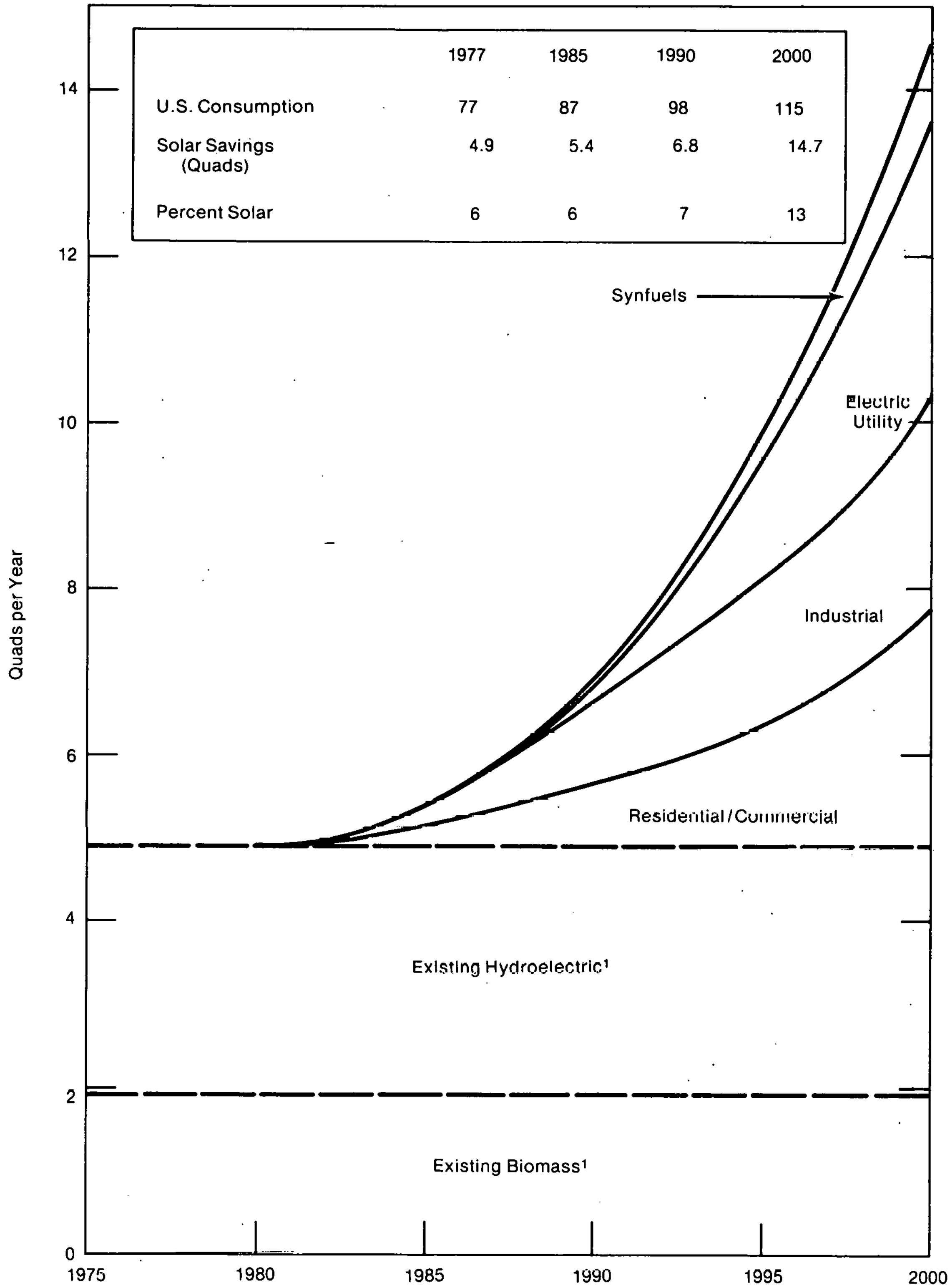
Significant energy savings would begin around 1985 and escalate rapidly through the turn of the century (see Figure S-3 and Table S-IV). Near-term

[2]The *Final Report of the Impacts Panel* (DPR) notes that the extra costs incurred over the nonsolar base case range from $61.5 billion for the solar base case to $180.4 billion for the solar maximum practical case. The maximum practical case is equivalent to the president's 20 percent goal.

Table S-III
Regional Solar Energy Savings in the Year 2000

		Energy Savings (Quads of fossil fuel equivalent)							
		Reference Case		19 Quads/Yr Scenario		22 Quads/Yr Scenario		26 Quads/Yr Scenario	
Regional Solar Energy Center	Census Region	Quads	Percent of Total Solar	Quads	Percent of Total Solar	Quads	Percent of Total Solar	Quads	Percent of Total Solar
Northeastern	New England	.6	4.1	.7	3.7	.9	4.0	1.0	3.8
	Mid Atlantic	1.5	10.2	1.9	10.1	2.3	10.2	2.6	10.0
Southeastern	South Atlantic	2.3	15.6	3.3	17.6	4.0	17.8	4.8	18.5
	South East Central	1.3	8.8	1.7	9.0	2.1	9.3	2.4	9.2
	South West Central	2.0	13.6	2.3	12.2	2.8	12.4	3.3	12.7
Mid America	North East Central	1.5	10.2	2.2	11.7	2.9	12.9	3.5	13.5
	North West Central	.8	5.4	1.0	5.3	1.3	5.8	1.4	5.4
Western Sun	Mountain	1.2	8.2	1.4	7.4	1.6	7.1	1.7	6.5
	Pacific[1]	3.6	24.5	4.3	22.9	4.7	20.9	5.3	20.4
Total[2]		14.7	(13)[3]	18.8	(16)	22.5	(20)	26.0	(23)

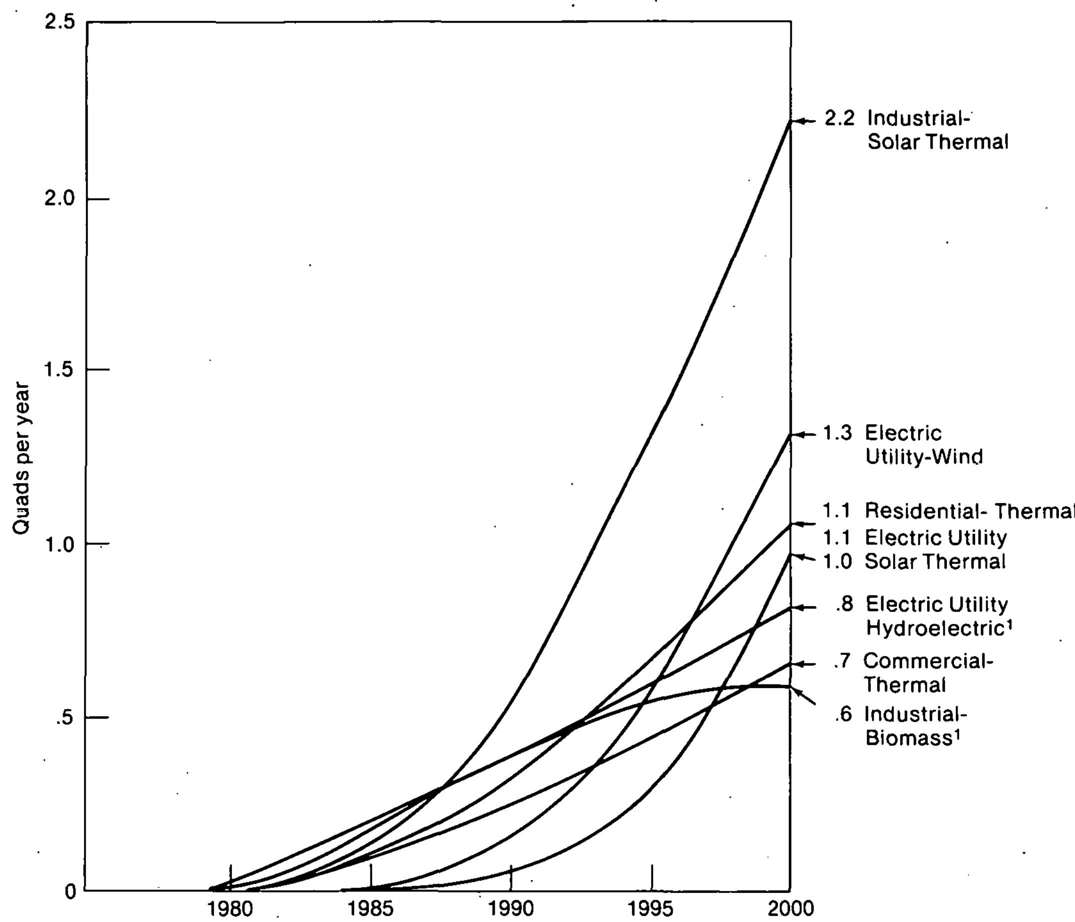
[1]The large solar energy production here is due primarily to hydroelectric production, much of which is in existence today.
[2]Columns may not add due to round off conventions.
[3]Numbers in parenthesis represent percent of projected national gross energy demand (115 Quads).



	1977	1985	1990	2000
U.S. Consumption	77	87	98	115
Solar Savings (Quads)	4.9	5.4	6.8	14.7
Percent Solar	6	6	7	13

Note: Throughout this report energy savings means primary fuel displaced.
[1]Hydroelectric energy savings are 3.0 quads and biomass energy savings are 1.9 quads.

Figure S-2
Growth of Annual Energy Savings by Market Sector—Reference Case



[1]*Existing industrial biomass (1.6 quads) and hydroelectric (3.0 quads) are not included.*

Figure S-3
Growth of Annual Energy Savings by Major Solar Technologies—Reference Case

(1985) energy savings would result from solar hot water and space heating systems in the residential and commercial sectors (0.25 quads), solar industrial process heat used as fuel savers to existing systems (0.13 quads), and an additional 0.2 quads each for industrial biomass and hydroelectric power.

By 1990, active solar thermal systems for buildings are expected to save about 0.6 quads annually. Another 0.4 quads of savings from wood stoves and 0.05 quads from small-scale wind and passive solar buildings designs are expected. In the industrial sector, solar process heat systems would contribute 0.5 quads and biomass utilization for process heat would increase by about 0.4 quads over the 1.6 quads currently used. Central electric utility solar technologies begin to come on line around 1986. Large-scale wind machines used in fuel- and water-saver modes are expected to save about 0.15 quads by 1990 and solar thermal repowering systems[1] about 0.05 quads. Hydroelectric utilization, including small-scale systems (less than 15 MWe) at existing dams, would increase by 0.4 quads over the present level of 3.0 quads. The total solar contribution is, therefore, expected to be somewhat less than 2.4 quads by 1990 over the present level of use.

By the turn of the century, about 9.6 quads of additional savings may be expected from solar technologies. The major contributors would be active direct thermal systems for buildings (1.7 quads), wood stoves (an additional 0.3 quads over the 1978 level), residential wind systems (0.3 quads), passive building designs (0.2 quads), solar process heat (2.2 quads), new biomass process heat (an additional 0.6 quads over the 1978 level), utility-size wind machines (1.3 quads), ocean thermal energy conversion (0.1 quads), new hydroelectric (1.0 quads) synthetic fuels and chemicals from wood biomass (0.5 quads), and methane from animal waste (0.2 quads).

Barriers to Solar Commercialization

Any level of accelerated commercialization will re-

[1]Solar thermal repowering involves the retrofit of existing oil- and gas-fired steam plants in areas of high insolation with the solar thermal central receiver system.

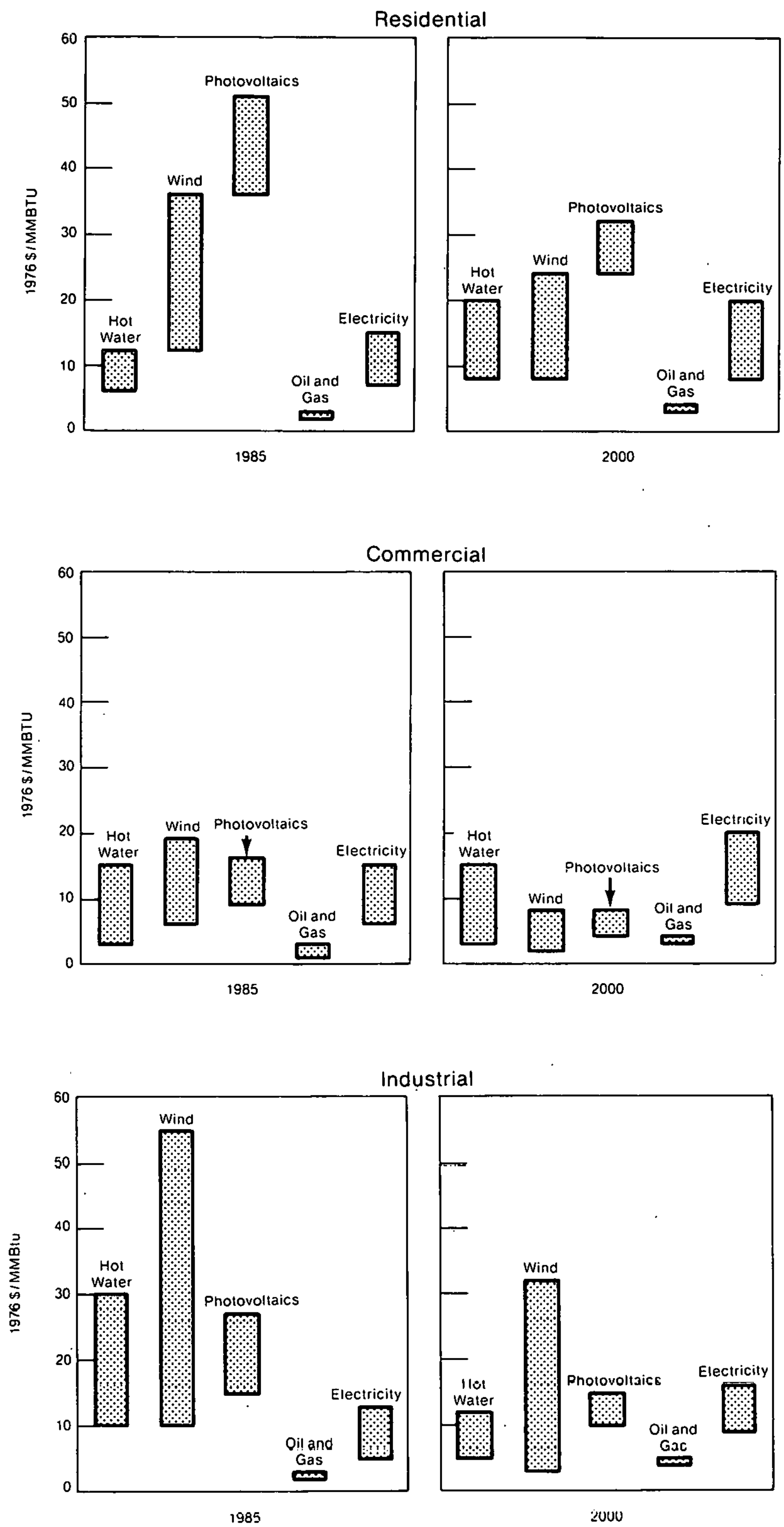
Table S-IV
Annual Energy Savings by Technology
(Quads of Primary Fuel Displaced)

Sector	Technology	1978	1985	1990	2000
Residential	Thermal	—	0.13	.31	1.06
	Passive	—	0.01	.04	0.20
	Wind	—	—	0.05	0.31
	Photovoltaics	—	—	0.02	0.18
	Wood Stoves	0.30	0.40	0.47	0.60
Commercial	Thermal	—	0.12	0.27	0.66
	Passive	—	—	0.01	0.02
	Wind	—	—	—	0.02
	Photovoltaics	—	—	—	0.03
Industrial	Solar Thermal	—	0.13	0.50	2.18
	Biomass	1.60	1.80	2.00	2.20
	Wind	—	—	—	0.05
	Photovoltaics	—	—	—	0.03
	Thermal Electric	—	—	—	0.02
	Total Energy	—	—	—	0.01
	Small Scale Hydro.	—	—	—	0.15
Electric Utility	Wind	—	—	0.15	1.32
	Solar Thermal	—	—	0.05	0.06
	Photovoltaics	—	—	—	0.01
	Ocean Thermal	—	—	—	0.10
	Biomass Electric	—	—	0.01	0.03
	Hydro.	3.00	3.20	3.40	3.80
Synthetic Fuels and Chemicals	Wood	—	—	—	.0.45
	Animal Waste	—	—	—	0.20
Total		4.90	5.79	7.28	14.59

Source: Kathy K. Rebibo, Toward a National Plan for the Commercialization of Solar Energy: Price/Demand Scenarios and Projections of Solar Utilization Under the National Energy Act, The MITRE Corporation, MTR-8057, 1979.

quire that solar technologies be successfully developed and actively marketed by industry (and government, as appropriate). This will not be an easy achievement. Inflation and uncertainties in foreign energy supplies and domestic energy policy make it hard for both industry and the public to judge the role solar energy may play in the solution of energy-related problems.

Solar energy development is further handicapped by the unique economic and institutional characteristics of the current solar market. In the past, new energy sources have offered the public a cost-effective alternative with clear advantages over prevailing energy sources. However, solar energy systems usually require higher capital costs than conventional energy alternatives. Further, the economic merits of solar are not immediately apparent and are difficult to project. Consumers must be willing to trade off the higher initial costs of solar technologies against expected future energy savings. This situation is exacerbated by the inequitable tax treatment that solar has received relative to conventional energy sources. The NEA financial incentives are intended to provide some reduction of the economic barriers facing commercially available solar technologies over the next five years. But these incentives may not be sufficient to make most solar systems competitive now, and when incentives expire in 1984, solar systems are expected to suffer price disadvantages compared to federally-subsidized conventional fuels. Price regulation, average pricing policies, and expensing allowances that affect conventional fuels favorably also give conventional fuels actual or perceived price advantages relative to solar. Figure S-4 compares expected delivered energy costs for selected technologies and conventional fuels in the years 1985 and 2000.



Note: Shaded areas represent ranges of expected prices.

Figure S-4
Comparative Cost of Delivered Energy

The federal government has responded to the nation's growing need for renewable energy resources with an increasing commitment to help develop and commercialize solar energy technologies. The Domestic Policy Review on Solar Energy (DPR) during the summer of 1978, the appointment of Solar Resource Managers within DOE, the establishment of Regional Solar Energy Centers (RSECs), and the rapid growth of the Solar Energy Research Institute (SERI) reflect this commitment.

As a result of the DPR, the administration has set a goal of solar technologies' providing 20 percent of the nation's energy by the year 2000. The effective coordination of solar commercialization activities requires policy direction and consistent guidelines for implementation. The DPR will provide the policy direction and the National Plan for the Accelerated Commercialization of Solar Energy (NPAC), ordered by Congress in P.L. 94-385, will provide an initial set of implementation guidelines. This report represents the initial phases of the planning process to achieve the solar utilization goal.

Since this analysis preceded the determination of a solar goal by the administration, a range of goals was analyzed as a function of various levels of federal financial incentives. Detailed regional and technology market projections resulted. In the first phases of accelerated commercialization, these projections can provide a framework for regional and programmatic emphasis. Further analysis of the projections can yield requirements, rates of growth, and impacts related to varying levels of accelerated solar commercialization.

Specific commercialization program requirements will be determined using the collective data base and the experience of the four RSECs and other federal agencies that have been involved in commercialization planning and programs. State and local governments, SERI, private industry, the public, and federal contractors are also expected to provide valuable contributions and experience.

The Energy Technology Offices of DOE have solar technology development plans which provide reasonable expectations of commercial readiness. Solar Resource Managers can provide the initial technology-specific implementation program elements required to meet programmatic requirements. The four RSECs are developing regionally-specific data bases and experience invaluable to the development of regional commercialization implementation strategies. SERI can provide monitoring and policy analyses, and the DPR can provide guidelines for federal policies.

Under a continuing NPAC process, progress towards the objectives and industrial/market response can be continuously monitored and evaluated. Based on this evaluation, programmatic requirements can be continuously revised and updated.

The Metrek analysis is based on projections of solar technology market penetrations and associated impacts. They were developed from computer market penetration models (Rebibo, 1977) which stimulate on a year-by-year basis market decisions to purchase solar and conventional technologies in each market sector to satisfy an assumed energy demand. An extensive data base in conjunction with these models includes estimates (current and future) of:

- size of the potential market
- solar technology costs and expected cost reductions (experience curves)
- competing technology costs
- regional fuel prices
- mix of competing fuels
- regional climate data
- "suitability" (orientation of existing buildings, land availability, etc.)
- energy load profiles
- market lags reflecting initial resistance to new technologies

There is greater uncertainty in the projections of a single case than in the relative difference between the cases. Variations in market penetration projections under varying assumptions should be considered more valid than absolute numbers of a single scenario.

Assumptions of future fuel prices and the demand for energy are important factors in the projections of solar utilization. In this analysis, it is assumed that the delivered price of oil (to the industrial sector) reaches $25 per barrel (1976 $) in the year 2000. U.S. energy consumption is expected to reach 115 quads (quadrillion BTUs) in 2000. A full description of the macro-economic assumptions can be found in MITRE's Report, *Toward a National Plan for the Commercialization of Solar Energy—Price/Demand Scenarios and Projections of Solar Utilization Under the National Energy Act.*

Additional models were used in assessing environmental, health and economic impacts of solar technology market penetration. The Strategic Environmental Assessment System (SEAS) provided national and regional levels of environmental pollutants for varying levels of solar market penetration. A model developed by Resources for the Future determined health impacts and economic damages associated with the estimated pollution levels projected by SEAS. The INFORM model, a part of SEAS, determined other economic consequences of solar technology market penetration.

The effects of accelerated levels of commercialization were measured against a Reference Case based on the financial incentives in the National Energy Act. The Reference Case projected an annual energy savings from solar technologies in the year 2000 of about 15 quads.[1] This includes 4.9 quads of hydroelectric and biomass combustion currently in place.

The Reference Case is a success-oriented scenario based on the following premises:

- Current technology development programs are successful, program costs are met, and technologies are commercially available by the date shown in Table II-I (Column 3, Estimated Market Availability).
- Industry is willing to produce and market the systems in a timely fashion.
- Existing federal and state financial incentives and barrier removal programs, including those of the recently enacted National Energy Act, are effectively implemented. The federal energy tax credits that apply to solar technologies are summarized in Table II-I (Column 4, Investment Tax Credit).
- Nonfinancial commercialization programs directed toward obtaining public visibility, information exchange and dissemination, and the removal of legal and institutional barriers are implied in the solar market acceptance. Such programs currently exist for commercially available solar technologies; projections of impacts for the Reference Case assume that the current level of nonfinancial commercialization programs will be extended to each technology as it matures. Accelerated commercialization implies additional tax or other major financial incentives and even more aggressive programs to handle the nonfinancial problems. These nonfinancial problems include product definition, perceived risk by consumers, solar/utility interface, restrictive codes, covenants and zoning, land acquisition and environmental restrictions (for large utility and biomass fuel applications), and acceptance by and integration within existing industry infrastructures.
- The market acceptance of solar technologies is based on the competitive economic position of the technologies tempered by a market lag function. This market lag function (logit or S-shaped curve) is derived from historical data on the rate of acceptance of new energy technologies. Thus, it is assumed that the initial market reluctance to accept new solar technologies will be overcome at a rate similar to that of emerging energy technologies in the past.

In essence, the Reference Case assumes successful commercialization of solar technologies at a rate consistent with that of other emerging technologies in the past. Central to this scenario, as well as to the accelerated scenarios later discussed, is the assumption that the capital costs of solar systems will decrease in real dollars over time. It is further assumed that potential solar users will respond positively to the increasingly favorable economics, thus creating a demand for solar systems. Industry, then, will respond positively to the perceived demand and will actively develop the required infrastructure to market, manufacture, install, service, and warranty solar systems. Other participants such as financiers, code officials, government officials, and utility executives will also take measures to alleviate the other institutional, financial, and technical barriers impeding the use of solar. Although federal actions may be implemented to accelerate infrastructure development and remove barriers, in the absence of mandatory solar utilization, it is assumed that system cost will be the primary determinant of the rate of solar acceptance.

In this analysis, solar system capital costs decrease over time due to product development, automation, learning, materials substitution, and continued technology development. Capital costs per million BTUs per year of energy produced are shown in Figure II-1 for individual solar technologies and conventional alternatives. Solar costs are derived through time as a function of cumulative production, scale, and annual production capacity. In each case, the costs decline, in real dollars, from the current cost to an ultimate mass production cost. In determining ultimate costs, system costs were broken down by component. System components subject to cost decreases such as collectors, photovoltaic arrays, heliostats, and wind machines were analyzed in terms of material, fabrication, and installation costs which would be associated with the anticipated ultimate designs. Costs associated with system components currently mass-produced or commonly available (support structures, pumps, piping, inverters, etc.) were held relatively constant depending upon whether or not further development work is anticipated to decrease their costs. The capital cost per unit of energy produced is further enhanced by improved performance resulting from research and development. In most cases, MITRE cost/performance estimates were used (Bennington et al., 1976 and Curto et al., 1979). When available, detailed cost/price analyses of other DOE contractors were used. The McDonnell Douglas study of mass-produced, high-performance heliostats for solar thermal central receiver applications is an example. Their

[1] Throughout this report, energy savings from solar refers to primary fuel displaced.

Table II-I
Current Status of Solar Commercialization

Solar Technology	Market Sector	Market Availability	Current Federal Commercialization Activities					Current Market Status
			Investment Tax Credit	R&D	Demonstrations	Federal Buys	Barrier Removal Programs	
Solar Thermal								
Electrical Applications	Industrial	1983	—	X	X			No current market.
	Residential	1983	—	X	X	X		
	Commercial	1983	—	X	X	X		
	Utility	1986	—	X	X			
Low Temperature	Residential	1976	30%-20% $2,200 total to 1985		X	X	X	60,000 heating and hot water systems installed. Large merchandising operations (e.g., Sears) have entered the market. National and regional advertising efforts have increased dramatically since passage of NEA. Systems are moving closer to packaged, modularized systems.
	Commercial	1976	10% to 1982		X	X	X	
	Industrial	1976	10% to 1982		X		X	Large numbers of low-temperature, agricultural systems. No privately funded medium- or high-temperature systems have been built. Several large corporations (e.g., McDonnell Douglas) actively pursuing the market.
Cooling	Residential	1990	—	X	X		X	Absorption air-conditioning systems in commercial solar applications have been demonstrated, as well as residential solar-assisted heat pumps. Appropriate sizing of residential systems is being studied, along with compatibility of cooling and heating systems in packaged designs. Additional design work is required.
	Commercial	1990	—	X	X	X	X	
High Temperature	Industrial	1983	—	X	X		X	No current market for high-temperature process heat applications.
Passive	Residential	1976	30%-20% $2,200 Total to 1985	X	X		X	Early stages; expertise varies greatly by region. Roughly 100 A&E firms advertise their passive capabilities. Widespread A&E industry interest in passive as near-term solar potential. Technology not well developed or standardized.
	Commercial	1976	—	X	X		X	

Table II-I (Continued)
Current Status of Solar Commercialization

Solar Technology	Market Sector	Market Availability	Current Federal Commercialization Activities: Investment Tax Credit	R&D	Demonstrations	Federal Buys	Barrier Removal Programs	Current Market Status
Wind	Residential	1980	30%-20% $2,200 Total to 1985				X	Between 30 and 40 manufacturers, including foreign firms. Approximately 150,000 water pumping and 1,000 electrical generation systems presently installed, mostly small-scale systems. Federal demonstration program provides a guaranteed market for large (1-2 MW) system manufacturers. NEA incentives are expected to stimulate the market for small scale systems.
	Commercial	1980	10% to 1982				X	
	Industrial	1980	10% to 1982		X		X	
	Utility	1983	—		X		X	
Ocean Thermal	Utility	1995	—	X				No current market for ocean thermal energy conversion systems.
Photovoltaics	Residential	1985	30-20% $2,200	X	X			Single crystal silicon is the only commercially viable product. Limited market for remote and extraterrestrial applications. No major production facility investments. 1977 sales were 700 KW, or $10 million dollars. The federal photovoltaics program of $1.6 billion through 1988 includes a guaranteed federal market.
	Commercial	1985	10% to 1982	X	X	X		
	Industrial	1980	10% to 1982	X	X	X		
	Utility	1990	—	X	X	X		
Biomass	Industrial	—	10% to 1982					After hydroelectric, biomass is the single largest use of solar energy in the U.S., roughly 1.9 quads in 1977. Biomass utilization is constrained more by supply than by demand in the long run. Almost all utilization occurs in pulp and paper industry. Burlington, Vt. first electric utility to burn wood chips. Pullman Corp. operating two wood chip plants. Biomass combustion is a mature technology. Approximately 0.3 quads are utilized today for residential space heating.
	Residential	—	—					
	Commercial	—	—					
	Utility	—	—	X	X			
	Synfuels	1990	—	X	X			No current market for conversion to synthetic fuels and chemicals.

Table II-I (Concluded)
Current Status of Solar Commercialization

Solar Technology	Market Sector	Market Availability	Current Federal Commercialization Activities					Current Market Status
			Investment Tax Credit	R&D	Demonstrations	Federal Buys	Barrier Removal Programs	
Hydroelectric	Industrial	—	10% to 1982				X	Mature industry with about 3.0 quads of annual energy savings. Federal focus on small-scale (less than 15 MW) applications that have been either abandoned or left undeveloped.
	Utility	1976	—				X	

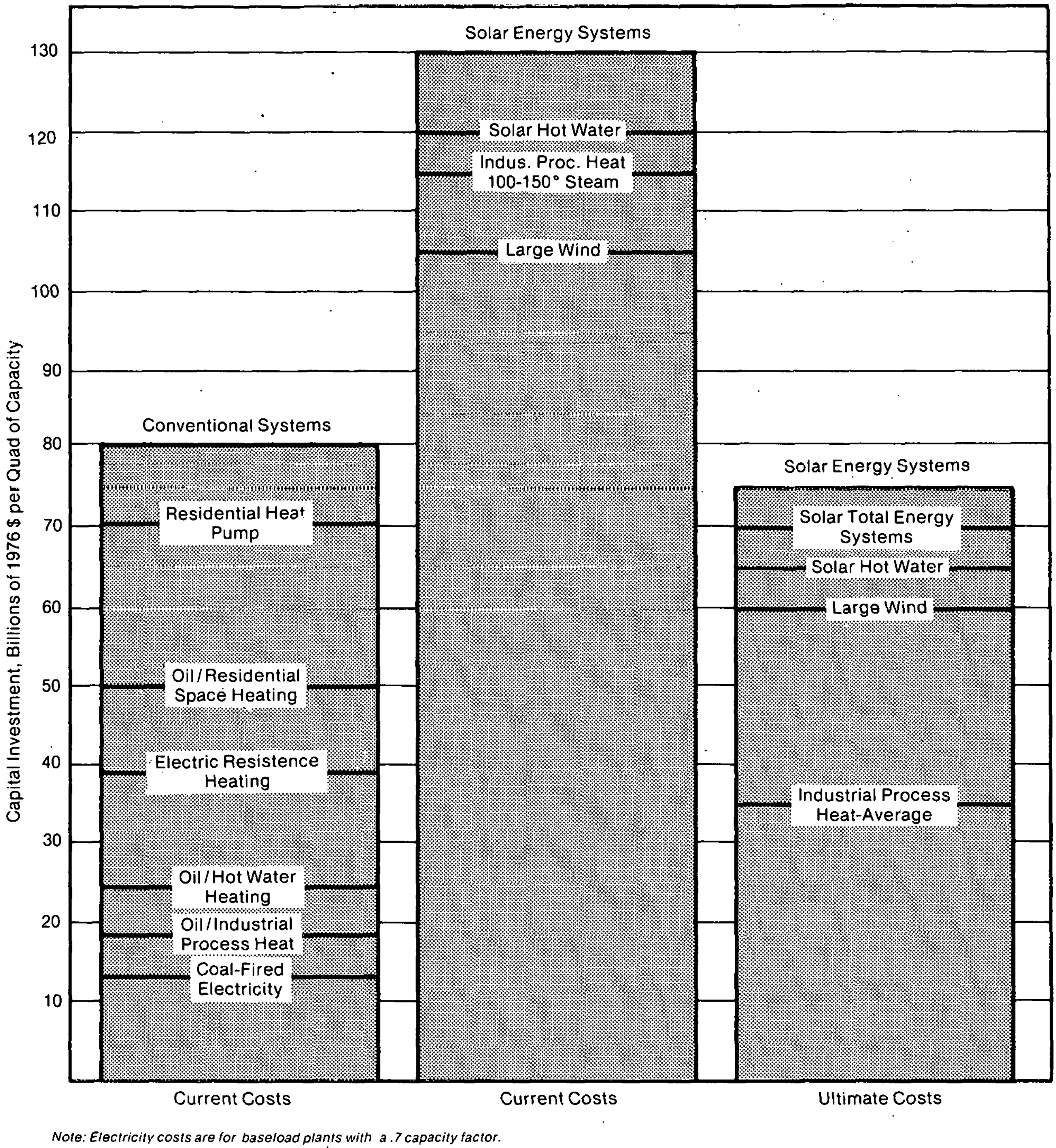
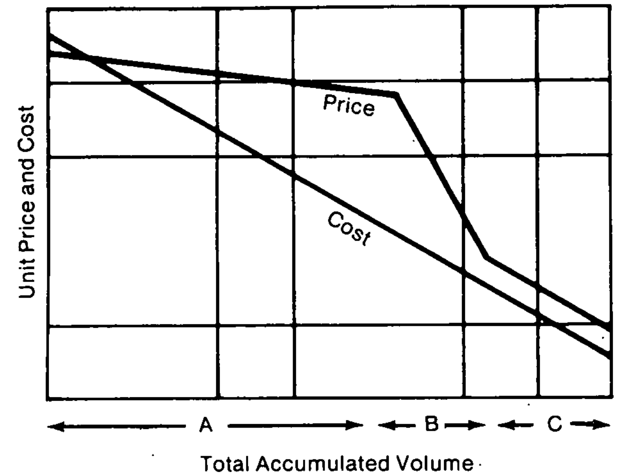


Figure II-1
Capital Costs per Quad of Capacity: Dispersed Solar Applications Compared to Conventional Fuels

study included prototype testing; materials and component testing; time-and-motion studies; pilot, early commercial, and ultimate production plant design; estimates of optimal level of repair criteria for O&M; design and evaluation of washing equipment; handling equipment and robotics for manufacturing equipment; and formulation of detailed cost estimates as a function of production volume and history. As a result of this analysis, it is expected that heliostat costs will decrease 80 percent from pilot production (2,500 units) to ultimate mass production (1,000,000 units per year, 10,000,000 units cumulative production). The cost decrease from $11,794 per heliostat ($22.33/square foot) to $2,322 per heliostat ($4.39/square foot) represents a reduction, in 1976 dollars, of $2,784 in labor, $2,728 in materials, and $3,960 in tooling write-offs.

Using the McDonnell Douglas estimates of heliostat price reductions, MITRE estimated costs and performance of an initial and ultimate central receiver industrial process heat facility. As shown in Figure II-2, most of the cost reductions are in the heliostats.

The estimates provided in this analysis should be considered as minimum potential costs. No attempt has been made to track the effects of competition on price and/or the expected profit margins that producers will require. The McDonnell Douglas estimates assume a constant 16 percent profit margin in estimating the price of heliostats. In many cases, price is held relatively constant as costs decrease or prices decrease parallel to cost, thus allowing an increasing percentage in profit margin as production increases as shown in Figures II-3a and II-3b. Even in those cases where prices decrease at a rate faster than cost (such as in Phase B of Figure II-3a) in a strategy of preemptive pricing, prices usually level off at reasonable levels and parallel costs. Figure II-3a is usually characteristic of a competitive market and Figure II-3b is characteristic of a strategy to discourage entry of new competitors by a dominant producer. Thus, while costs may be estimated with some certainty through engineering analyses, prices are uncertain due to ambiguities related to the future characteristics of the market.



Source: "Experience Curves as a Planning Tool," Patrick Conley, IEEE Spectrum, June 1970.

Figure II-3a
A Characteristic Pattern of Costs and Prices

There are further uncertainties involved in estimating the capital investment in total systems. Even in the construction of well-understood processes, uncertainties related to specific sites, availability and cost of labor, delivery schedules for

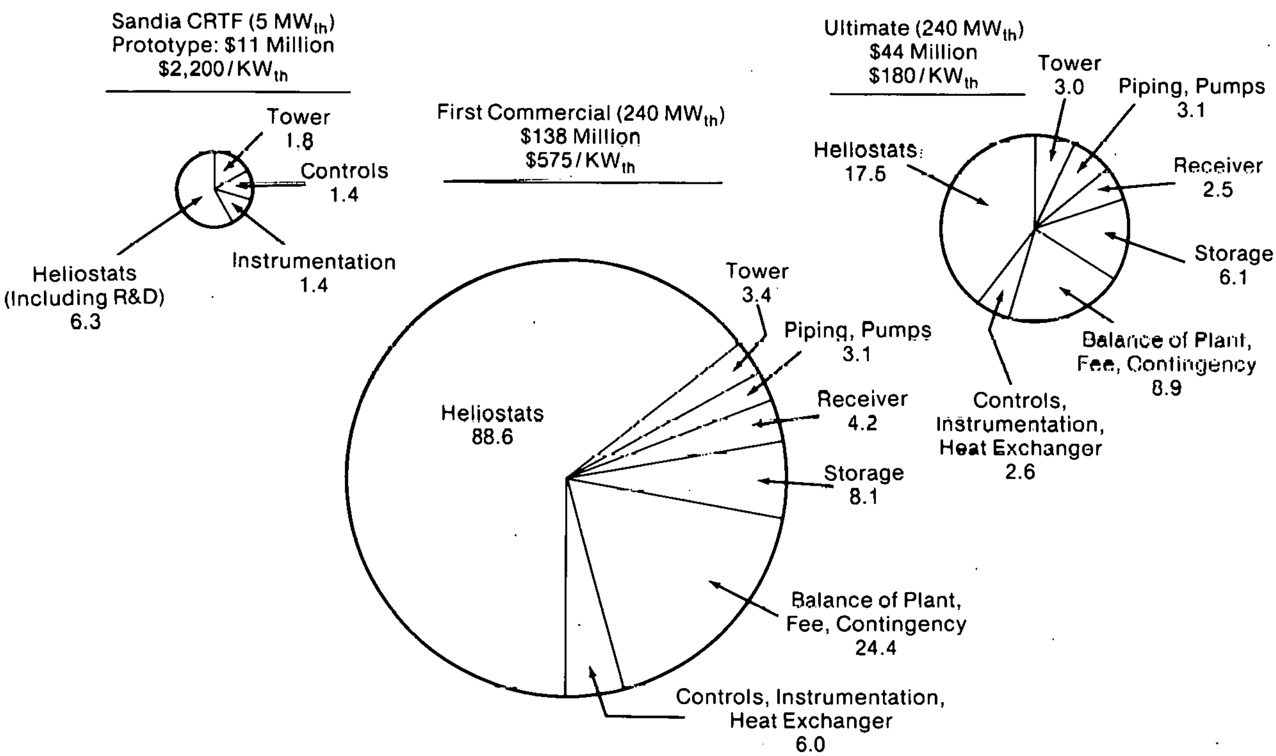
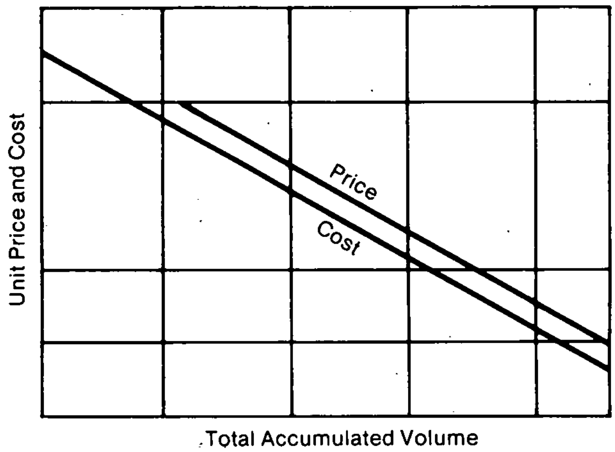


Figure II-2
Central Receiver System Costs, 1976 Dollars



Source: "Experience Curves as a Planning Tool," Patrick Conley, IEEE Spectrum, June. 1970.

Figure II-3b
An Alternative Pattern of Costs and Prices

components, weather, etc. all cause deviations from the original estimate. In the case of many solar technologies, systems have not yet been built around them and there is a lack of knowledge as to the practical issues of construction. Generally, the ability to estimate plant investment improves as the technology or process becomes better understood. However, construction estimates also tend to increase as the scheduled construction date nears. This phenomenon is apparent in active solar flat plate heating systems. In 1970, $2/square foot was a commonly accepted figure for active solar space heating systems (Tybout and Lof, 1970). In 1976, $20/square foot was a commonly accepted cost figure (Bennington et al., 1976). Current costs of $29/square foot to $48/square foot are consistent with actual system costs (Hirshberg and Hartman, 1979). In constant 1976 dollars, active solar space heating system costs have increased by more than a factor of 10 since 1970 and have increased by a factor of 1.6 to 1.8 since 1975. So, while recent engineering analyses may accurately estimate the price of future solar systems, it is highly possible that trends, biases, and unforeseen costs may cause these estimates to be increased significantly.

Inflation is responsible for further uncertainties in projecting solar system costs. In this study, costs were analyzed on a constant dollar basis, implying that there is no differential effect on solar by inflation relative to conventional technology system costs. Although this may be the case, the possibility exists that inflation may have differential cost impacts which may or may not favor the solar technologies. These differential cost impacts would likely result from differing labor and material mixes between solar and conventional technologies. Residential and commercial applications of solar as components of new buildings may more closely track construction and real estate escalation rates which are generally higher than GNP inflation rates.

As previously stated, the Reference Case represents a success-oriented scenario for solar development. If all current and proposed actions are successful, it would be reasonable to assume that solar system costs and prices would be reduced significantly. However, even within a success orientation, it is difficult to say with certainty how much and how fast solar prices will decrease. In this analysis, an attempt was made to treat prices consistently throughout all the cases examined.

National Impacts of Accelerated Commercialization

Achieving the administration's ambitious goal of solar technologies' providing 20 percent of the nation's energy needs by the year 2000 will require a major national commitment to resolve the obstacles hindering the commercialization of solar technologies. These obstacles include the unavailability of reliable solar equipment for some technologies, high initial solar capital costs, potential legal and institutional barriers, absence of a market infrastructure and manufacturing capacity, and a lack of information and educational programs.

The primary actions expected to promote accelerated commercialization of solar technologies include additional commitments to RD&D, financial incentives, and institutional programs. RD&D can underwrite front-end, high-risk costs and lower the risk to solar manufacturers by indicating a near-term federal commitment to the development and use of a solar technology. Risk to consumers can be reduced by RD&D programs which demonstrate the technological feasibility, reliability, and cost-effectiveness of solar technologies.

Financial incentives help to underwrite the risk assumed by the private sector in investing in a new technology. They can provide the difference between public and private values of the activity to society. They can provide parity in treatment for solar technologies in relation to the levels of subsidies provided to conventional energy sources or market parity at levels sufficient to make solar competitive with conventional fuels. Financial incentives can also provide a financial impetus to remove or accelerate the removal of institutional barriers that may hinder the use of solar technologies.

Nuclear, coal, oil, and gas technologies have benefited from a wide variety of federal energy subsidies. In FY 1977 federal subsidies for energy production totaled $19.1 billion (1976 $), including RD&D expenditures, tax incentives, and direct government intervention in the marketplace (see Figure III-1).

Where the economic impetus provided by financial incentives is not sufficient to overcome institutional barriers, institutional programs supported by the government may assist in their removal. Such programs could disseminate information on a timely basis to participants in the solar commercialization process and could catalyze the solar energy infrastructure to reduce the amount of time ordinarily required for full acceptance of a new technology.

These institutional programs fall into two categories: (1) those that attempt to remove barriers to commercialization or meet requirements for commercialization over a shorter time period than normal market forces would provide and (2) those that actively promote solar utilization through nonfinancial incentives.

Meeting Commercialization Requirements and Removing Barriers

There are often long delays, distortions, and costs involved when potential users try to obtain information concerning solar energy. The federal government can expedite solar commercialization by underwriting the costs of an information exchange process. The Agricultural Extension Service within the farm community and the Energy Extension Service are models in this area. The Residential Conservation Service under the NEA will also aid in this process.

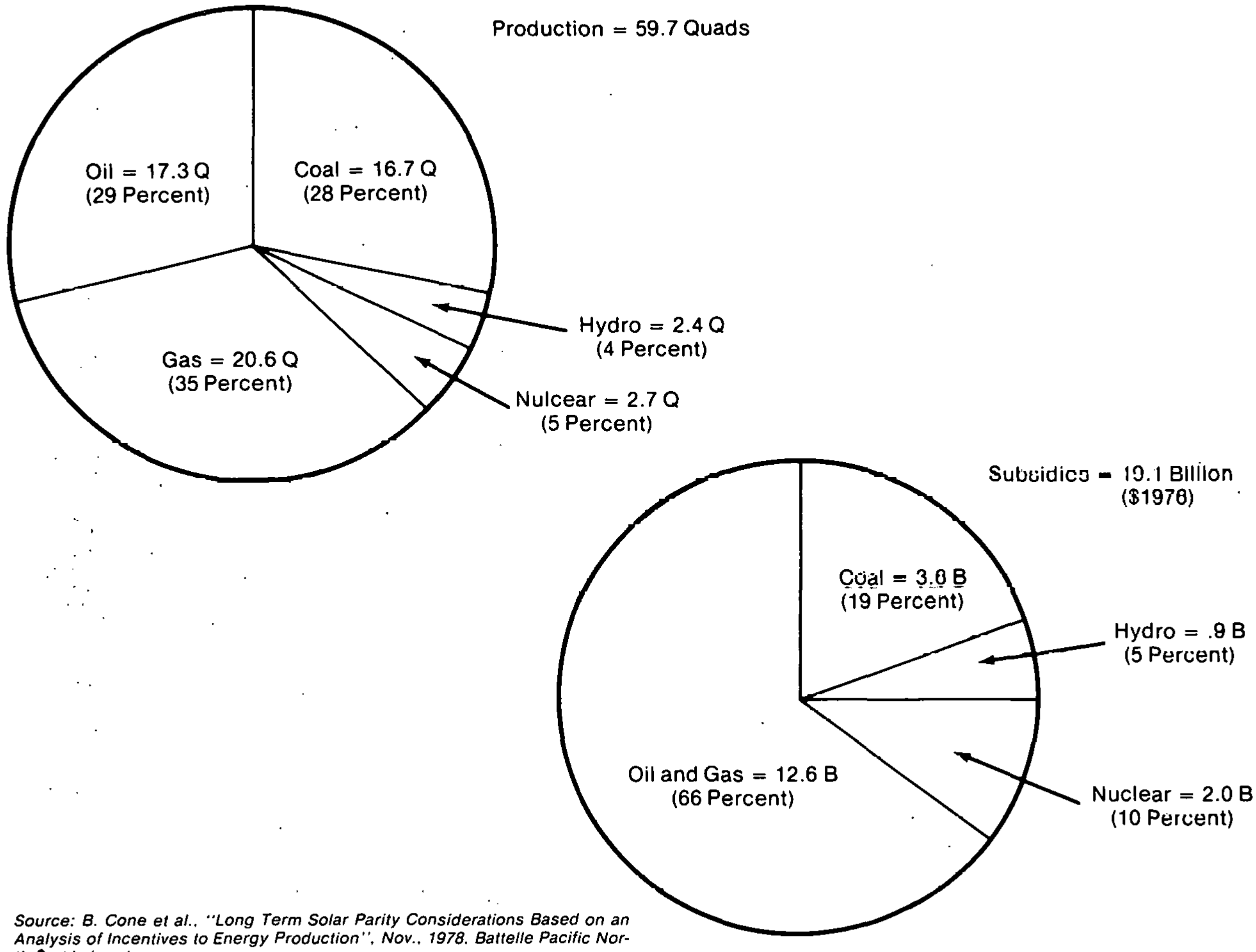
The federal government, assisted by the Regional Solar Energy Centers, can aid state and local governments in information exchange, development of model codes and covenants, and, where appropriate, by regulatory and legislative actions. Barriers such as zoning laws, building codes and covenants, and the lack of guaranteed solar access can inhibit solar commercialization. Uncertainties about discriminatory utility rate schedules may further impede solar growth, and local property taxes that include solar systems may impose severe economic handicaps to solar energy.

Nonfinancial Incentives

Over and above programs that may act to remove barriers, the federal government, with the Regional Solar Energy Centers, may actively promote solar energy through the use of nonfinancial incentives and through cooperative industry and state/local programs. The federal program may seek to partially underwrite front-end product and market development costs through cost-shared demonstrations, product evaluation, test marketing, and advertising. As called for under the NEA, the federal government can provide an early guaranteed market for solar technologies. Using methods similar to current anti-inflation activities, the federal government can identify specific focus groups with the assistance of the Regional Solar Energy Centers, and, through direct contact, solicit support in the form of actions which would be beneficial for solar use. These focus groups may be comprised of major industrial firms, large residential/commercial developers, major utilities, and state public utility commissions.

National Impacts

Three accelerated levels of solar commercialization were analyzed. Levels I, II, and III would contribute 18.8, 22.5, and 26.0 quads per year, respectively. The



Source: B. Cone et al., "Long Term Solar Parity Considerations Based on an Analysis of Incentives to Energy Production", Nov., 1978. Battelle Pacific Northwest Laboratory.

Figure III-1
Energy Production and Subsidies, 1977

national impacts of the widespread use of solar energy technologies were analyzed in terms of:

- energy savings
- capital investment
- solar industry development
- environmental and health effects

These impacts were analyzed as a continuum of increasing solar energy use. This approach permits the use of this analysis to derive the impacts for any level of commercialization as well as for differing expectations as to the level of market penetration for a given commercialization scenario.

In determining impacts, a series of models and inputs was used. Price/demand scenarios were developed in conjunction with the Domestic Policy Review (DPR) using the Project Independence Evaluation System (PIES) and FOSSIL I (Rebibo, 1979). These scenarios were input to the System for Projecting Utilization of Renewable Resources (SPURR) (Rebibo et al., 1977). Output from SPURR included solar market penetration estimates, gross capital and labor requirements, and estimates of sector splits and fuels displaced. Using these estimates, net environmental residuals and net economic effects were derived through linear interpolation of the SEAS (Strategic Environmental Assessment System) DPR estimates. These effects were then input to the BENEFITS model, developed by Ridker and Watson (1977) to determine health and environmental impacts (see Figure III-2).

Energy Savings

Expected energy savings by market sector and technology are shown in Table III-I for the Reference Case and the three accelerated levels of commercialization. The mix of solar technologies and the proportion of solar in each market sector does not change dramatically as solar energy utilization is increased. Hydroelectric capacity does not grow as fast as the other solar technologies due to resource limitations for large-scale hydro. Central utility technologies other than hydroelectric increase slightly faster than the average because the potential market is large and utilities are not limited in choosing sites as in the dispersed markets where the system must be placed on-site. Technology mixes tend to remain the same because it is assumed that the financial incentives for acceleration treat technologies uniformly. If other mechanisms such as government purchases or assistance to manufacturers or financial incentives for specific technologies are employed, then the technology mixes will show greater divergence with acceleration.

Private and Federal Expenditures

Except for biomass systems, solar technologies require a higher capital investment per unit of energy saved than alternative conventional energy sources. The total amount of private and federal expenditures required increases rapidly with acceleration as shown in Figure III-3. This graph includes not only the monies spent for purchases of solar equipment but also federal RD&D expenses.

Averaged over the next twenty years, private and federal expenditures amount to about $36 billion to $90 billion per quad. Overall, expenditures per quad increase with increased levels of commercialization because a greater number of solar systems that are intrinsically less economical are sold. However, several technologies, notably commercial active thermal systems and industrial thermal process heat systems, show a decrease with greater market penetration. In these cases, the production cost per system has decreased with experience, resulting in lower required expenditures.

Federal Costs

Projected federal costs to achieve reference and accelerated levels of commercialization are depicted in Figures III-4a and III-4b. Since this study emphasized tax credits as the primary form of federal incentive (see appendix), revenues lost to tax credits constitute the major component of federal cost. Alternatively, emphasis could be placed on regulation or desubsidization of conventional fuels. However, even though federal costs may be lower, the difference would still have to be paid from elsewhere in the economy. Secondary impacts of regulation may even prove to be more costly to the economy as a whole.

The cost level for the Reference Case includes revenues lost to tax credits, approximately $500 million dollars for research, development, and demonstration costs budgeted annually through 1983, and approximately $333 million dollars annually for continuation of current levels of hydroelectric construction, operation, regulation, tax exemption, and low-interest loan programs.

The Reference Case costs are optimistic for several reasons. Current RD&D programs are planned and funded based on the assumption that technological breakthroughs, development innovations, and successful demonstrations occur so that the technologies

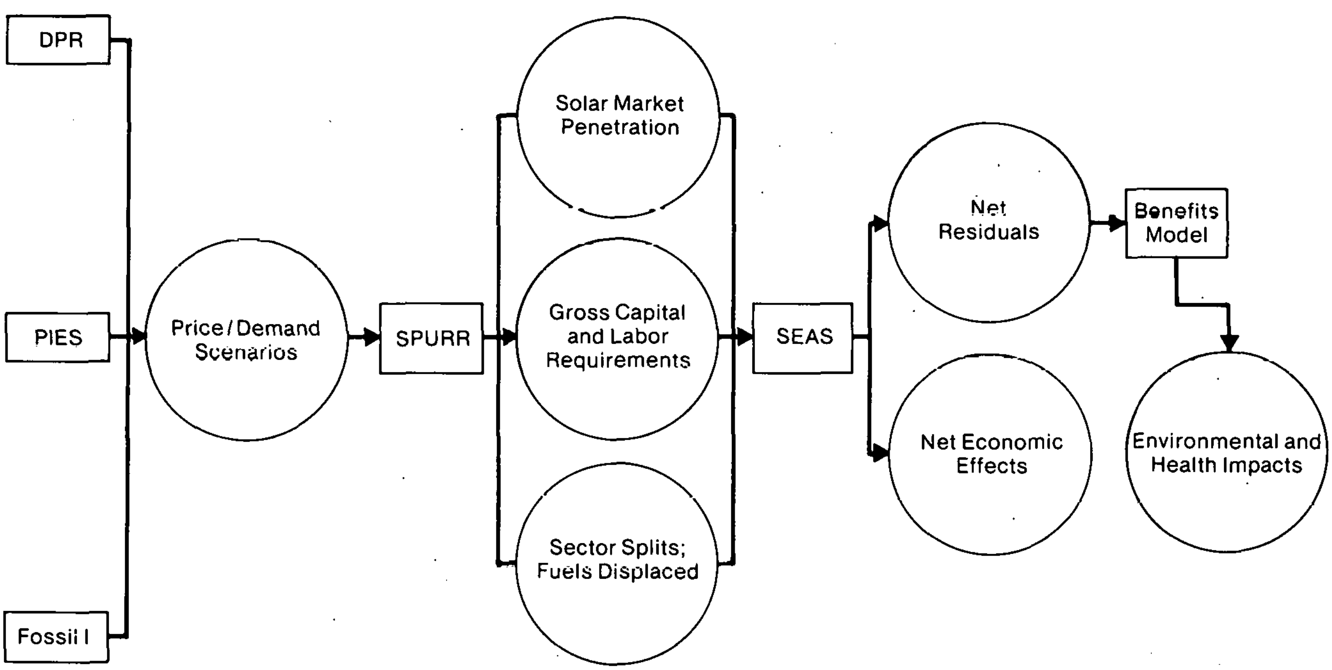
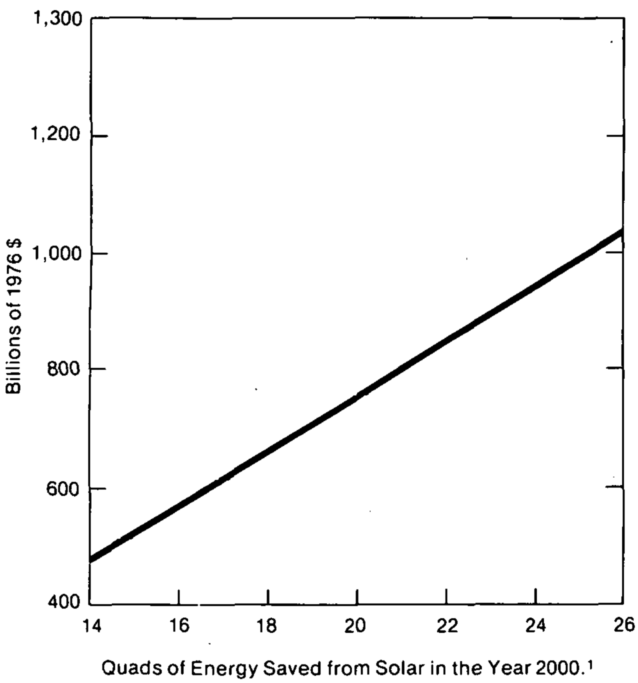


Figure III-2
Solar Impacts Assessment Methodology

Table III-I
Annual Energy Savings by Market Sector and Technology in the Year 2000
(Quads of Primary Fuel Displaced)

Sector	Sector Demand (Quads/Year[1])	Technology	Level of Commercialization: Reference Case		19 Quads/Yr Scenario		22 Quads/Yr Scenario		26 Quads/Yr Scenario	
			Quad	Percent of Total Solar	Quads	Percent of Total Solar	Quads	Percent of Total Solar	Quads	Percent of Total Solar
Residential	20.3	Thermal	1.1	7.5	1.5	8.0	1.8	8.0	2.3	8.8
		Passive	0.2	1.4	0.3	1.6	0.3	1.3	0.4	1.5
		Wind	0.3	2.0	0.4	2.1	0.5	2.2	0.6	2.3
		Photovoltaics	0.2	1.4	0.3	1.6	0.3	1.3	0.4	1.5
		Wood Stoves[2]	0.6	4.1	0.7	3.7	0.8	3.6	0.9	3.5
Commercial	18.0	Thermal	0.7	4.8	0.8	4.3	0.9	4.0	1.0	3.8
		Passive	*	—	*	—	*	—	*	—
		Wind	*	—	*	—	*	—	*	—
		Photovoltaics	*	—	*	—	*	—	0.1	0.4
Industrial	55.0	Solar Thermal	2.2	15.0	2.5	13.3	3.2	14.2	4.0	15.4
		Biomass[2]	2.2	15.0	3.2	17.0	3.7	16.4	4.0	15.4
		Photovoltaics	*	—	*	—	*	—	*	—
		Wind	0.1	0.7	0.1	0.5	0.1	0.4	0.1	0.4
		Solar Thermal Electric	*	—	*	—	*	—	*	—
		Solar Total Energy Systems	*	—	0.1	0.5	0.1	0.4	0.2	0.8
		Small-scale Hydroelectric	0.2	1.4	0.2	1.1	0.3	1.3	0.4	1.5
Electric Utility	49.0	Wind	1.3	8.8	2.0	10.5	2.5	11.1	2.8	10.8
		Solar Thermal	1.0	6.8	1.6	8.5	2.0	8.9	2.2	8.5
		Photovoltaics	*	—	0.3	1.6	0.5	2.2	0.6	2.3
		Ocean Thermal	0.1	0.7	0.2	1.1	0.3	1.3	0.4	1.5
		Biomass Electric	*	—	0.1	0.5	0.2	0.9	0.3	1.2
		Hydroelectric[3]	3.8	25.9	3.9	20.7	4.0	17.8	4.2	16.2
Synthetic Fuels and Chemicals	4.4	Wood	0.5	3.4	0.4	2.1	0.7	3.1	0.8	3.8
		Animal Waste	0.2	1.4	0.2	1.1	0.3	1.3	0.3	1.2
		Total**	14.7	(13)	18.8	(16)	22.5	(20)	26.0	(23)
		Incremental Over Reference Case	0		4.2		7.9		11.4	
		Incremental Over Current Level	9.8		13.9		17.6		21.1	

[1] Includes fossil fuel equivalent of end use electricity demand as well as demand of energy for generation. Thus, there is double accounting of intermediate fuels and energy produced from those fuels. Actual gross demand is 115 quads.
[2] Includes current use of 0.3 quads of biomass in the residential sector and 1.6 quads in the industrial sector.
[3] Includes 3.0 quads current use.
*Less than 0.1 quads.
**Numbers in parenthesis represent percent of projected national gross energy demand.



[1]Includes existing use of biomass (1.9 quads) and hydroelectric (3.0 quads). Computations of expenditures per "new" quad of solar should not include the existing capacity.

Figure III-3
Gross Capital Expenditures (1980 to 2000) to Accelerate the Commercialization of Solar Energy

are commercially available and economically competitive on schedule. Also, it is assumed that information exchange and dissemination programs will effectively reach all of the decision makers; legal and institutional barriers will be removed; industry will be willing and able to produce and market solar systems at the required rate; and that the public will make major investments in solar systems for residences, stores, factories, and utilities.

Even if these assumptions prove correct, federal costs will most likely be higher than the levels of Figures III-4a and 4b due to the large number of uncertainties in a technological innovation as complex as solar energy. Also, research, development, and demonstration are expected to continue at a higher level after 1983 than before. Photovoltaics and ocean thermal systems are still in the research phase and most other technologies are in the demonstration phase. Solar thermal space heating and hot water, wood burning, passive space heating, and wind electricity generation are the only technologies currently commercially available.

Projected federal solar incentives range from $.19 per MMBTU for the Reference Case to $1.40 per MMBTU for the highest level of commercialization. Average historical federal energy incentives have ranged from $.05 per MMBTU for natural gas to $1.90 per MMBTU for nuclear energy. The comparison of solar subsidies with historical energy subsidies, illustrated in Figure III-5a, is useful but not precise due to variations in type of subsidy and state

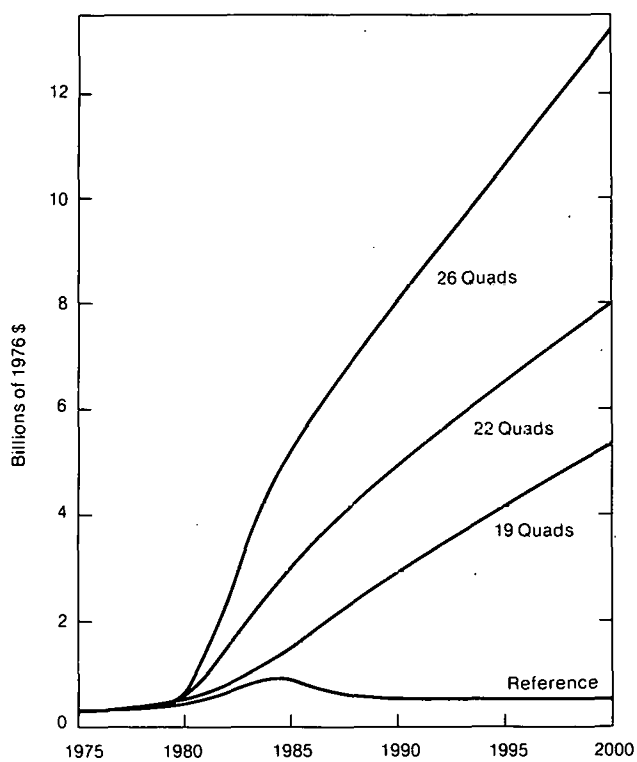


Figure III-4a
Annual Federal Cost to Accelerate the Commercialization of Solar Energy

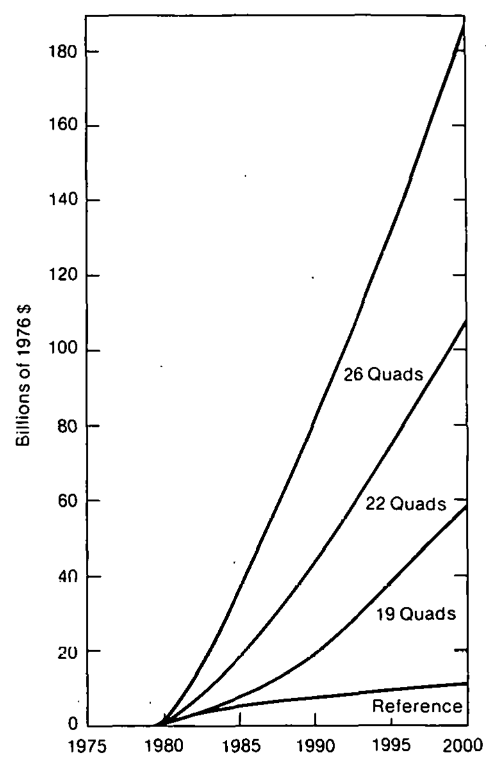


Figure III-4b
Cumulative Federal Cost to Accelerate the Commercialization of Solar Energy

of technology development. Solar technologies will not produce substantial amounts of energy until the last decade of the century. However, they require large expenditures, initially. The conventional technologies with which solar is compared (with the exception of nuclear energy) are producing energy at fully developed levels. Comparison of federal subsidies per annual energy production is depicted in Figure III-5b.

Subsidies for nondefense nuclear energy, which currently represents 50 GWe of capacity and satisfies 2.8 quads per year of demand, totaled $19 billion between 1950 and 1977 for liability insurance, research and development, enrichment plants, the Atomic Energy Commission, and the Nuclear Regulatory Commission. Energy production in 1970 after twenty years of subsidies totaling $10 billion, a period comparable to the solar time frame used in this report, was one-quarter quad.

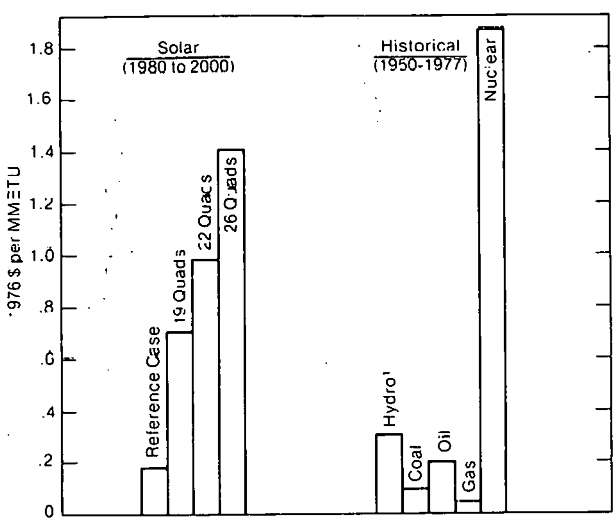
Federal subsidies for hydroelectricity for the period 1933 to 1977 totaled $25 billion for tax-exempt power revenues, construction and operation of dams, low-interest loans, and regulation of non-federal dams. Hydroelectricity currently represents 60 GWe of capacity and satisfies 3.0 quads per year of demand. For more information concerning historical energy subsidies, see the appendix.

Solar Industry

In terms of energy savings, hydroelectric is today's largest solar technology. It is supported by a mature industry with considerable federal assistance (approximately $1 billion in 1977, including prorated electricity subsidies). The other major solar technology today is the use of biomass for process heat by industry. Almost all of this occurs in the pulp and paper industry with the use of wood residues.

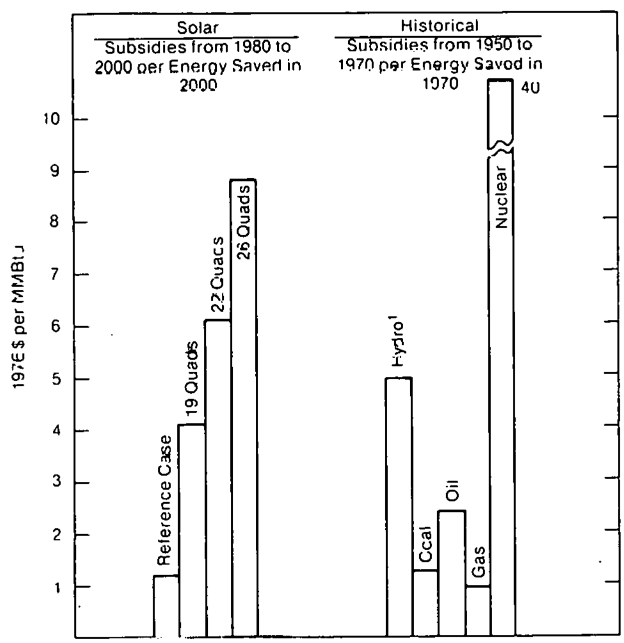
Although still small in terms of national energy savings, new solar industries are beginning to establish commercial markets in solar hot water and space heating systems, buildings designed with passive solar systems, and small-scale wind machines. Currently, there are approximately 60,000 buildings with active solar thermal systems (excluding swimming pool heaters), about 90 percent of which are hot water systems. This is growing at a rate of about 10,000 new systems per year. Passive solar design in new buildings is used in an estimated 1,000 buildings today and is doubling each year. Small-scale wind machines, a solar technology which has had commercial success in the past, is making a comeback. There are currently about 150,000 farm-type wind machines used primarily for water pumping. This figure is expected to grow at a rate of 2,000 to 3,000 per year. In addition, there are approximately 1,000 wind generators in place producing electricity. About 100 to 200 are added each year.

Solar-related employment is expected to be over 1 million people in the year 2000 in the Reference Case. This includes both direct solar employment (for example, solar manufacturers) and indirect employment (for example, steel workers). About one-third of the work force would be direct and two-thirds indirect. Figure III-6 shows how this labor force is expected to increase with increased commercialization.



¹*Hydro subsidies and production are from 1933 to 1977.*

Figure III-5a
Comparison of Projected Federal Solar Incentives (to 2000) per MMBTU of Annual Energy Savings to Average Historical Federal Incentives per MMBTU of Annual Energy Produced



¹*Hydro subsidies are from 1933 to 1953 and production in 1953.*
Note: Historical subsidies include pro-rated electricity incentives.

Figure III-5b
Projected Solar Incentives and Energy Savings Compared to Historical Incentives and Energy Produced

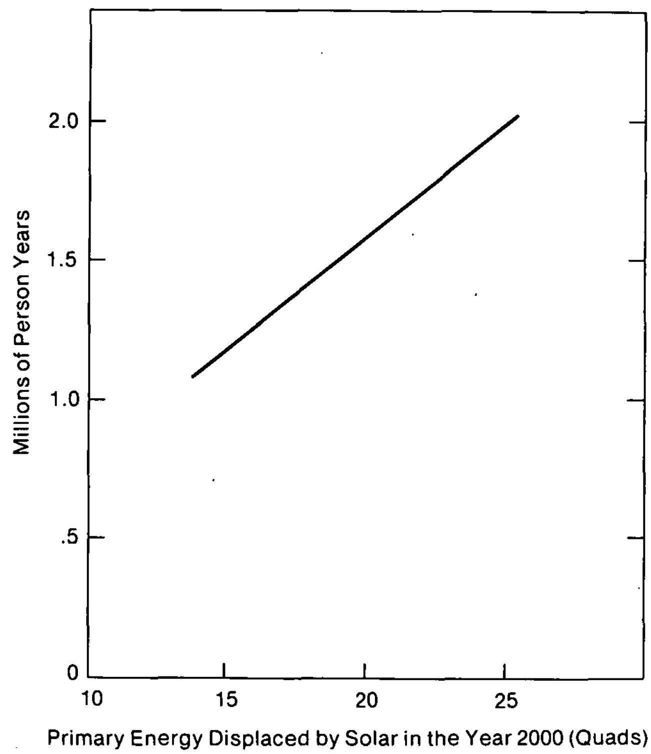


Figure III-6
Direct and Indirect Annual Solar Employment in the Year 2000

Expected numbers of systems in place in the future for the Reference Case and a highly accelerated commercialization case are shown in Table III-II.

Annual sales are an important consideration to the solar industry. These are shown in Figure III-7 for the year 2000 for increasing levels of accelerated commercialization.

Environmental and Health Impacts

For the most part, solar energy has positive long-run environmental and health impacts. Short-term environmental impacts from solar energy are not as generally benign. The manufacture and construction of solar systems has a certain front-end environmental cost associated with it as is the case in the financial sense. With regard to both financial and environmental criteria, the front-end cost is counterbalanced against savings during the life of the system.

By way of example, Figure III-8 depicts the initial capital cost of a solar hot water system versus the undiscounted annual costs and savings over the system life. There is an initial capital or system cost of $2,370 (assuming no financing) in the year of installation. Following installation, the owner pays property tax and O&M costs and also accrues savings from conventional fuels displaced so that the system more than pays for itself on a simple payback basis.

The same solar hot water heater has an associated life-cycle pollution balance. In the year of installation, there are several indirect construction residuals produced due to the manufacture of the solar system. The indirect construction residuals associated with the same capacity of an alternative energy form—for instance, a coal-fired electric power plant—are somewhat less than those associated with solar. In the year of installation, the solar system is a net pollution contributor. The solar system manufacture and installation results in an additional 2 pounds of particulates and 5 pounds of SO_2. The amounts of biochemical oxygen demand (BOD), total suspended solids (TSS), and nitrous oxides (NO_x) decrease slightly. Following system start-up, however, the solar system causes no further residuals and causes savings or negative residuals through precluding the use of approximately one-half ton of coal per year (approximately 10 million BTUs). The net savings pay back the net positive residuals from manufacture and installation within three years and result in significant positive environmental impacts over the life of the system.

The general effect resulting from this example can be broadened, with some reservation, to represent what may happen on a national basis with regard to net changes in pollution damages resulting from accelerated solar utilization. At increasing levels of solar utilization, more solar systems will be built in a relatively short period of time thus exacerbating the front-end pollution damages. Since the number of systems built increases dramatically prior to the year 2000 with the majority of systems built in the 1990s, solar may possibly still be a net pollution contributor by the turn of the century and will continue to be a net pollution contributor until the rate of market growth begins to stabilize. Beyond that point, solar will provide significant environmental and health benefits to the country.

The SEAS model calculates indirect construction residuals and direct operating residuals for varying energy mixes and economic scenarios. Based upon changes in energy mixes resulting from the increasing levels of solar utilization projected in this analysis, a modest decrease is seen in several pollutants on a national basis when compared to the Reference Case. These decreases are shown in Figure III-9 along with 1975 levels of pollutants as a current reference.

The economic benefits derived from these reductions in pollutants are extremely difficult to quantify. A preliminary analysis of the impact of reduced pollution on health effects indicated that each additional quad of solar energy used above the Reference Case will result in $10 to $15 billion in health benefits. An alternative method of accounting for the economic benefit of reduced pollution is to look at the reduction in pollution control costs. On this basis, each additional solar quad above the Reference Case would save approximately $0.5 billion between now and the year 2000 (Conopask, 1979). Although both of these attempts to quantify the economic benefits of decreased pollution resulting from solar energy are preliminary, they strongly indicate significant economic benefits from solar-related pollution abatement.

Table III-II
Estimated Solar Energy Systems Sold by the Year 2000

			1985		1990		2000	
Technology	Market Sector	Typical System Size	Reference Case (14 Quads)	High Level of Commercialization (25 Quads)	Reference Case (14 Quads)	High Level of Commercialization (25 Quads)	Reference Case (14 Quads)	High Level of Commercialization (25 Quads)
Thermal hot water	Residential	35-70 sq. ft.	4,170,000	8,360,000	9,350,000	18,590,000	25,550,000	35,710,000
	Commercial	160-175 sq. ft.	150,000	330,000	360,000	550,000	810,000	880,000
Thermal heating and hot water	Residential	115-130 sq. ft.	1,320,000	3,120,000	2,600,000	6,280,000	6,690,000	13,600,000
	Commercial	1115-1250 sq. ft.	130,000	270,000	290,000	430,000	600,000	700,000
Thermal cooling, heating and hot water	Residential	120-240 sq. ft.	170,000	1,040,000	300,000	1,900,000	950,000	4,880,000
	Commercial	1835-1920 sq. ft.	90,000	180,000	170,000	320,000	380,000	630,000
Passive heating	Residential	150-350 sq. ft.	150,000	370,000	970,000	2,350,000	4,870,000	9,930,000
	Commercial	700-2600 sq. ft.	10,000	20,000	40,000	70,000	130,000	150,000
Small-scale wind	Residential	4kWe	154,000	440,000	1,040,000	2,500,000	6,350,000	12,140,000
	Commercial	40kWe	290	554	5,000	9,510	26,000	45,000
	Industrial	200 kWe	3	9	590	860	3,915	4,115
Large-scale wind	Industrial	5 modules of 2.5 MWe	0	1	25	22	84	63
	Utility	100 MWe	0	0	21	171	358	734
Solar thermal electric	Industrial	500-750 kWe	0	0	107	215	827	860
	Industrial	14 MWe	0	0	35	79	261	253
	Utility	100 MWe	0	0	11	237	285	809
Photovoltaics	Residential	3-4 kWe	21,000	65,000	700,000	1,700,000	6,000,000	12,300,000
	Commercial	54-66 kWe	0	0	2,960	9,900	32,135	59,000
	Industrial	460-540 kWe	0	0	0	0	655	681
	Industrial	13-15 MWe	0	0	0	0	145	156
	Utility	100 MW	0	0	0	37	6	226
Ocean thermal	Utility	400 MWe	0	0	0	0	3	14
Biomass electric	Utility	46 MWe	0	43	6	87	13	107
Thermal low temperature[1]	Industrial	100,000 sq. ft.	161	389	620	1,491	3,669	8,267
Thermal medium			2,740	5,686	10,396	18,099	25,166	56,545
temperature	Industrial	100,000 sq. ft.	392	755	1,479	3,401	12,703	34,321
Thermal high temperature	Industrial	100,000 sq. ft.						
			0	0	1	8	48	300
Solar total energy systems	Industrial	500,000 sq. ft.						

[1] *Low temperature = less than 100°C; medium temperature = 100°-150°C; high temperature = over 150°C.*

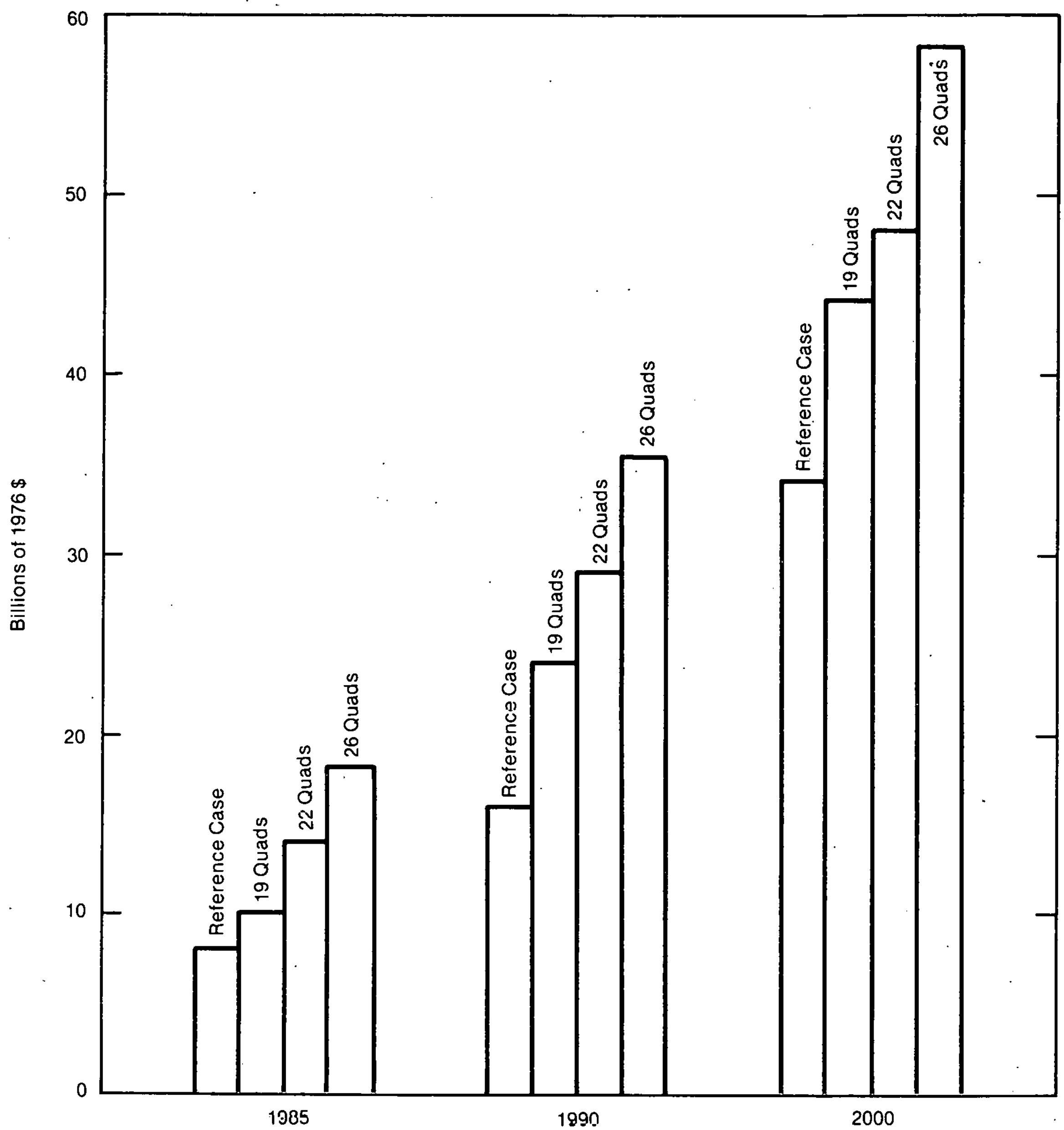


Figure III-7
Annual Solar Sales with Increased Commercialization

Other Benefits of Solar Energy Not Included

Accelerating the use of solar energy will result in several additional national benefits not included in the total national cost analysis. Although there is some overlap, these benefits are in the areas of embargo protection, increased world stability, national security, decreased environmental hazards, increased employment, and the provision of a secure energy supply.

Embargo Protection

Our increased dependence on imported gas and oil carries with it the potential threat of a debilitating embargo. We are currently spending approximately $3 billion per quad to stockpile oil as insurance against an oil embargo. The use of solar and other renewable energy technologies would provide even more protection.

Following the 1973 oil embargo, the rate of growth of GNP dropped drastically. Based on potential GNP, defined as the output the economy could produce with the existing technology under conditions of high sustainable utilization (U.S. Council of Economic Advisors, 1977), the cumulative loss in GNP for the period 1974 through 1976 was $377 billion. This loss can be attributed to the embargo and the increase in energy prices that followed.[1]

[1]Effects of the embargo were estimated by using the 1972 GNP to energy consumption ratio and assuming the one-month embargo reduced energy consumption by 2 percent. Two percent = 25 percent/12. Twenty-five percent of energy consumption is imported oil; 1/12 represents one month of the year.

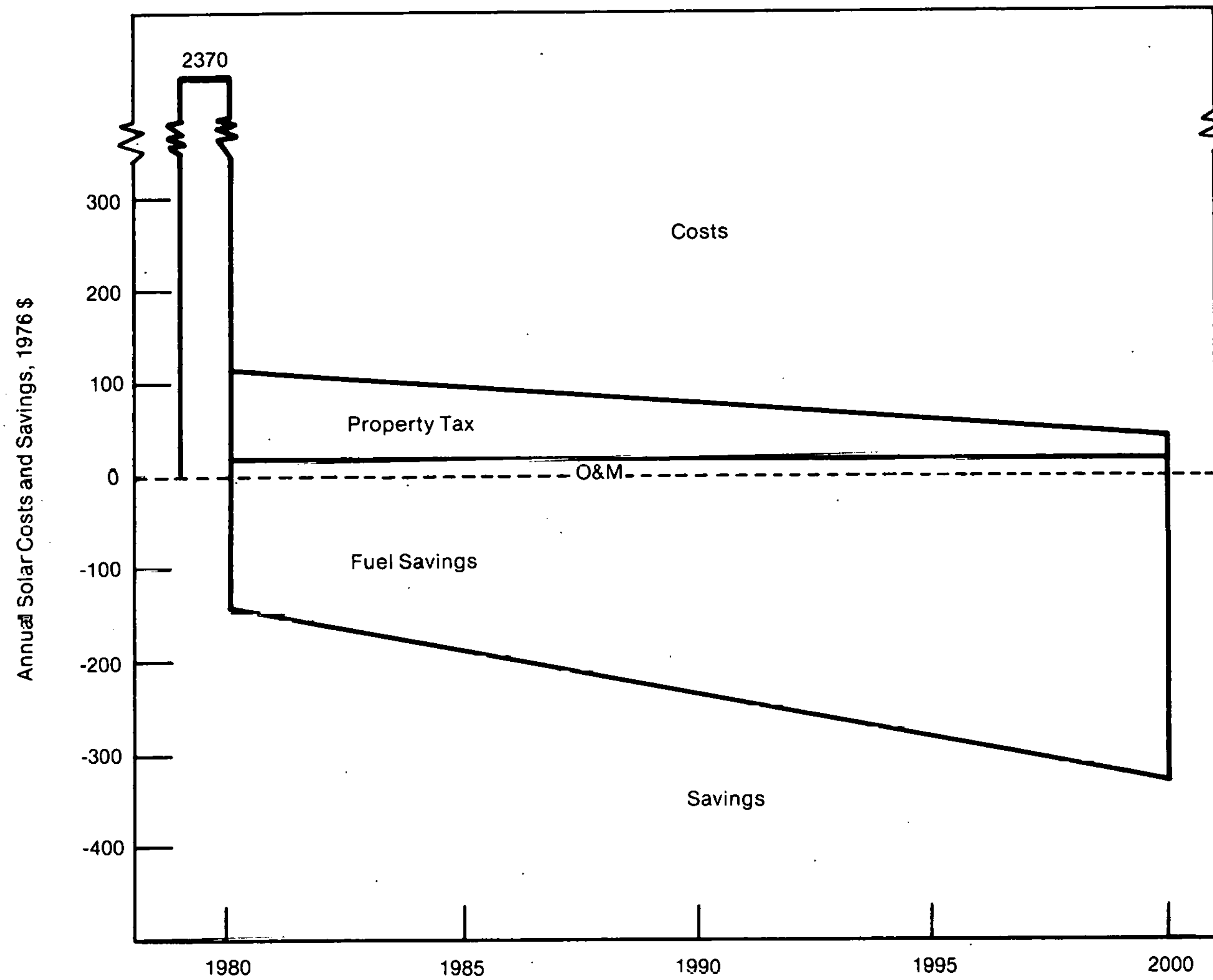


Figure III-8
Example of Annual Solar Costs and Savings for a Solar Hot Water System, 1976 Dollars

Increased World Stability

A decrease in the use of depletable energy resources (especially oil) by the U.S. will lessen the world pressures on energy resources. Commercialization of solar energy within the U.S. could result in the increased use of solar technologies worldwide through export of the technological capability and the equipment itself. This would further decrease pressure on the world oil market as well as provide a possible economic gain for this country through exports of solar equipment. Use of solar technology is especially appropriate in developing countries which have not yet established a large centralized energy infrastructure. A healthy, viable solar industry in this country may contribute to the energy needs of developing countries, further promoting world stability.

An additional economic gain to the U.S. could result if economic development within the third world is promoted. The Overseas Development Council has reported estimates that a 3 percent increase in the growth rates of the non-oil-exporting developing countries could result in an annual increase of 1 percent in the growth rates of the industrialized countries (McLaughlin et al., 1979).

National Security

Development of a viable solar energy industry and requisite infrastructure indicates a U.S. commitment to solve its energy problems. As oil and gas are displaced by solar energy, U.S. national security will be improved and the nation will enjoy greater flexibility in the design of foreign policies.

Decreased Environmental Hazards

In addition to the reduction in economic damages accounted for in the total national cost, the environmental threat from carbon-dioxide build up, nuclear waste, thermal pollution, and industrial sludge from coal scrubbers would be reduced. Increasing concentration of CO_2 in the atmosphere may lead to a gradual heating of our biosphere with potentially serious global consequences. Study is currently underway to better understand the future

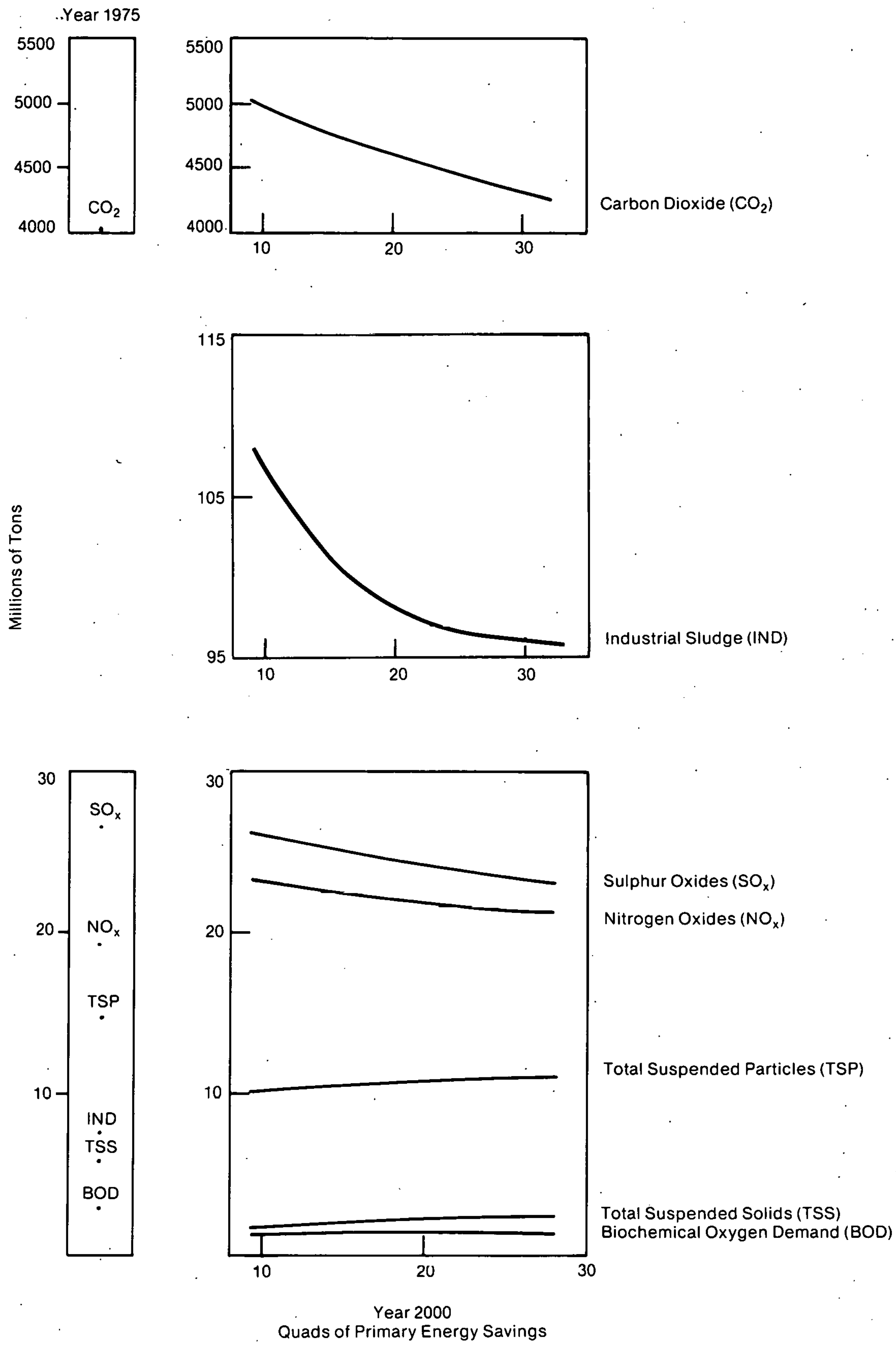


Figure III-9
The Impact of Increased Levels of Solar Energy on Selected Pollutants in 1975 and 2000

causes and affects of CO_2 buildup. CO_2 emissions in 2000 are expected to be 9 percent less with an increase of 11 quads of solar over the Reference Case.

Radioactive wastes from nuclear power plants pose serious problems because of the lack of adequate disposal methods. In 1976, a 1,000 MW commercial nuclear power plant operating under normal conditions produced 30 metric tons of nuclear wastes. Each ton contained 30 kg of fissionable material when loaded and 10 kg of transuranium elements when discharged. The increased use of solar technologies results in approximately thirteen less 1,000 MW nuclear plants in the high solar case than in the Reference Case. This implies a yearly reduction of 390 metric tons of radioactive waste.

Sludges left over from the removal of sulfur from coal may pose a major disposal problem in the future. The current annual 9 million tons of industrial sludges is expected to reach about 100 million tons by the year 2000 in the Reference Case primarily due to the control of sulfur oxides from coal burning. This amount is expected to be 5 percent less with 11 additional quads of solar energy. These sludges, the consistency of toothpaste, must be disposed of in such a way that the heavy metals they contain will not leak into water supply sources.

This country has exhibited a willingness to pay for a safe and healthy environment. The cost of pollution abatement equipment to control selected air and water pollutants was $32 billion in 1975 and is expected to be over $50 billion in 1990.

Increased Employment

Increased use of solar energy is expected to create additional jobs. These benefits are not part of the total national cost analysis because the national economic model assumed a fully employed economy. Although all of the effects of developing a large solar industry are not clear, there is a strong potential for economic gain, especially in the near term where unemployment is a major national concern. The size of the solar industry is expected to be almost twice as large in the high solar case (with 11 additional quads) than in the Reference Case.

Secure Energy Supply

It is possible that the most important argument for the commercialization of solar energy is the need for a secure and readily available supply of energy to guarantee economic growth through the end of the century and beyond.

It is especially important to recognize the long lead times (twenty to thirty years) required to develop new energy technolgies. While this lead time can be compressed by spending large sums of money, there is a great deal of inertia because of the immense economic, social, and political problems involved in shifting to a different energy source. In the development of commercial nuclear power, this long lead time was recognized and federal assistance for the the development of nuclear power set a powerful precedent for the acceleration of the development of an energy technology.

Regional use of solar technologies varies according to fuel prices, energy demand, climate, availability of biomass and hydro resources, and local incentive programs. Solar projections have been disaggregated by Census Regions (Figure IV-1). Market penetration is generally expected to be highest in southern and western regions where insolation and hydro resources are greatest. The regional projections for the Reference Case for the year 2000 are summarized in Figure IV-2.

The New England Region

The New England Region is expected to have a relatively high percentage of solar market penetration by the year 2000 primarily because of high fuel costs and uncertainty about the availability of oil and gas supplies. Wind and biomass are important renewable resources in this region. Over thirty-five electric utility wind systems[1] and 35,500 residential wind systems are expected to be installed by the year 2000.

The Mid-Atlantic Region

Solar energy is expected to contribute only 9 percent of the energy needs in the Mid-Atlantic Region in 2000 with the Reference Case incentives. Solar heating and cooling of buildings and wind systems are expected to displace sizable amounts of energy in this region. It is estimated that there will be over 8 million solar homes and about sixty-five 100-MWe wind systems installed by 2000.

The South Atlantic Region

The South Atlantic Region will be the second largest user of solar energy. Every solar technology shows

[1]Each utility wind system has a rated capacity of 100 MWe and is comprised of an array of large-scale wind machines, each with a rated capacity of 1.5 to 2 MWe.

Figure IV-1
U.S. Census Regions

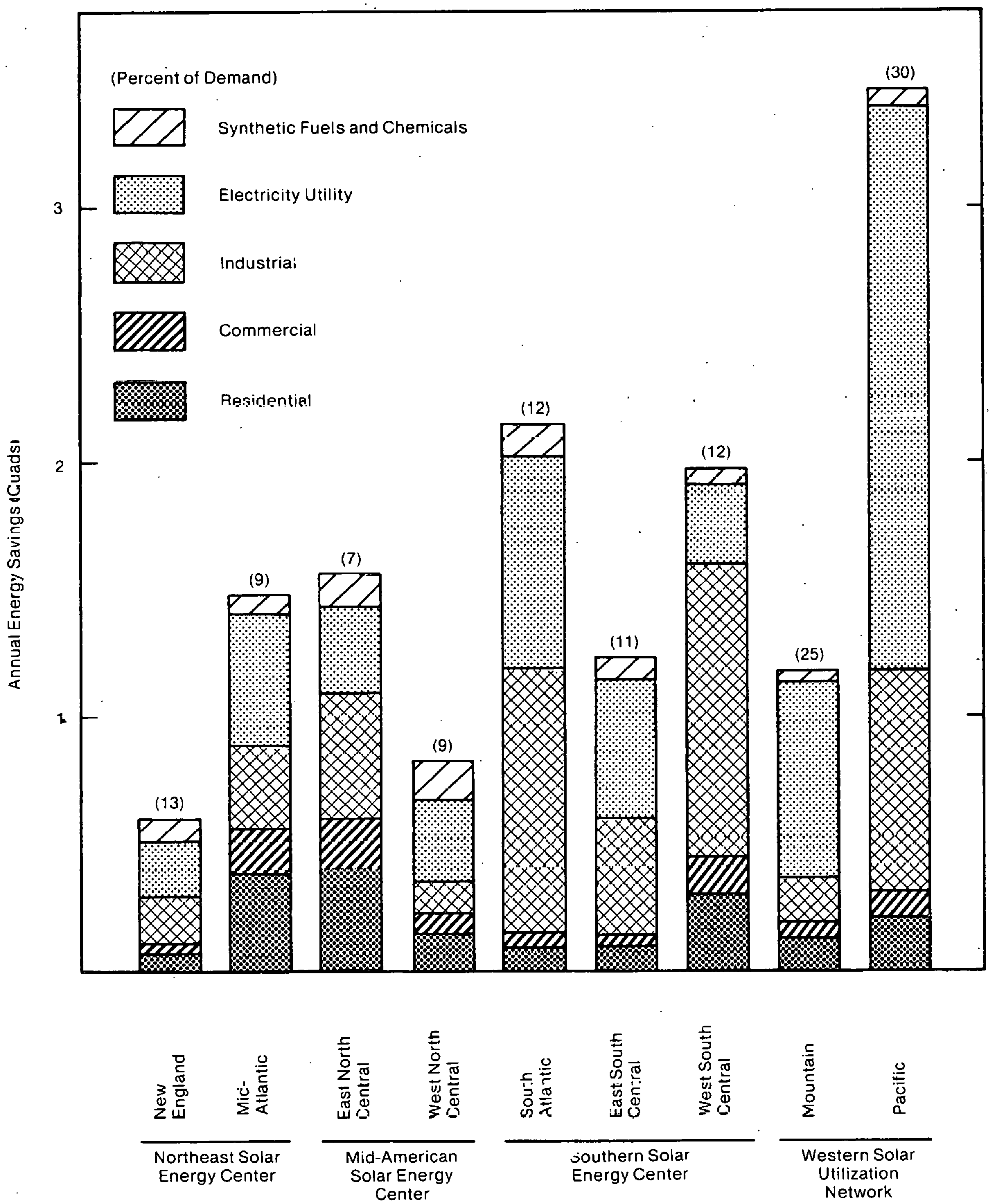


Figure IV-2
Regional Solar Market Penetration in the Year 2000, Reference Case

promise because of high fuel prices and the high availability of solar resources. This region is the largest user of biomass for both process heat and for conversion to synthetic fuels and chemicals. Approximately 0.9 quads of biomass is expected to be used for energy purposes by the year 2000.

The East North Central Region

The East North Central Region is the largest region in terms of total energy needs. The total solar contribution is somewhat limited because of a scarcity of hydro and biomass resources. This region is expected, however, to use more square feet of solar collectors for heating and cooling of buildings than any other region with almost 8 million systems in place by 2000. Agricultural and industrial process heat and wind energy conversion systems will also be important. About 8,000 process heat systems and sixty-six utility-size wind systems are expected to be installed by 2000.

The East South Central Region

Eleven percent of the energy needs of the East South Central Region is projected to come from solar energy by 2000. The major contributors should be wind, biomass and hydroelectric with approximately sixty-eight large-scale wind systems and energy savings of 0.4 quads from biomass and 0.25 quads from hydroelectric.

The West North Central Region

The West North Central Region has good insolation and a large heating load for buildings which contributes to the penetration of solar building applications. By 2000, there are expected to be over 3 million solar homes in this region. Central utility solar thermal electric systems are also expected to make an important contribution with over sixty systems (100 MWe) in place by 2000.

The West South Central Region

It is estimated that solar technologies will satisfy about 12 percent of the energy demand in the West South Central Region by the turn of the century. Large industrial energy demand and good insolation are responsible for making this region the largest user of solar process heat technologies. Over 17,000 systems are expected to be operating by the year 2000. Other large contributors include biomass, heating and cooling of buildings (5.5 million systems) and central utility solar thermal electric (sixty-three 100-MWe systems).

The Mountain Region

In spite of the low prices for coal and electricity in this region, solar technologies are expected to supply 25 percent of the region's energy requirements in 2000. Projections indicate that hydroelectric, saving 0.6 quads of fuels, and central utility solar thermal electric with thirty-five systems will be major contributors.

The Pacific Region

The Pacific Region is the most favorable for solar energy. Thirty percent of the region's energy needs is expected to come from solar in 2000. Out of the estimated 3.4 quads of solar, 1.9 quads are expected to be hydroelectric. Other solar technologies are also expected to do well. This region has an ample supply of biomass, wind and sun. The year 2000 projections include 5.5 million residential and commercial buildings with active or passive solar systems, almost 10,000 industrial process heat systems, seventeen utility-size wind systems, and seventy-five utility solar thermal electric systems.

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Appendix—Using Federal Tax Incentives to Accelerate Solar Energy Commercialization

The federal government can accelerate the commercialization of solar energy technologies in several ways. The government can mandate the use of solar energy systems. It can desubsidize conventional fuels or deregulate oil and gas prices. It can also directly subsidize solar. Or it can design a package to accelerate the acceptance and use of solar technologies that includes a mix of these actions.

This study emphasized federal subsidies over regulatory measures. Although subsidies in the form of tax credits require a change in the tax code through appropriate legislation, they do not require the oversight of an additional federal bureaucracy. More important, they involve only minor costs to the government if the technology does not gain acceptance in the marketplace.

Three Levels of Federal Commitment Analyzed

Three levels of commercialization and the associated level of federal commitment were chosen for this analysis. These commercialization levels bracket the options presented by the DPR. They are based on an analysis of historical levels of subsidies for conventional fuels and the net national benefits that would result from solar use. Each level of commercialization would involve three broad categories of federal action: technological development, institutional and market response activities, and direct subsidies.

Since solar technologies are generally capital-intensive and a large segment of the total costs are incurred at the time of purchase and installation, subsidies are needed to overcome this high first cost and promote their use until they become competitive. Subsidies can take many forms: loan guarantees, tax-credits, low interest loans, tax exemptions, and cash grants. All of these, though different in form, can be represented using a single index known as "effective subsidy." Such a procedure lends itself to evaluation of impacts using analytical models.

In this study, three different levels of effective subsidies were chosen. The effective subsidies are divided into two categories: a sustained level of subsidy to reflect parity with the subsidies provided to conventional fuels and temporary front-end subsidies to provide an initial market boost.

Sustained Subsidies

The sustained subsidies evaluated for solar technologies reflect: (1) the necessity of a federal subsidy for solar to compete with conventional fuels (a parity-level subsidy) and (2) the desirability of reducing the cost of solar to the consumer to reflect the benefits associated with the use of solar technologies discussed in Section II.

In designing the parity level of the sustained incentive, subsidy levels historically provided for conventional fuels were reviewed (Table A-I). Historical averages range from $0.05 for natural gas to $1.90 for nuclear power per million BTUs of energy produced. Table A-II lists the 1977 subsidies for these fuels. Current levels differ somewhat from historical averages because some incentives such as depletion allowances have become a small component of total subsidies during the last five years. Because the cause-effect relationships between subsidies and energy production are difficult to identify, these values were used as rough measures of parity.

Subsidies of $0.20 to $1.00 per million BTUs were used as the parity level of incentive for solar technologies. These values were used for each solar technology regardless of the specific fuel against which it may potentially compete.

Table A-I
Energy Production and Incentives[1] by Energy Type, 1933 to 1977

Energy Type	Period	Incentives (Inc.) (Billions of 1976$)[2]	Production (Prod.) (Quads)	$ Incentive per Million BTUs (Inc./Prod.)
Hydro	1933-1977	26	73	.36
Coal	1950-1977	33	378	.09
Oil	1950-1977	97	454	.21
Gas	1950-1977	25	458	.05
Nuclear	1950-1977	19	10	1.90
Total		200	1,373	.15

Source: B. Cone et al., "Long Term Solar Parity Considerations Based on an Analysis of Incentives to Energy production," Nov., 1978, Battelle Pacific Northwest Laboratory.
[1]Incentives include pro-rated subsidies for electricity.
[2]Average annual GNP deflator 5.4% applied to 1977 $ [Statistical Abstract of the U.S., 1978, 99 ed., p. 483, Table 782, U.S. Department of Commerce, Bureau of the Census, Washington, D.C., 1978.]

Table A-II
Energy Production and Incentives[1] by Energy Type, 1977

Energy Type	Incentives (Inc.) (Billions of 1976$)	Production (Prod.) (Quads)	$ Incentive per Million BTUs (Inc./Prod.)
Hydro	.9	2.4	.38
Coal	3.6	16.7	.22
Oil	12.6	17.3	.73
Gas	-0.04[3]	20.6	-.002
Nuclear	2.0	2.7	.74
Total	19.1	59.7	.32

Source: Same as above.
[1]Incentives include pro-rated subsidies for electricity.
[2]Average annual GNP deflator 5.4% applied to 1977 $ [Statistical Abstract of the U.S., 1978, 99 ed., p. 483, Table 782, U.S. Department of Commerce, Bureau of the Census, Washington, D.C., 1978.]
[3]For the period 1955-1977 a net negative incentive results from an increase in intrastate gas prices over regulated interstate gas prices.

Similarly, the sustained component of subsidies reflecting the net national benefits that may be derived from the use of solar technologies was estimated to be in the range of $0.70 to $0.90 per million BTUs of energy provided by solar technologies.

In designing the sustained component of the subsidy levels for solar energy, the higher limits of the ranges specified for parity and national value were used for the highest level of commercialization and the lower values for the lowest level of commercialization. The components of the sustained subsidy levels are shown in Table A-III.

The total sustained levels of subsidies designed for the three accelerated commercialization levels are approximately equal to parity with the average cost of conventional fuels, parity with oil, and parity with nuclear power, respectively.

Since the major costs for solar energy systems are capital costs incurred at the time of installation, the sustained levels of subsidies were converted to subsidies that would reduce installed cost.

Investment tax credits effective at the time of purchase were selected. For example, if a specific solar system is expected to displace 80 million BTUs of conventional fuel equivalent every year during a lifetime of twenty years, then the sustained subsidy level for this system under the lowest accelerated commercialization level would be $72.00 ($0.90 times 80 MMBTU/year) for each of the twenty years. The present worth of these equal payments for twenty years at a discount rate of, say 10 percent, amounts to $612.00.[1] This would be the amount of subsidy for the installed cost of the system under consideration. If the system costs, for example, $15,000 to purchase and install, then the subsidy would amount to an equivalent investment tax credit of 4.08 percent.

Using a similar procedure, a typical solar system was chosen for each market sector and the equivalent investment tax credits were computed.

[1]The present worth factor at 10 percent interest for an equal payment of one dollar for twenty years is found from compound interest tables to be 8.5. This factor multiplied by $72.00 is $612.00.

Front-end Subsidies

Solar commercialization is bound to occur as conventional fuel costs rise. Since the goal of this study is the acceleration of the commercialization process, there is a pronounced need for higher incentives in the near term. They should be provided on a temporary basis until solar systems become competitive due to increased conventional fuel prices and lower production costs for solar technologies. Such incentives were provided by the federal government to ensure the commercialization of nuclear power (see Figure A-1). During the fifties, substantial amounts of federal funds were disbursed even though there was very little output from nuclear plants. Since the early sixties, however, nuclear power has contributed significantly in meeting the growing demand for electricity.

It is expected that solar commercialization will follow the nuclear commercialization pattern. Most of the solar technologies should be economically competitive with conventional systems by 1990. Front-end incentives were, therefore, designed to be phased out by the year when the average solar system for a given market sector becomes competitive with the weighted average cost of using conventional fuels.

Figure A-2 shows the life-cycle costs of using a typical solar system for hot water and space heating

Table A-III
Components of Sustained Subsidy Levels (1976 $/MMBTU)

Level	Parity Level Subsidy	National Value Subsidy	Total Sustained Subsidy
I	0.20	0.70	0.90
II	0.80	0.80	1.60
III	1.00	0.90	1.90

[1]Refers to fossil-fuel equivalent displaced.

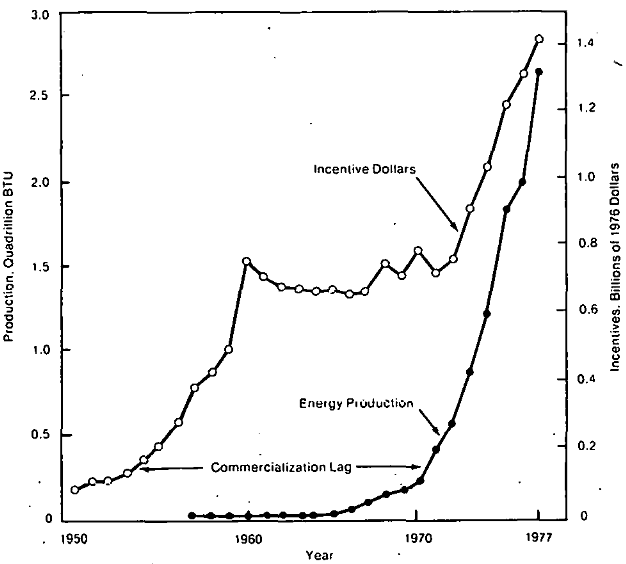


Figure A-1
Nuclear Energy Production and Incentives

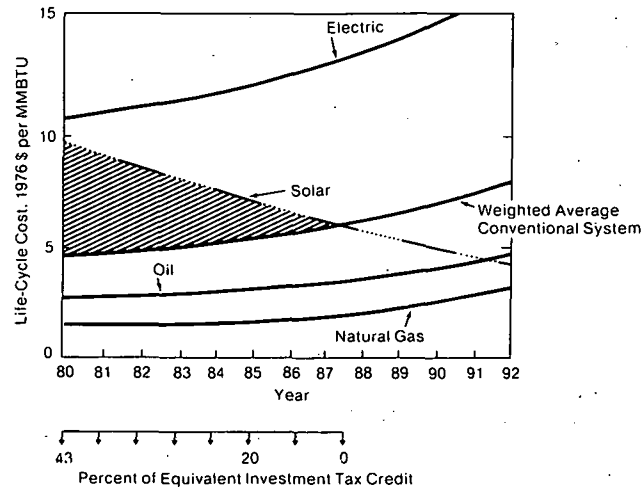
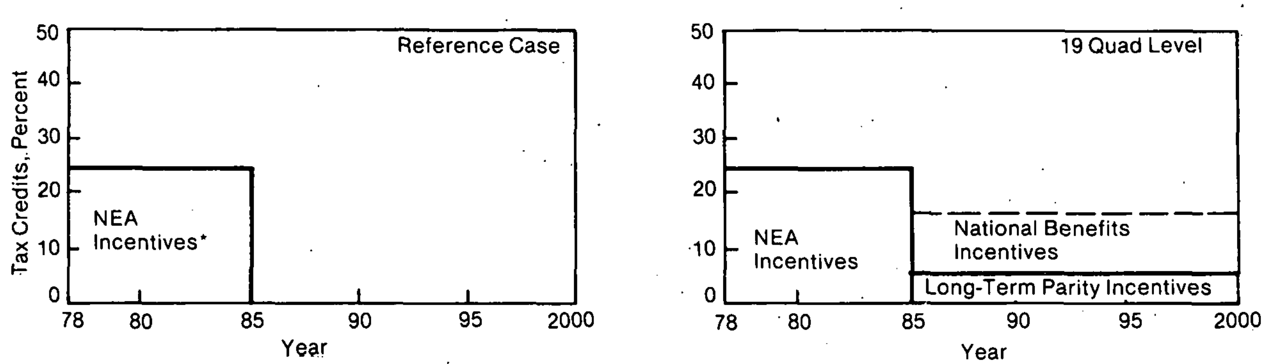


Figure A-2
An Illustration of the Derivation of Front-End Incentives for Residential Heating and Hot Water Solar Systems



**Residential tax credit = 30% of first $2000, 20% of the next $8000 up to $2200. This is an average credit of 25-26% for heating/hot water system.*

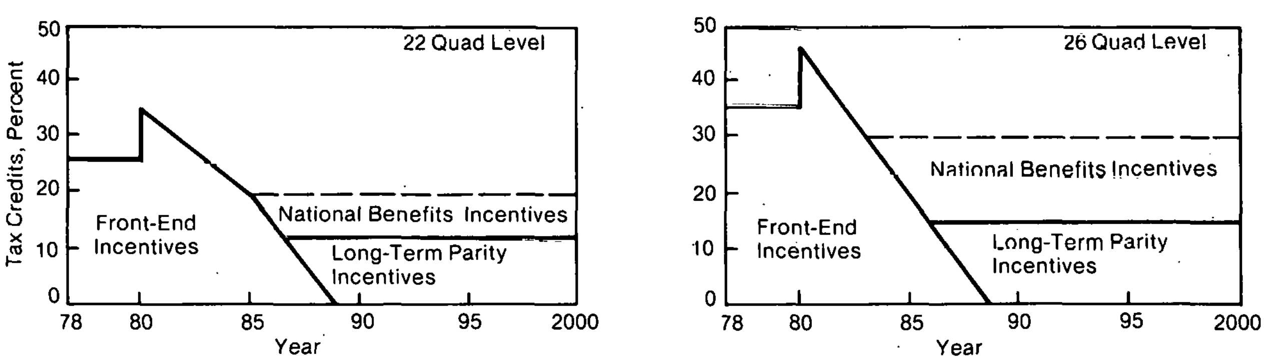


Figure A-3
Tax Credit Levels Under Various Options, Residential Sector

as a function of time. The life-cycle costs of using each of the conventional fuels (oil, gas, electricity) are also plotted as a function of time, assuming a 3.4 percent growth rate in conventional prices. The weighted average conventional system life-cycle cost is derived by weighing the cost of each system by the fraction of the specific fuel used. The life-cycle cost of a solar system declines over time due to the expected reduction in the cost of production, distribution, and installation of solar systems as a consequence of mass production. The respective front-end incentives for each of the first few years are indicated at the bottom of Figure A-2. These are expressed as equivalent investment tax credits that are required to make the solar system life-cycle cost equal to the weighted average life-cycle cost of conventional systems. This method was used to determine the front-end incentives for the industrial, commercial, utility, and the synthetic fuel market sectors.

In Figure A-3, a plot of the combined front-end incentives and the sustained long-term incentives are shown in terms of equivalent investment tax credits over time. Although the incentives are expressed as equivalent tax credits, not all the incentives will be in the form of tax credits since tax credits may not be suitable for some consumers. The equivalent tax credits may, for example, be divided between tax credits and low-interest loans. Since both the tax credits and the interest rates on debt financing influence the amortization factor for solar system initial costs, a direct relationship can be derived for their equivalency in analytical terms. However, since the relationship is nonlinear, a graphical plot as shown in Figure A-4 was derived from a parametric analysis of the amortization factor.

Summary of Subsidy Levels

Tables A-IV, A-V, and A-VI show the subsidies for each of the three levels for each of the four major market sectors.

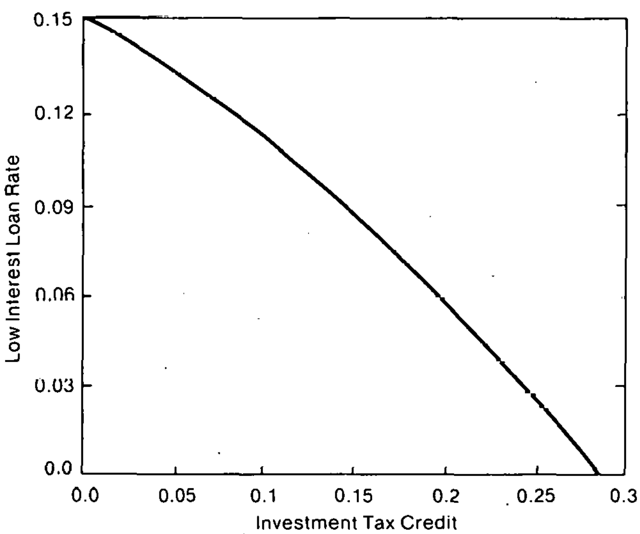


Figure A-4
The Relationship between Low Interest Loan Rate and Investment Tax Credit

Table A-IV
Level I Subsidy Levels

Market Sector	Front-End Tax Credit (Percent)	Target Year for Enactment
Residential	15	1987
Commercial	9	1983
Industrial / Synfuels	5.9	1983
Utility	15	1980

Table A-V
Level II Incentive Packages

Market Sector	Front-End Tax Credit Initial Year	Front-End Tax Credit Last Year	Front-End Loan Program	Sustained Tax Credit	RD&D Expenditures
Residential	1980 NEA + 5%	1982 NEA + 1%		20%	
Commercial	1980 NEA + 26%	1986 18%		15%	
Industrial[1]	1980 NEA + 10%	1988 Standard ITC + 11%	1980-1983 $50 million annually 1984-1988 $125 million annually	Standard ITC + 11%	NEA Level
Synfuels[1]	NEA + 10%	Standard ITC + 11%		Standard ICT + 11%	NEA level
Utility[1]	1980 Standard ITC + 30%	1990 Standard ITC + 20%		Standard ITC + 10%	NEA + $1 billion 1980-1990

[1] *This sector has a standard investment tax credit of 10%.*

Table A-VI
Level III Incentive Packages

Market Sector	Front-End Tax Credit Initial Year	Front-End Tax Credit Last Year	Front-End Loan Program	Sustained Tax Credit	RD&D Expenditures
Residential	1980 NEA + 13% (Under this option, the NEA maximum of $2,200 is eliminated)	1982 NEA + 3%		30%	
Commercial	1980 NEA + 48%	1986 22%		18%	
Industrial[1]	NEA + 15%	Standard ITC + 13%	1980-1983 $50 million annually 1984-1988 $155 million annually	Standard ITC + 13%	NEA + 3
Synfuels[1]	NEA + 15%	Standard ITC + 13%		Standard ITC + 13%	NEA + $1 billion, 1980-1995
Utility[1]	1980 Standard ITC + 40%	1990 Standard ITC + 23%		Standard ITC + 10%	NEA + $1.3 billion 1980-1990

[1] *This sector has a standard investment tax credit of 10%.*

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