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

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MTR--8057

DE83 016953

Prepared for
The Department of Energy
Conservation and Solar Applications

Contract No. EM-78-C-01-5147

AC01-78CS35147

May 1979

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ABSTRACT

Three macroeconomic scenarios were developed as an economic backdrop for projecting solar technology market acceptance under various government policies and commercialization programs. These scenarios assume three levels of future world oil prices--$18, $25 and $32 per barrel (1976 $) in the year 2000. This range is intended to encompass the most likely set of energy futures. The scenarios are discussed in terms of their underlying assumptions and changes in fuel and resource consumption by sector of the economy. Estimates of the future utilization of solar technologies for the mid-price scenarios are given. These estimates are based on the solar subsidies and incentive programs in the National Energy Act.

ACKNOWLEDGEMENTS

The macroeconomic scenarios documented in this report were developed through the combined efforts of many individuals. The Impacts Panel of the Domestic Policy Review defined the initial set of scenarios. Responsible panel members were Richard Caputo of the Solar Energy Research Institute, James MacKenzie of the Council for Environmental Quality, Michael Maher of the Department of Commerce and Grant Miller, Narasimhan Kannan and Kathy Rebibo of The MITRE Corporation.

William Marcuse, Harry Davitian and Joan Lukachinski of Brookhaven National Laboratory contributed to the refinement and revision of the initial set of scenarios. Many individuals at The MITRE Corporaiton helped to develop detailed data at the regional and market sector level needed for solar market penetration analyses. These include Gerald Bennington, Marcia Bohannon, Narasimhan Kannan, Grant Miller, Kathy Rebibo, Michael Shulman, Peter Spewak and James Taul.

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INTRODUCTION

In developing government programs to accelerate the commercialization of solar energy technologies, the effectiveness and costs of the programs can be measured through estimates of the projected market penetration of the solar technologies. MITRE is currently using computer simulation models to make these projections. The simulation models require input on energy prices and energy demand by fuel type. Macroeconomic scenarios have been developed which consist of a consistent set of assumptions on future energy prices, demand and fuel consumption. This report describes three such scenarios that were developed to support solar energy commercialization planning and the projected solar market penetration.

These macroeconomic scenarios evolved in the course of two separate studies. The first is the Domestic Policy Review (DPR) of Solar Energy conducted by an intergovernmental Task Force with representatives of over 30 federal agencies and departments[1]. The second study is a DOE-sponsored activity to develop a National Plan for Accelerated Commercialization (NPAC) of Solar Energy.

The DPR defined three economic scenarios based on differing oil prices which were believed to encompass the most likely futures. Oil prices of $18, $25 and $32 per barrel in the year 2000 were chosen. The prices of other fuels and the sectorial utilization of fuels

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[1] Status Report on Solar Energy Domestic Policy Review--Public Review Copy. Domestic Policy Review Integration Group, Allan Hoffman, Chairman. August 25, 1978.

were determined for each of the three scenarios based on the price of oil. The scenarios were initially developed by a subgroup of the DPR Impacts Panel based on much discussion, forecasts by the Department of Commerce, and examination of the results of national models such as the Brookhaven models and the Gulf/SRI model. The scenarios were reviewed and revised slightly by other members of the Impacts Panel and by members of other panels within the DPR.

The NPAC study began in June 1978, shortly after the DPR. Since both studies are concerned with the commercialization of solar energy they have been carefully coordinated. It was decided to use the same basic macroeconomic scenarios in NPAC that were developed for the DPR. However, since assumptions on energy demand and conventional fuel prices have a large impact on the projections of solar utilization under various solar policy options, the scenarios were subjected to further review. Assumptions on projected energy demand and fuel prices by sector and fuel type were sent to the following organizations:

Arthur D. Little, Inc.
Data Resources, Inc.
Donovan, Hampster & Rattien, Inc.
Electric Power Research Institute
Exxon Company
Gas Research Institute
Solar Energy Research Institute
SRI International
Standard Oil Company
Stanford University

In addition, comments were solicited from Mr. Martin Adams in the office of the Assistant Secretary for Energy Technology, from

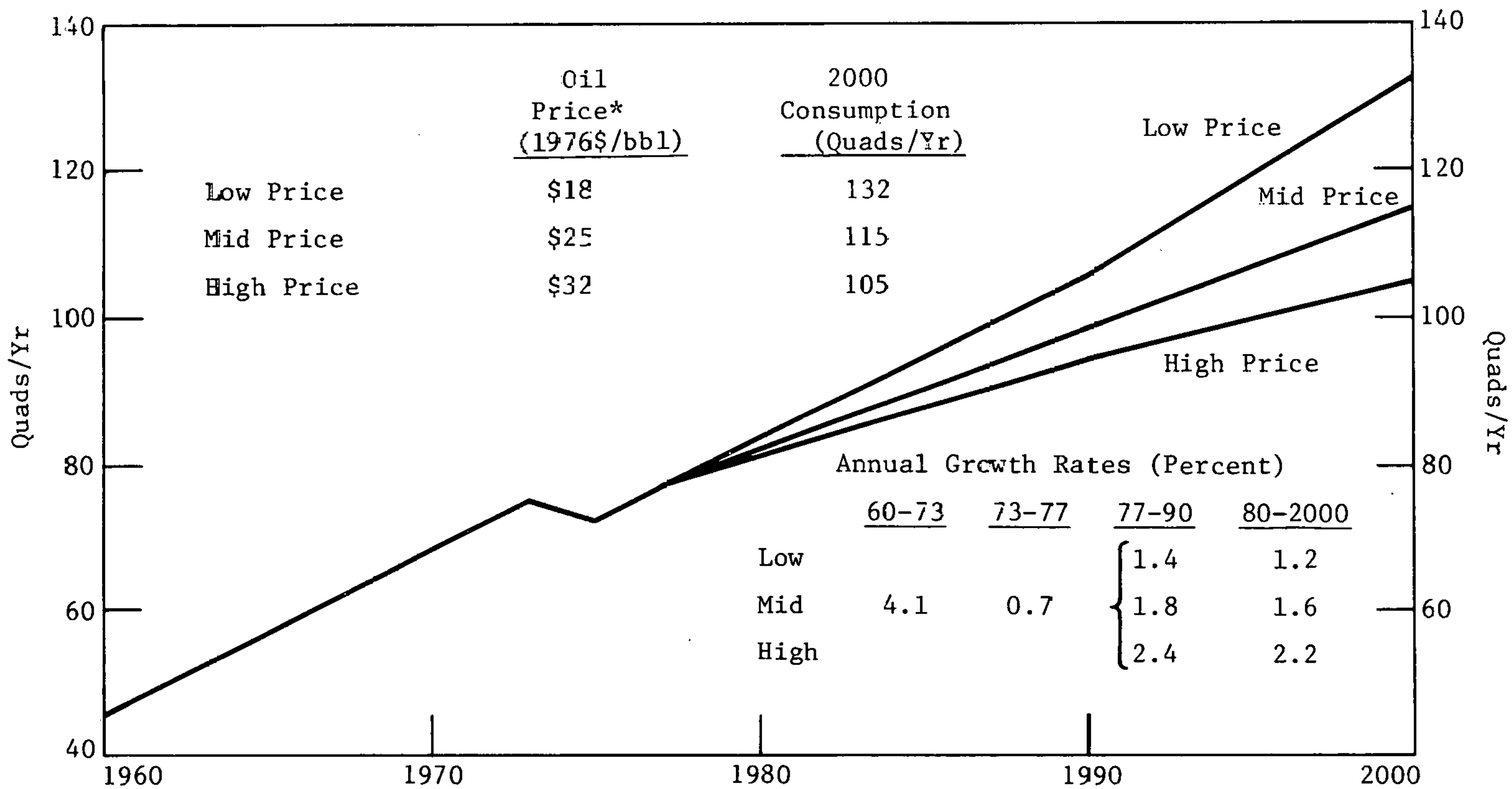
Mr. Billy Owens in DOE's Policy Analysis Division, and from Mr. Michael Maher, Senior Policy Analyst at the Department of Commerce.

No major inconsistencies were pointed out by those who responded to these inquiries. Modelers familiar with the SRI International model felt that our $18 per barrel case was most consistent with the SRI base case. Other respondents sent reports documenting their scenarios; these are discussed in a later section on comparisons with other forecasts.

In order to further verify the scenarios, DOE funded Brookhaven National Laboratory to perform a comparative analysis of our scenarios with scenarios developed using the Brookhaven National Laboratories/Dale W. Jorgenson Associates combined model system. The price responsiveness of demand and changes in fuel and resource consumption patterns were compared. As a result of this analysis, energy consumption in the high-price case was modified to reflect lower supply price elasticities. Energy consumption was raised from the 95 quads (quadrillion Btus) used by the DPR to 105 quads.

Key Findings

The demand for energy will continue to increase a 1.3, 1.7 and 2.3 percent annual growth rate expected for the high-, mid- and low-price cases respectively. The total U.S. energy consumption will reach 105, 115 and 132 quads in the three cases by the year 2000 as shown in Figure 1.



*Price to industrial sector

FIGURE 1
U.S. ENERGY CONSUMPTION

The amount of oil used in the mid- and high-price cases will be lower than that used today. It will be slightly higher in the low-price scenario. Gas will remain at about the same level it is today but will decline from 16 to 25 percent of the total energy used. Use of coal will increase from today's level of 19 percent to 32 to 34 percent in the year 2000. Nuclear use will increase from 3 percent to about 13 percent and the use of energy resources to generate electricity will increase from 29 percent to about 42 percent.

In addition, the country is expected to increase the use of renewable energy resources. These include large- and small-scale hydroelectric, solar and wind energy technologies, the use of biomass to generate heat and electricity, the conversion of biomass to fuels and chemicals, and geothermal energy. Currently these energy resources account for approximately six percent of the energy used. Today's primary renewable resources are hydroelectric generation and biomass used by the wood and paper industries for process heat and electricity. Under the incentives provided in the National Energy Act passed in October 1978, this is expected to increase to 7, 13 and 16 percent for the low-, mid- and high-price scenarios respectively.

The prices of all conventional fuels are expected to increase reflecting the higher prices for oil. Both gas and oil are expected to be deregulated by 1985 and to reach approximately the world oil price by that time. Following 1985 the price of gas and oil is expected to increase at about two, three and four percent per year for the three scenarios. The price of coal is expected to be influenced by oil prices but will increase at a lower rate than oil. The annual rate of coal price increases are about 0.7, 1.5 and 2.4 percent for the three scenarios. Electricity rates are expected to increase at about the same rate as coal.

UNDERLYING ASSUMPTIONS

Projections of energy futures are always based implicitly or explicitly on underlying assumptions about the economy in general, about societal attitudes and about federal policy. The premises upon which the scenarios are based represent our current preception of likely possibilities. But no one can anticipate with assurance what will actually happen during the time frame under consideration.

Population

The current U.S. population of 220 million people is expected to increase to about 264 million by the year 2000 (Figure 2). The annual growth rate will decrease to less than 0.7 percent by the turn of the century.

Gross National Product

The Gross National Product (GNP), which measures domestic economic activity, is expected to grow from the current level of about 1.8 trillion 1976 dollars to a range of 3.4 to 3.8 trillion 1976 dollars by the year 2000 (Figure 3). In the 1965-1973 period, prior to the oil embargo, the economic growth rate was 3.7 percent. This

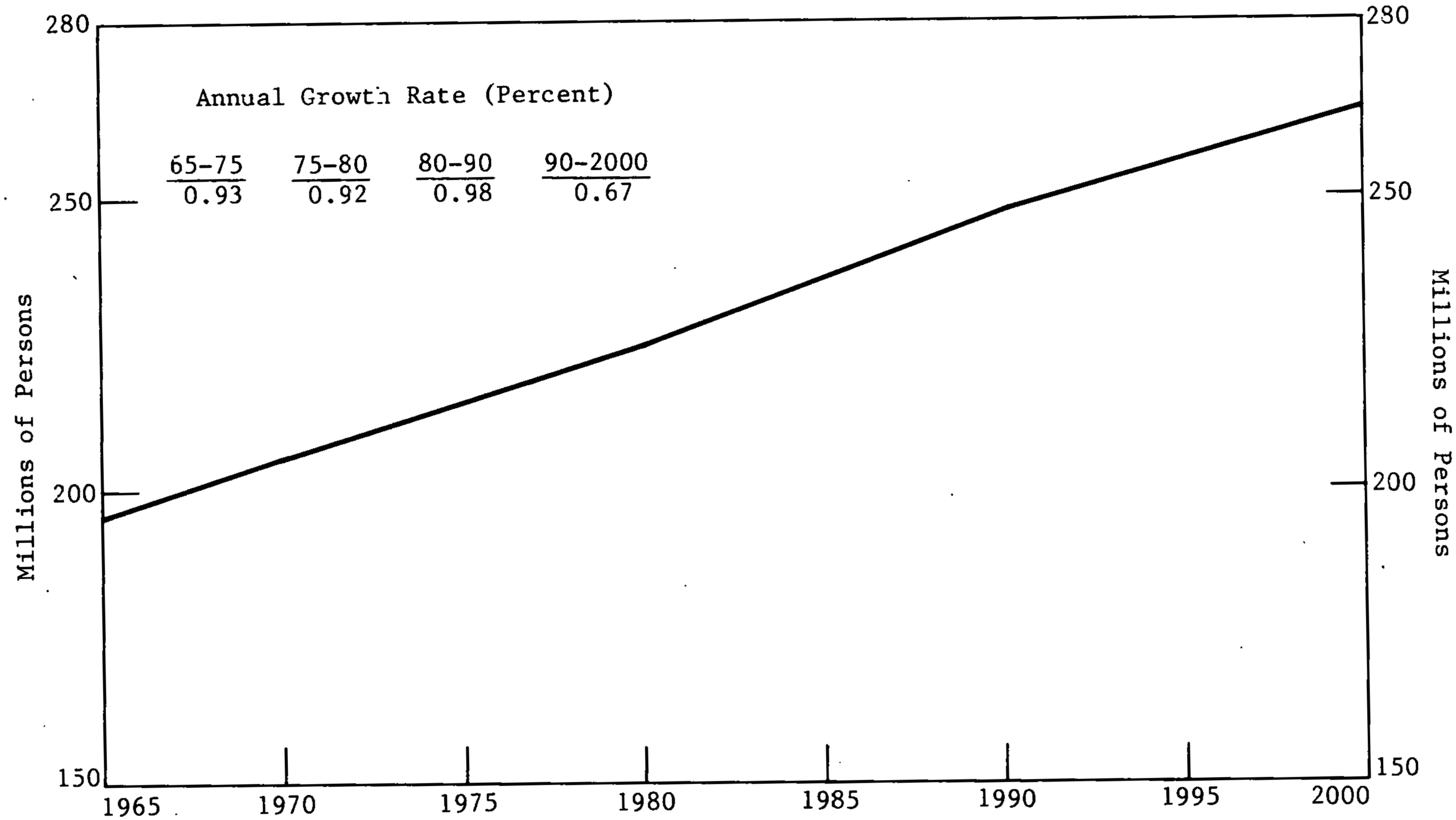


FIGURE 2
U.S. POPULATION

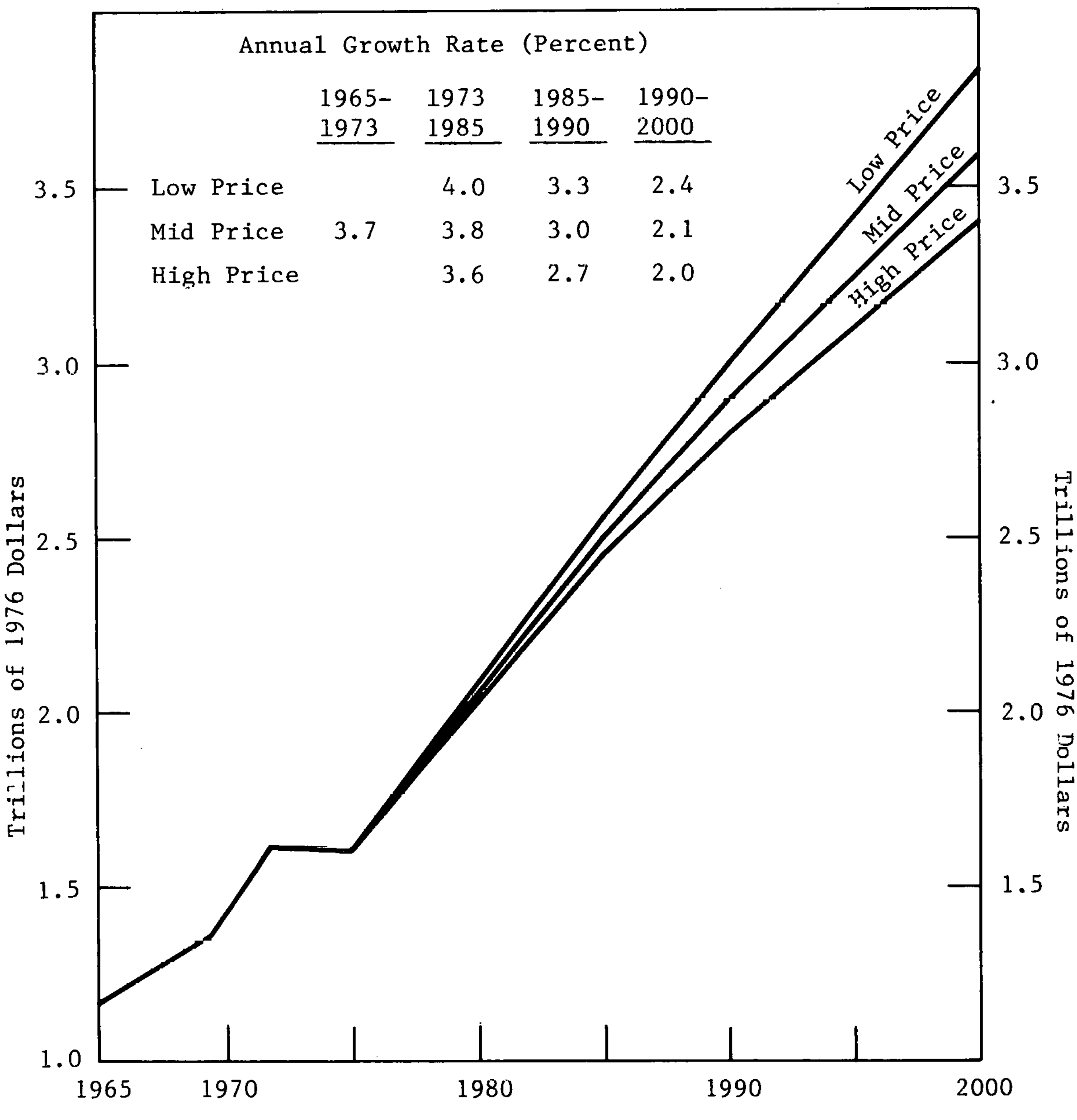


FIGURE 3
REAL GROSS NATIONAL PRODUCT

rate of economic growth is expected to decrease due partly to lower population growth, higher energy costs, and the increasing costs of environmental protection.

Inflation

The extremely high inflation rates experienced in the past decade are assumed to stabilize. In the mid-price scenario average real inflation rates of five percent are expected, with rates of four and seven percent assumed for the low- and high-price scenarios respectively (Figure 4).

Societal Attitudes

Societal attitudes will continue to emphasize improvement of our environment. Interest in energy conservation will increase slowly with increased government pressure and higher energy costs. However, it is not assumed that there will be any major shifts in life style.

Federal Energy Policy

The Federal Government is expected to pursue, with slowly increasing success, the philosophy of President Carter's National Energy Plan toward reducing oil imports and encouraging energy conservation. Deregulation of gas and oil prices is expected by 1985. There will be continued public pressure against the use of nuclear power and less support by the Federal Government. Federal policy will encourage the use of coal and renewable energy resources. There will be continued pressure to enforce compliance with existing environmental policies at a rate compatible with economic growth.

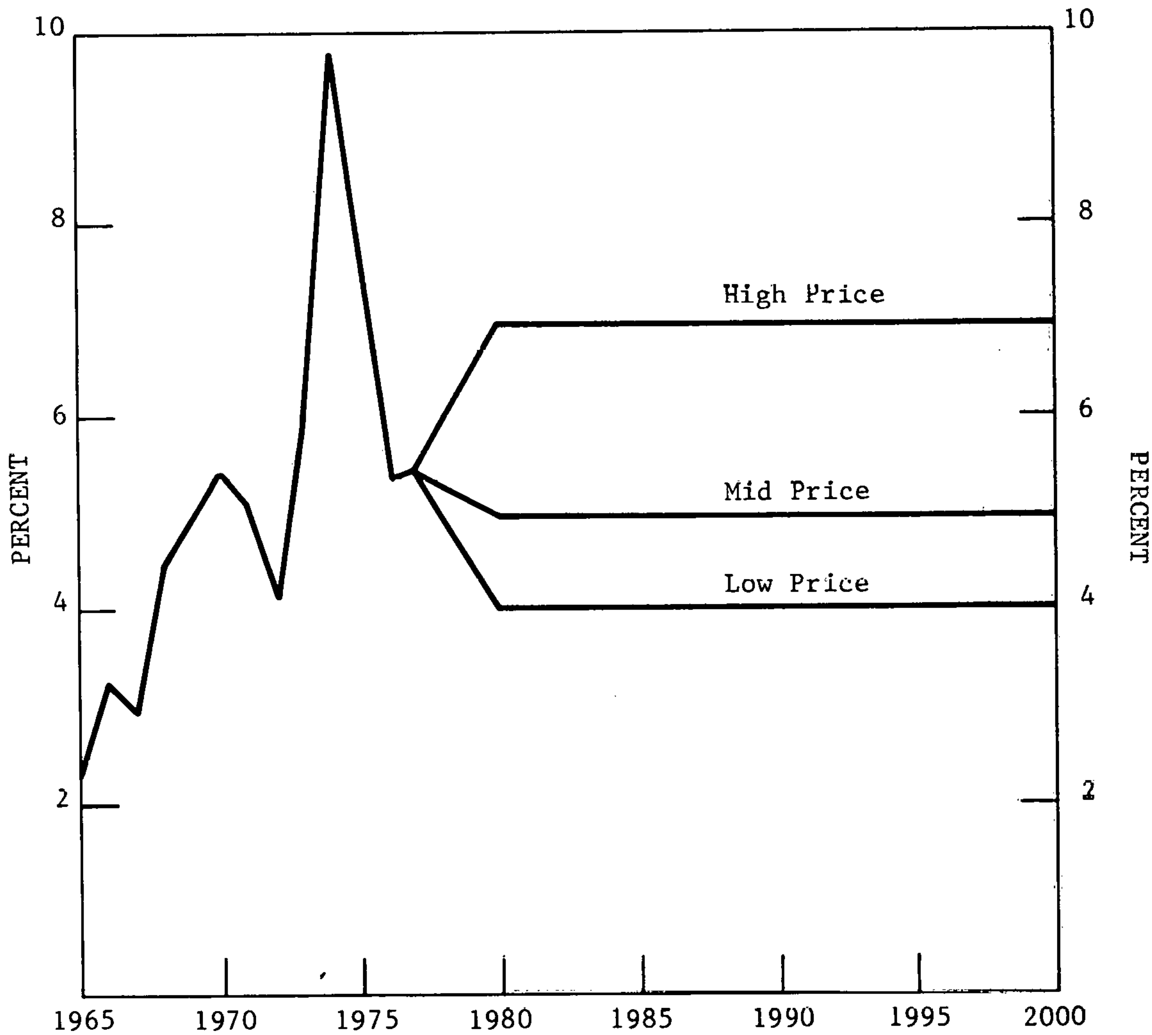


FIGURE 4
INFLATION RATE

New Technologies

New energy technologies that generate cleaner energy more efficiently and that utilize a wider resource base will continue to be developed by both the government and industry. These include more efficient burners for oil and gas, gas and electric heat pumps, solar and wind energy conversion systems, more efficient ways of generating electricity from high sulfur coal without degrading the environment, coal gasification and liquefaction, and the use of shale oil and geothermal energy. It is assumed that as new technologies become economically competitive, they are developed and marketed by industry at a rate consistent with historic experience of technology innovation. It is further assumed that major non-financial barriers to adoption are overcome through normal market forces with a level of Federal intervention consistent with past experience.

ENERGY CONSUMPTION

One of the primary factors that affects estimates of the future market acceptance of solar technologies is the size of the potential market and the mix of competing fuels.

Energy Supply by Resource

In the mid-price scenario, the overall demand for energy increases at a moderate rate with coal and nuclear substituting in ever greater amounts for oil and gas. In addition there is an increased reliance on renewable energy resources such as biomass, hydro, solar, wind and geothermal.[1] These changes are illustrated in Figure 5.

Energy consumption is expected to be inversely proportional to fuel prices ranging from 105 quads in the year 2000 in the high-price scenario to 115 quads in the mid-price case to 132 quads in the low-price case (Figure 6). Higher fuel prices result in lower consumption through a reduction in economic activity (GNP), a more efficient use of resources, and through moderately decreased demand. In each scenario, fuel prices are keyed to the price of oil. The oil price differences of $18, $25 and $32 per barrel are due primarily to differences in the availability of oil. Thus, the consumption of oil changes most dramatically between the three scenarios. U.S. oil consumption, currently at 37 quads, is expected to be 25 quads in the high-price case, 29 quads in the mid-price case and 42 quads in the low-price case. Even though the total consumption of oil is expected to decrease, oil imports will probably continue to rise or remain at the current level of about 17 quads.

<u>Energy Supply by Market Sector</u>

A look at the energy consumption by market sector, Figure 7, shows that the greatest growth is expected in the industrial sector. Industrial demands for energy, which includes petrochemical feedstocks, are expected to respond to higher energy prices by conservation and interfuel substitution. The reduced rate of population

[1]These resources are measured in terms of fossil fuels displaced rather than energy produced.

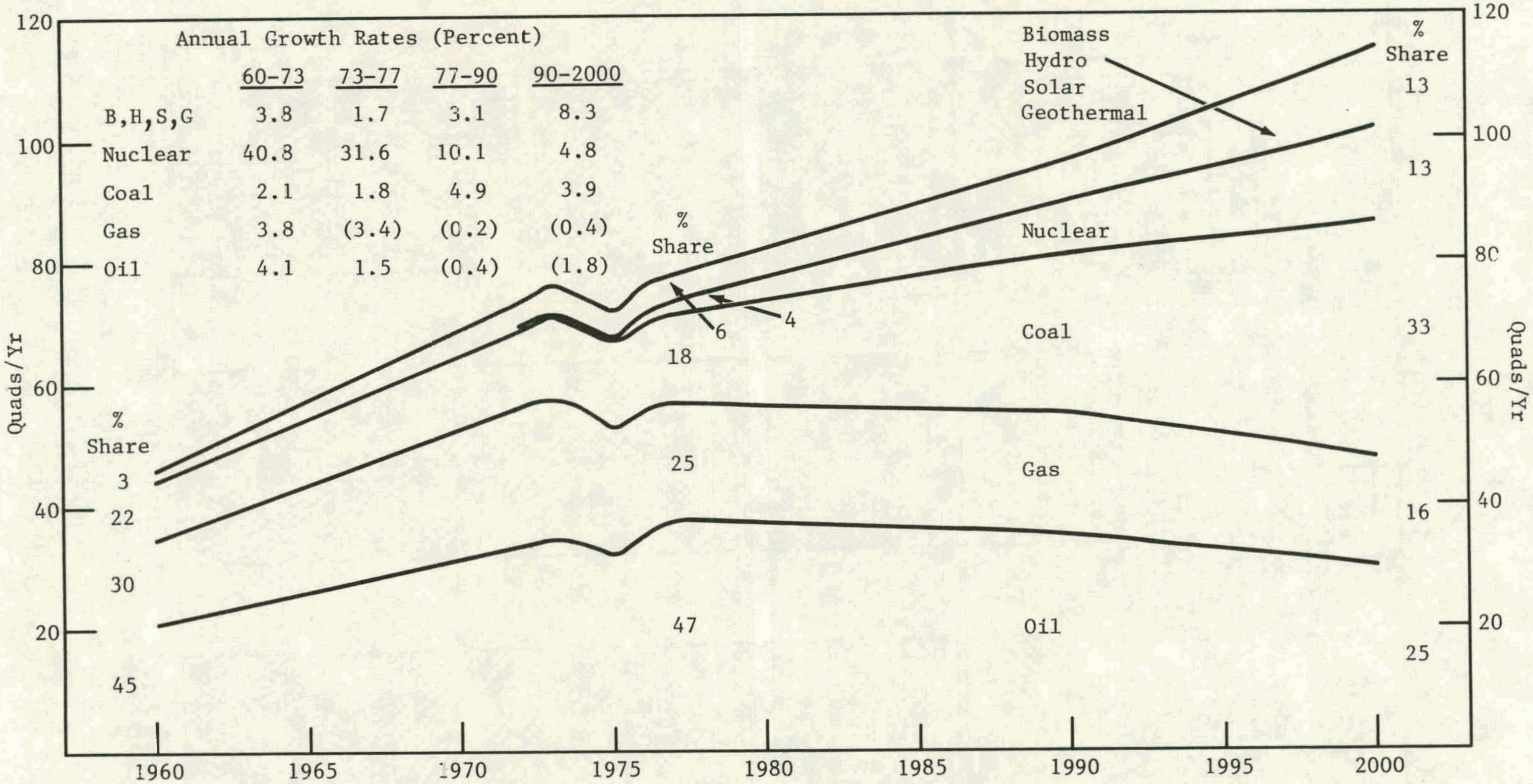


FIGURE 5
U.S. ENERGY SUPPLY BY RESOURCE—MID PRICE SCENARIO

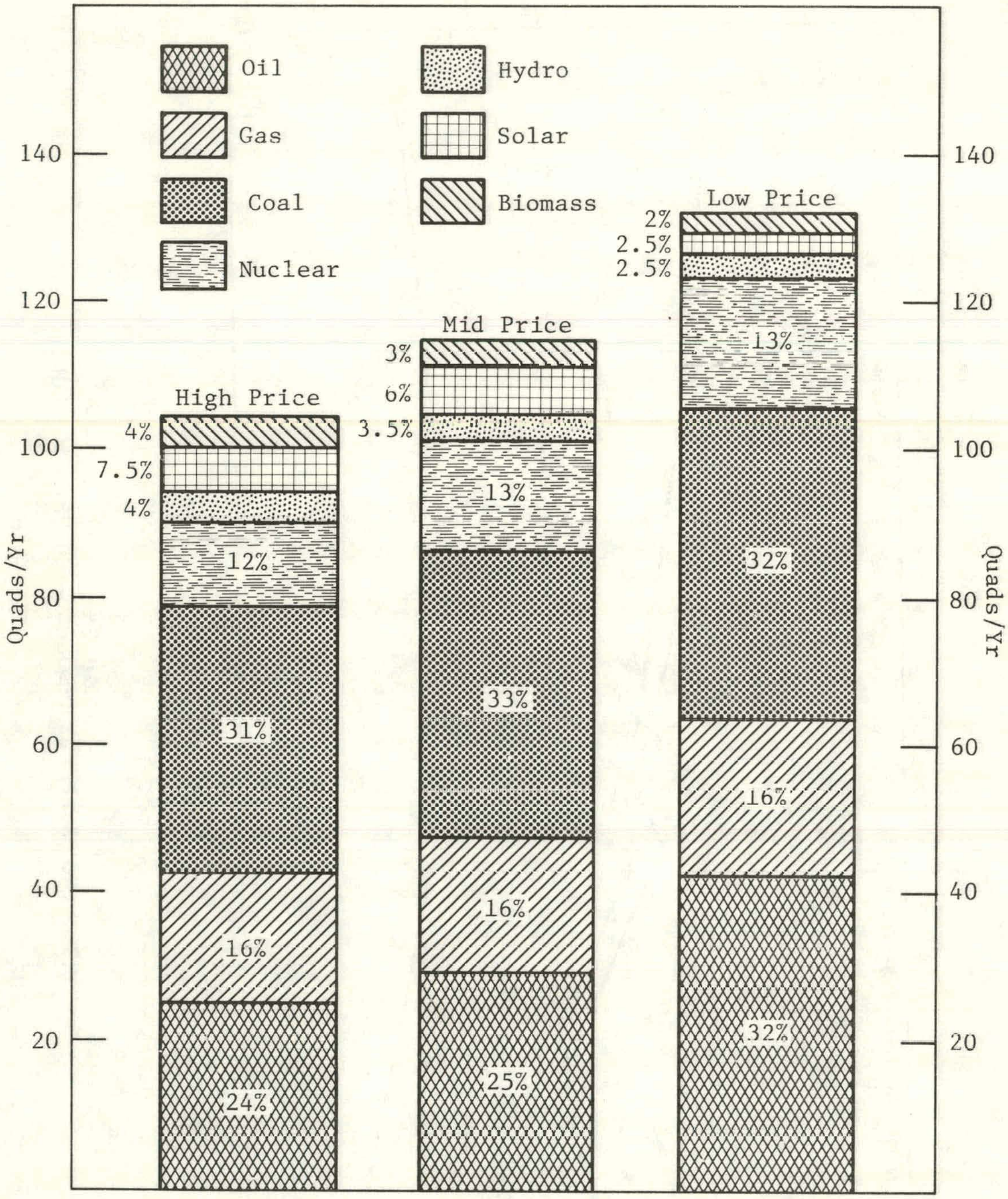


FIGURE 6
U.S. ENERGY SUPPLY BY RESOURCE IN 2000

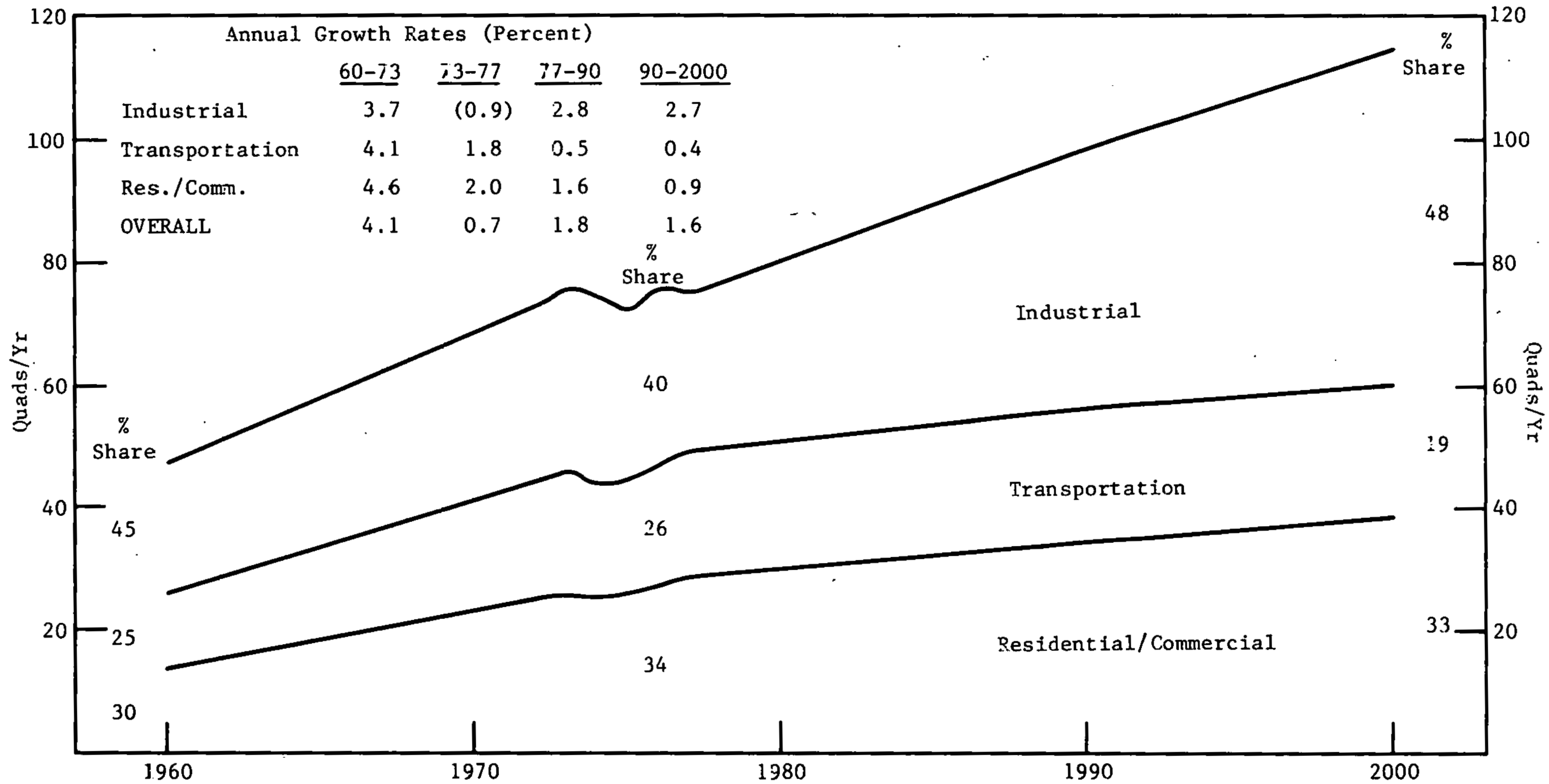


FIGURE 7
U.S. ENERGY SUPPLY BY MARKET—MID PRICE SCENARIO

growth, in addition to energy conservation, will contribute to the dramatic decrease in the growth rate of energy use in the next two decades in the residential/commercial and transportation sectors.

ENERGY PRICES

Different assumptions on the price of oil have been used in defining the three scenarios. It is expected that gas and coal prices will rise in proportion to oil (Figure 8). Gas prices should rise rapidly approaching those of oil by 2000 while coal prices are expected to escalate at a much lower rate. Fuel prices will rise rapidly between now and 1985 due to assumed phased deregulation of gas and oil although not as rapidly as in the period immediately following the oil embargo. The rate of price escalation for fuels will slow down substantially after 1985 as shown in Table I. Electricity prices are expected to continue to rise with an annual growth rate of between 0.6 and 2.5 percent depending upon the scenario. This corresponds to the rise in the price of coal.

The oil prices[1] of $18, $25 and $32 per barrel in 2000 used in defining the scenarios are the prices delivered to industry. The corresponding world oil prices[1] in 2000 are $13.00, $19.20 and $25.45 per barrel respectively. Following deregulation the world oil and the domestic wellhead prices will be approximately the same. The fossil fuel supply prices are shown in Table II along with the assumptions on price markups to each market sector. The prices of

[1]All prices in this report are in 1976 dollars.

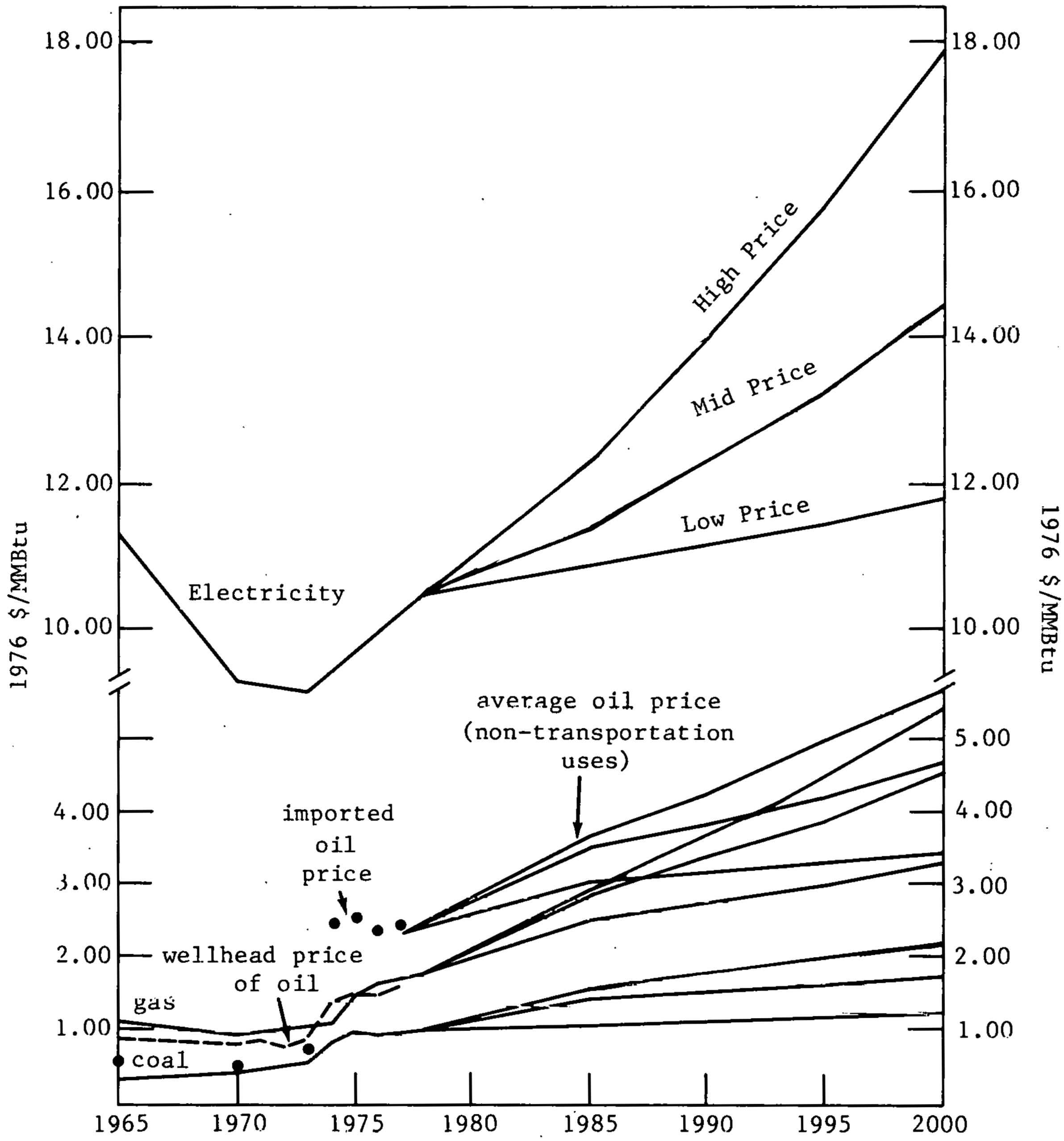


FIGURE 8
DELIVERED FUEL PRICES

TABLE I

ANNUAL GROWTH RATES FOR ENERGY PRICES
(percent per year)

		1965-1973	1973-1978	1978-1985	1985-2000
Electricity	Low	(3.6)	3.3	0.6	0.6
	Mid			1.5	1.5
	High			2.5	2.5
Gas	Low	(1.5)	11.8	5.1	2.0
	Mid			7.4	3.1
	High			7.6	4.2
Oil*	Low	(0.4)	12.5	2.9	1.2
	Mid			6.3	2.5
	High			7.1	3.9
Coal	Low	4.2	13.7	1.3	0.7
	Mid			5.7	1.5
	High			6.4	2.4

*Growth rates on oil given for wellhead prices

TABLE II

FOSSIL FUEL SUPPLY PRICES AND SECTOR MARK-UPS IN 2000
(1976 $/MMBtu)

FUEL	SUPPLY PRICE[1]			REFINING EFFICIENCY	AVERAGE MARKUPS			
	Low	Mid	High		Resid.	Comm.	Indus.	Utility
Oil	2.24	3.41	4.39	0.92	1.84	1.22	0.77	0.70
Gas	2.34	3.49	4.27	0.92	1.34	0.76	0.58	0.64
Coal	0.68	1.25	1.57	0.995	-	-	1.25	0.38

[1] Oil and gas prices are at the wellhead and coal is at the minemouth.

coal, gas and oil as delivered to utilities and industry reflect the new-contract or marginal price rather than the average price. New-contract prices are used because this is the price against which a new solar energy technology must compete. For example, suppose an industry is building a new facility and is considering solar versus coal for generating process heat. It is assumed that a new coal contract will be necessary if the coal-fired boiler is used; therefore the economic comparison of the two systems will be based on the new-contract price of coal.

Supply price elasticities are of interest to assess the reasonableness of the scenarios. The supply price elasticities (shown in Table III) reflect the percentage change in energy consumption for each percent change in supply price. These are within the typical range of elasticities used with the Brookhaven National Laboratory/Dale W. Jorgenson Associates Model.

In addition to sectorial differences, fuel prices also vary considerably by region of the country. Regional solar market penetration analyses have been done for each of the U.S. Census regions. These nine regions are depicted in Figure 9 and the regional fuel prices are shown in Figure 10. The regional price variations (but not the actual prices) were taken from a computer run of the American Gas Association Demand/Market Place Model (TERA-II)[1].

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[1]The scenario used is labeled "Reference Scenario 6/22: House/Senate May Compromise, 1978." It is assumed that gas is deregulated by 1985. Price variations in the year 1990 were used.

TABLE III

AVERAGE SUPPLY PRICE AND ENERGY CONSUMPTION IN THE YEAR 2000

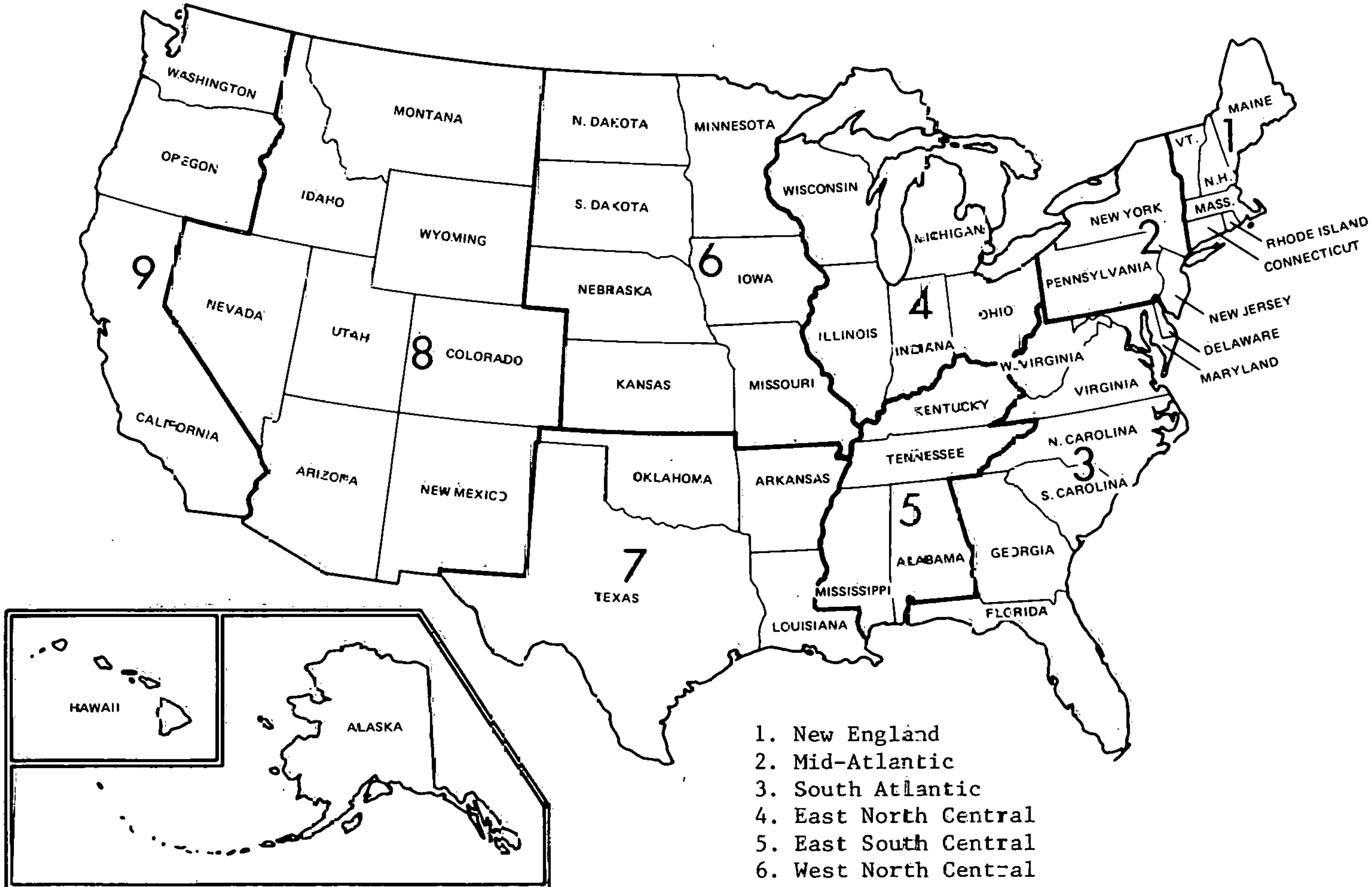
FUEL	LOW PRICE		MID PRICE		HIGH PRICE	
	Supply Price ($/MMBtu)	Consumption[1] (Quads)	Supply Price ($/MMBtu)	Consumption[1] (Quads)	Supply Price ($/MMBtu)	Consumption[1] (Quads)
Oil	2.24	45.7	3.41	36.6	4.39	32.6
Gas	2.34	21.0	3.49	18.2	4.27	17.1
Coal	0.68	48.3	1.25	39.0	1.57	42.3
Nuclear	0.50	17.0	0.70	15.0	0.78	13.0
U.S.	1.46	132	2.15	115	2.78	105

SUPPLY PRICE ELASTICITIES[2]

Scenarios	Elasticity
Low price to mid price	-.36
Mid price to high price	-.35

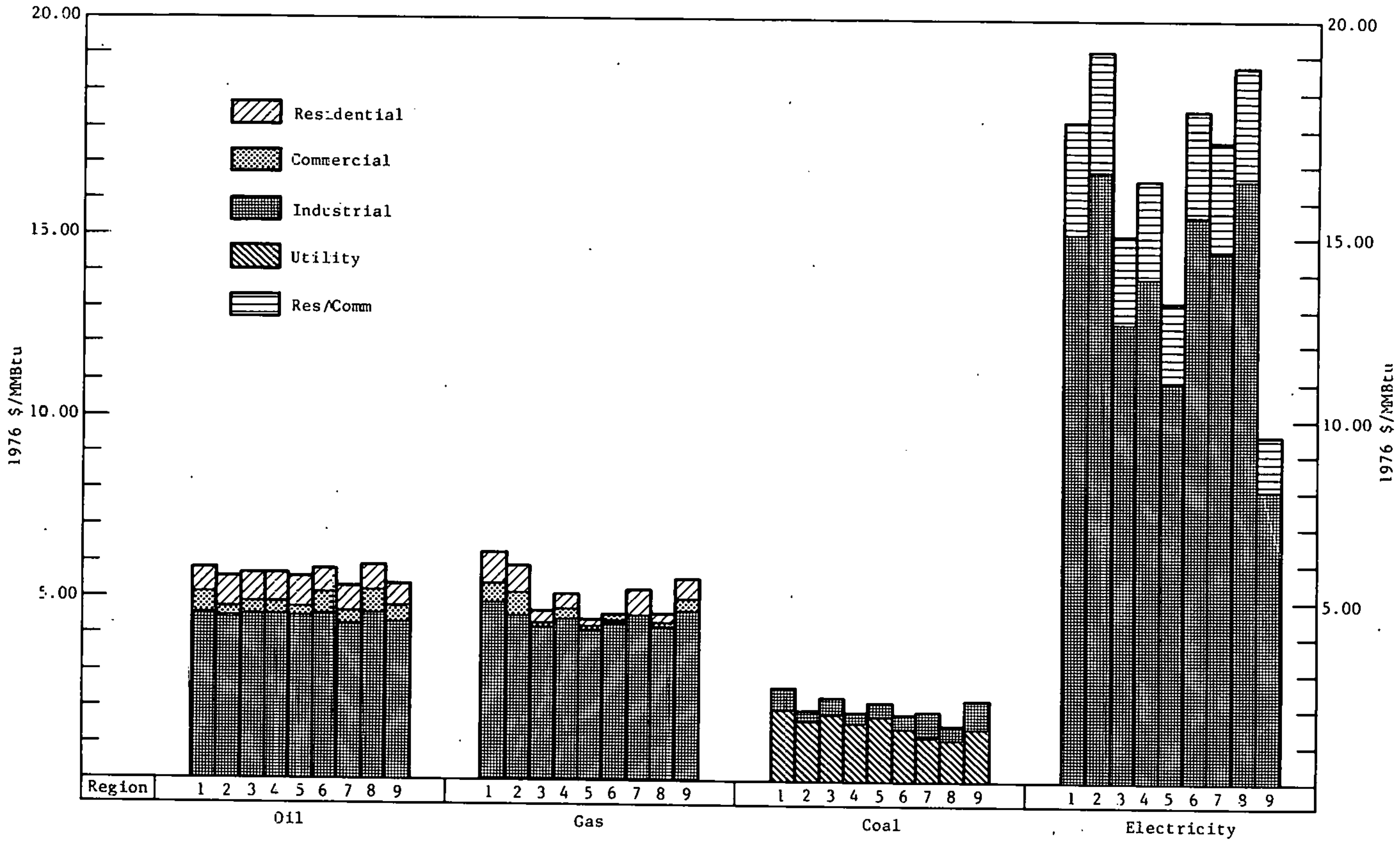
[1]Geothermal and solar are included with oil; biomass and hydro are included with coal.

[2]Supply price elasticity = $\frac{\ln \text{(ratio of energy consumption)}}{\ln \text{(ratio of average supply price)}}$



1. New England
2. Mid-Atlantic
3. South Atlantic
4. East North Central
5. East South Central
6. West North Central
7. West South Central
8. Mountain
9. Pacific

FIGURE 9
U.S. CENSUS REGIONS



REGIONS

1	New England	4	East North Central	7	West South Central
2	Mid Atlantic	5	East South Central	8	Mountain
3	South Atlantic	6	West North Central	9	Pacific

FIGURE 10
REGIONAL AND SECTORIAL DELIVERED FUEL PRICES IN THE YEAR 2000—MID PRICE SCENARIO

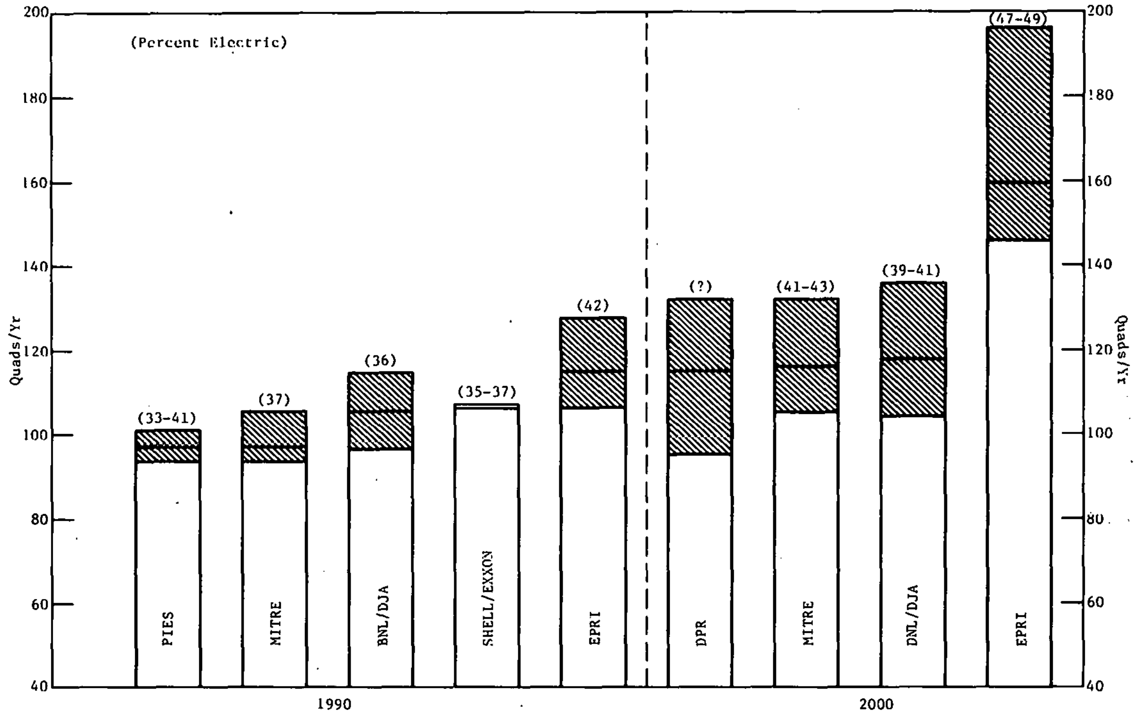
Sectorial differences are based on the current fuel and electricity price variations and projections from TERA-II and the DOE PIES model.

COMPARISON WITH OTHER FORECASTS

In order to assess the reasonableness of the MITRE price/demand scenarios, it is useful to compare them with other forecasts. The forecasts chosen for comparison all reflect to some extent the provisions and philosophy of the National Energy Plan proposed by President Carter in April 1977. Different approaches and methodologies were used including two well known national energy models.

A comparison of energy demand forecasts is illustrated in Figure 11. Except for the EPRI (Electric Power Research Institute) projections, there is a good consensus among the studies chosen. The EPRI low-demand scenario is "based primarily on the objectives and policies described in President Carter's National Energy Plan." This scenario assumes 146 quads of energy consumption in the year 2000 as compared with the MITRE high-demand scenario of 132 quads.

Energy price comparisons are summarized in Figures 12 and 13. Gas and oil prices are expected to continue to rise rapidly through the end of the century in all studies shown. The MITRE scenarios assume that coal prices will also continue to increase although at a lower rate than gas and oil. Both the PIES and the BNL/DJA models indicate a rise in coal prices similar to that of MITRE. The EPRI projections are only slightly lower.



References

PIES - Preliminary runs of the DOE PIES model to examine energy impacts from the NEA legislation passed in October 1978. Tables from the PIES runs were delivered to MITRE accompanying a Memorandum for Omi Walden from Al Alm, October 20, 1978. Low, Mid and High oil-price cases are given.

MITRE - The MITRE Low, Mid and High oil-price cases used for solar commercialization assessment, December 1978.

BNL/DJA - Scenarios developed using the Brookhaven National Laboratory/Dale W. Jorgenson Associates combined model system. Three oil-price cases developed for the DOE Policy and Evaluation Division assuming deregulation of "old" oil. Documented in a letter from Harry Davitian of Brookhaven to Peter Spewak of MITRE dated November 15, 1978.

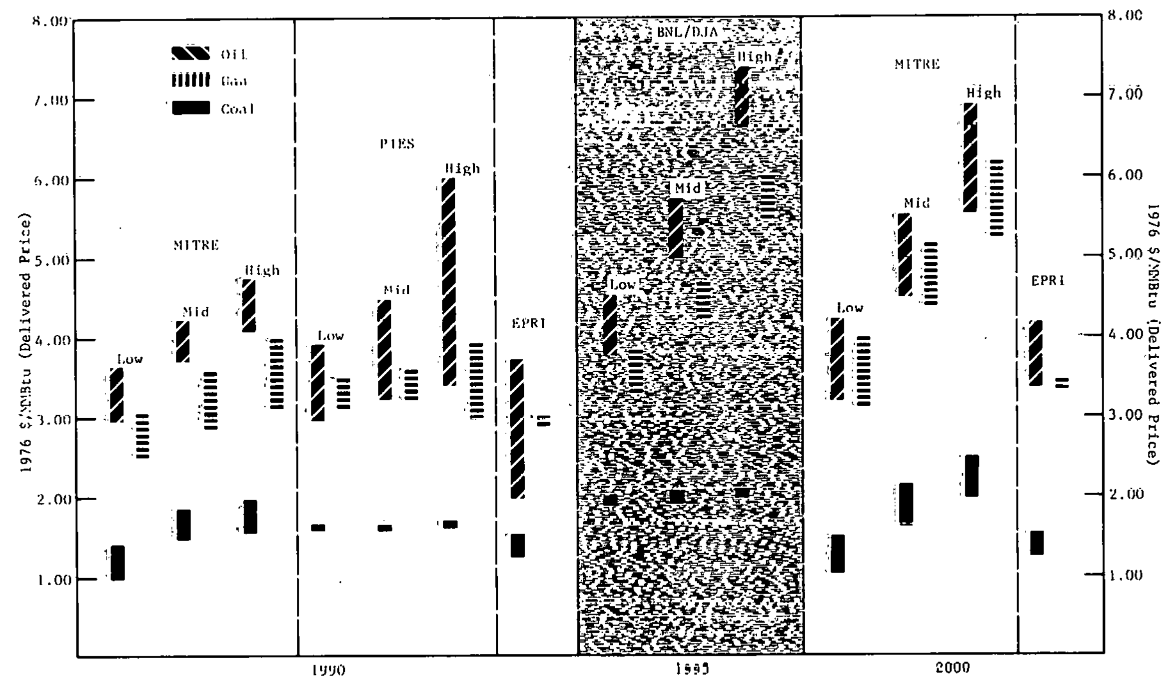
SHELL - The National Energy Outlook 1980-1990. Shell Oil Company, P.O. Box 2463, Houston, Texas 77001. July, 1978.

EXXON - Energy Outlook 1978-1990. EXXON Company, P.O. Box 2180, Houston, Texas 77001. May 1978.

EPRI - DEMAND 77. EPRI EA-621-SR, Volume 1. Electric Power Research Institute, Palo Alto, CA. March, 1978. Three cases are shown: Baseline, High Electricity and Conservation. The Conservation case with 146 quads in the Year 2000 is based on the energy conservation aspects described in the National Energy Plan of April 1977.

DRP - Status Report on Solar Energy Domestic Policy Review, Public Review Copy. Domestic Policy Review Integration Group, Room GB-145, Forrestal Building, Washington, D.C. August 24, 1978.

FIGURE 11
A COMPARISON OF U.S. ENERGY CONSUMPTION PROJECTIONS



References

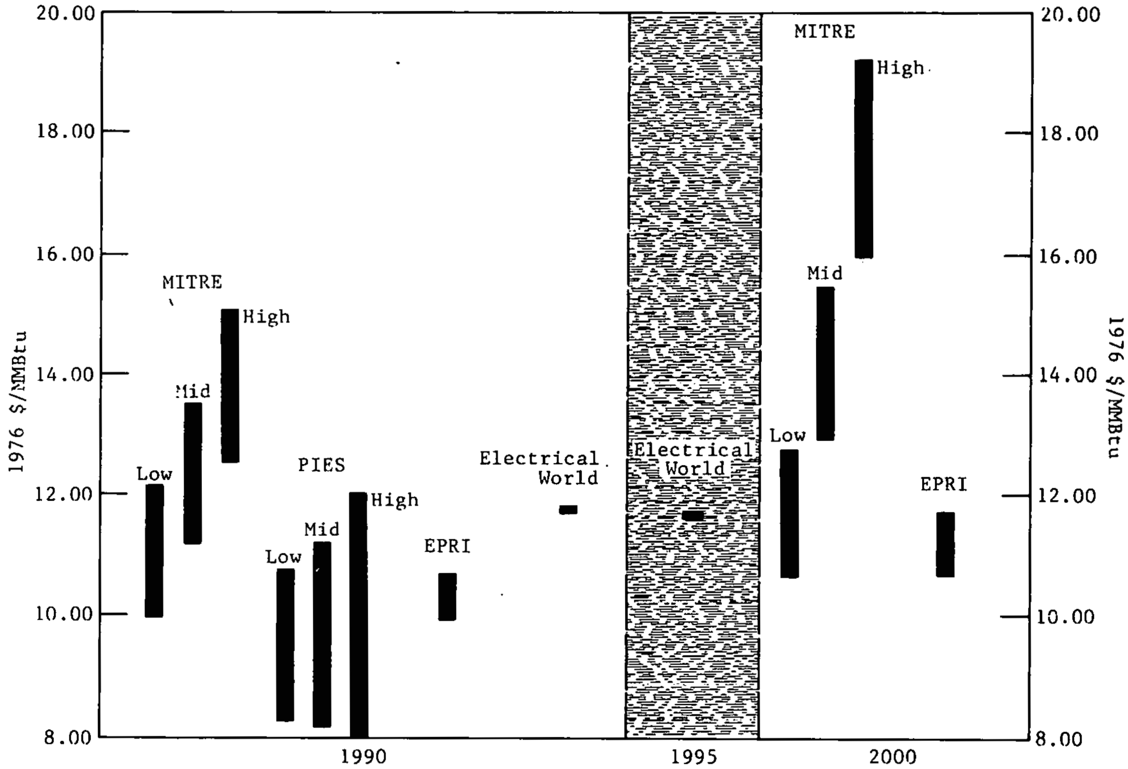
MITRE - The MITRE Low, Mid and High oil-price cases used for solar commercialization assessment, December 1978. Range of prices reflects sectorial price differences.

PIES - Preliminary runs of the DOE PIES model to examine energy impacts from the NEA legislation passed in October 1978. Tables from the PIES runs were delivered to MITRE accompanying a Memorandum for Omi Walden from Al Alm, October 20, 1978. Low, Mid and High oil-price cases are given. Range of prices reflects sectorial price differences.

EPRI - SUPPLY 77. EPRI EA-634-SR. Electric Power Research Institute, Palo Alto, CA. May 1978. Range in oil and coal prices shows low to high expected prices.

BNL/NJA - Scenarios developed using the Brookhaven National Laboratory/Dale W. Jorgenson Associates combined model system. Three oil-price cases developed for the DOE Policy and Evaluation Division assuming deregulation of "old" oil. Documented in a letter from Harry Davitian of Brookhaven to Peter Spewak of MITRE dated November 15, 1978. Range of prices reflects sectorial price differences.

FIGURE 12
COMPARISON OF FOSSIL FUEL PRICES



REFERENCES

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PIES - Preliminary runs of the DOE PIES model to examine energy impacts from the NEA legislation passed in October 1978. Tables from the PIES runs were delivered to MITRE accompanying a Memorandum for Omi Walden from Al Alm, October 20, 1978. Low, Mid and High oil price cases are given. Range of prices reflects sectorial price differences.

EPRI - SUPPLY 77. EPRI EA-634-SR. Electric Power Research Institute, Palo Alto, CA. May 1978. Range shows low to high expected prices.

Electrical World - "28th Annual Electrical Industry Forcast", Electrical World. September 15, 1977.

FIGURE 13
A COMPARISON OF ELECTRICITY PRICES

Other studies, however, indicate that the price of coal will stabilize. The Energy Model Forum published the results of a study in 1978 entitled Coal in Transition which looks at the results of ten different energy models. In a scenario which uses 50 quads of coal in the year 2000, 25 percent more than the mid-price scenario, the median average price of coal is not projected to rise significantly over what it is today. There appears to be a great deal of uncertainty in how the rise in gas and oil prices will affect the price of coal.

The greatest discrepancy in fuel prices is in the projections for electricity prices. In the future, electricity will be generated primarily from coal and nuclear fuels. In MITRE's scenarios, electricity price increases follow those of coal. This gives residential/commercial electricity prices in the year 2000 between $10 (Pacific Region) and $20 (Mid Atlantic Region) per MMBtu for the mid-price case. Industrial prices are over 15 percent lower. These estimates are considerably higher than those made by Electrical World in their "28th Annual Electrical Industry Forecast" and by EPRI. DOE's PIES Model also projects electricity prices considerably lower than those of the MITRE scenarios even though their coal prices are similar.

MARKET SECTOR ASSUMPTIONS

The macroeconomic scenarios are presented at a rather general level. In the analysis of accelerated commercialization of solar energy for which these scenarios were developed, further detail was required in many areas. In particular, further dissaggregration of energy demand is needed in order to estimate future market penetration of solar energy technologies. Expected energy consumption in the year 2000 is broken out for each scenario by market sector and fuel type in Tables IV, V and VI. (Similar tables for the years 1978 and 1990 can be found in the Appendix) It is further disaggregrated in the building sector by energy needed for hot water and for space heating and cooling. In the industrial sector, energy needed for process heat applications is broken out.

Additional information developed on each scenario for the solar impacts analysis is summarized below for the buildings, industrial and utility sectors.

Building Sector

The expected number of residential and commercial buildings (Figure 14) is taken from a General Electric study[1] and is assumed to be the same for all scenarios. The energy demand for hot water and space heating and cooling changes, however, because of varying levels of conservation, conventional system efficiency and fuel mixes. The increases in the number of buildings with conservation and the conservation savings are indicated in Figure 14.

[1]General Electric. Solar Heating and Cooling of Buildings: Phase 0 Feasibility and Planning Study Final Report. Vol. 3: Book 3, Document No-745D4219. General Electric (Space Division). Valley Forge, PA. 1974.

TABLE IV

SCENARIO: LOW PRICE

U.S. ENERGY DEMAND DATA FOR THE YEAR 2000
QUADS - PRIMARY FUEL

USES / FUELS	END-USES: Residential & Commercial: Heat[1]	END-USES: Residential & Commercial: Other	END-USES: Industrial: Process Heat	END-USES: Industrial: Other	END-USES: Transportation	INTERMEDIATE USES: Electric Utility	INTERMEDIATE USES: Synthetic Fuels	GROSS ENERGY USE	PERCENT
PRIMARY									
Oil	3.0	-	4.2	7.8	22.1	4.9	-	42.0	32
Gas	7.0	-	6.3	4.8	1.0	1.9	-	21.0	16
Coal	-	-	10.7	5.8	-	25.7	0.9	42.7	32
Nuclear	-	-	-	-	-	7.0	-	17.0	13
Hydro	-	-	-	0.1	-	3.4	-	3.5	2.5
Solar	1.0	0.1	1.3	-	-	0.9	-	3.3	2.5
Geothermal	-	-	-	-	-	0.4	-	0.4	0.5
Biomass	0.4	-	1.9	-	-	-	0.1	2.4	2
INTERMEDIATE									
Electricity	16.7	11.5	2.8	22.2	0.6	54.2			
Synthetic Fuels	0.2	-	0.3	0.2	0.3		1.0		
TOTAL	28.3	11.5	27.5	40.9	24.0			132.3	

[1] Space heating/cooling and water heating

TABLE V

SCENARIO: MID PRICE

U.S. ENERGY DEMAND DATA FOR THE YEAR 2000
QUADS - PRIMARY FUEL

FUELS \ USES	END-USES					INTERMEDIATE USES		GROSS ENERGY USE	PERCENT
	Residential & Commercial		Industrial		Transportation	Electric Utility	Synthetic Fuels		
	Heat[1]	Other	Process Heat	Other					
PRIMARY									
Oil	2.0	-	2.0	5.0	18.2	2.0	-	29.2	25
Gas	6.1	-	6.8	4.0	0.8	0.5	-	18.2	16
Coal	-	-	4.4	4.9	-	24.8	3.8	37.9	33
Nuclear	-	-	-	-	-	15.0	-	15.0	13
Hydro	-	-	-	0.2	-	3.8	-	4.0	3.5
Solar	2.0	0.5	2.1	0.1	-	2.4	-	7.1	6
Geothermal	-	-	-	-	-	0.5	-	0.5	0.5
Biomass	0.6	-	2.2	-	-	-	0.6	3.4	3
INTERMEDIATE									
Electricity	16.1	10.5	1.9	19.7	0.8	49.0			
Synthetic Fuels	0.5	-	0.6	1.1	2.2		4.4		
TOTAL	27.3	11.0	20.0	35.0	22.0			115.3	100.0

[1] Space heating/cooling and water heating

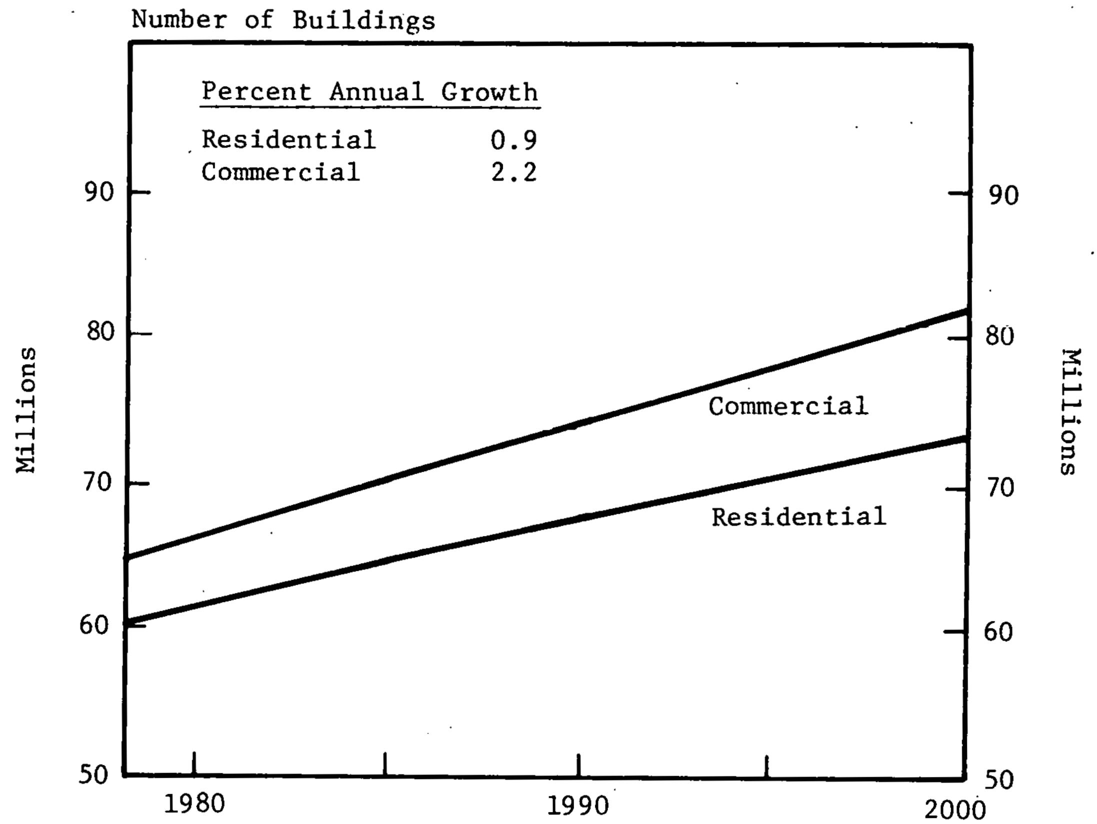
TABLE VI

SCENARIO: HIGH PRICE

U.S. ENERGY DEMAND DATA FOR THE YEAR 2000
QUADS - PRIMARY FUEL

FUELS \ USES	END-USES: Residential & Commercial: Heat[1]	Residential & Commercial: Other	Industrial: Process Heat	Industrial: Other	Transportation	INTERMEDIATE USES: Electric Utility	Synthetic Fuels	GROSS ENERGY USE	PERCENT
PRIMARY									
Oil	1.1	-	1.3	4.6	16.7	1.5	-	25.2	24
Gas	6.0	-	6.2	3.9	0.7	0.3	-	17.1	16
Coal	-	-	3.3	3.3	-	21.5	4.8	32.9	31.5
Nuclear	-	-	-	-	-	13.0	-	13.0	12.5
Hydro	-	-	-	0.2	-	3.9	-	4.1	4
Solar	2.4	0.6	2.3	0.2	-	2.5	-	8.0	7.5
Geothermal	-	-	-	-	-	0.6	-	0.6	0.5
Biomass	0.7	-	2.4	-	-	0.1	1.2	4.4	4
INTERMEDIATE									
Electricity	14.1	9.3	1.1	17.8	1.1	43.4			
Synthetic Fuels	0.9	-	1.1	1.5	2.5		6.0		
TOTAL	25.2	9.9	17.7	31.5	21.0			105.3	100.0

[1] Space heating/cooling and water heating



CONSERVATION PACKAGE (above low price case)

Percentage of Buildings with Conservation

	1978	1985	1990	2000
Mid Price	10	12.5	15	20
High Price	10	12.5	15	20

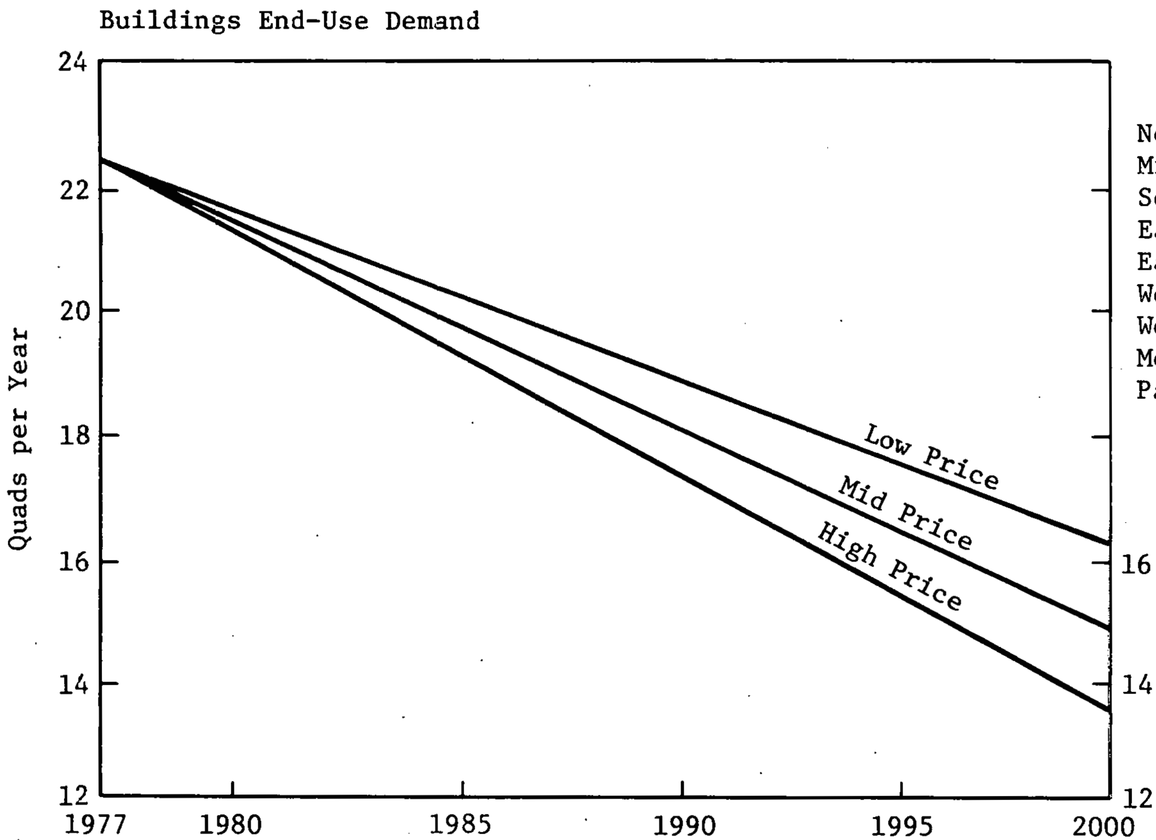
Percentage Decrease in End-Use Demand from Conservation Package

	New	Retrofit
Mid Price	40	30
High Price	50	50

FIGURE 14
RESIDENTIAL COMMERCIAL BUILDING INVENTORY

Building end-use demand, that is, the fuels and electricity purchased, is expected to decrease over time as shown in Figure 15. This is so in spite of the expected increase in the number of buildings and the increase in primary energy demand. Two main factors account for the decrease in purchased fuels. The first and foremost is the increased performance of conventional heating systems, particularly the heat pump. By the year 2000, the average winter-time coefficient of performance (COP) of the heat pump is expected to be about 2.5 and it is assumed that over half of the electric space heating load will be satisfied by heat pumps. Today's electric heating loads are serviced primarily by electric resistance heaters with a COP of 0.98. Gas and oil furnaces which today are assumed to operate at about 0.55 COP are expected to show improved efficiencies in the mid- and high-price scenarios primarily because of higher efficiency furnaces and the introduction of gas heat pumps. Current and expected energy demand and average COP's can be found in the Appendix. Building demand, end-use demand and primary energy consumption are given for each scenario.

The second factor contributing to the decrease in end-use demand in residential and commercial buildings is the shift from gas and oil to electricity. Currently less than 15 percent of the energy purchased for hot water and space heating and cooling for buildings is electricity (Table VII). This is expected to increase to about 35 percent by the year 2000. Since electricity is used over twice as



Regional Breakout

New England	3%
Mid Atlantic	21%
South Atlantic	20%
East North Central	14%
East South Central	7%
West North Central	6%
West South Central	16%
Mountain	4%
Pacific	9%

In the Year 2000 57% of the End-Use Demand is for Residential Buildings and 43% for Commercial Buildings

FIGURE 15
END-USE DEMAND FOR RESIDENTIAL AND COMMERCIAL BUILDINGS

efficiently as gas and oil in end-use, the amount of energy purchased on a Btu basis is considerably less. This reduction in end-use demand does not carry over to primary demand, however, because of conversion, transmission, and distribution losses associated with electricity.

TABLE VII

PERCENTAGE OF FUELS PURCHASED IN BUILDING SECTOR

FUEL	1976	2000		
		LOW PRICE	MID PRICE	HIGH PRICE
Gas	60	46	48	55
Oil	26	19	14	9
Electricity	13	35	38	36

Federal solar commercialization activities are the most intense in the building sector. In addition to RD&D, there are programs to remove legal and institutional barriers, promote information exchange, and improve customer confidence. These programs are spearheaded by energy tax credits. In the residential sector, the tax credit is 30 percent of the first $2000 and 20 percent of the next $8000 for a maximum of $2200. This tax credit expires at the end of 1985. The commercial tax credit for solar equipment of ten percent of the installed price is good through 1982. These tax credits apply to passive and active thermal, wind and photovoltaics but not to wood stoves.

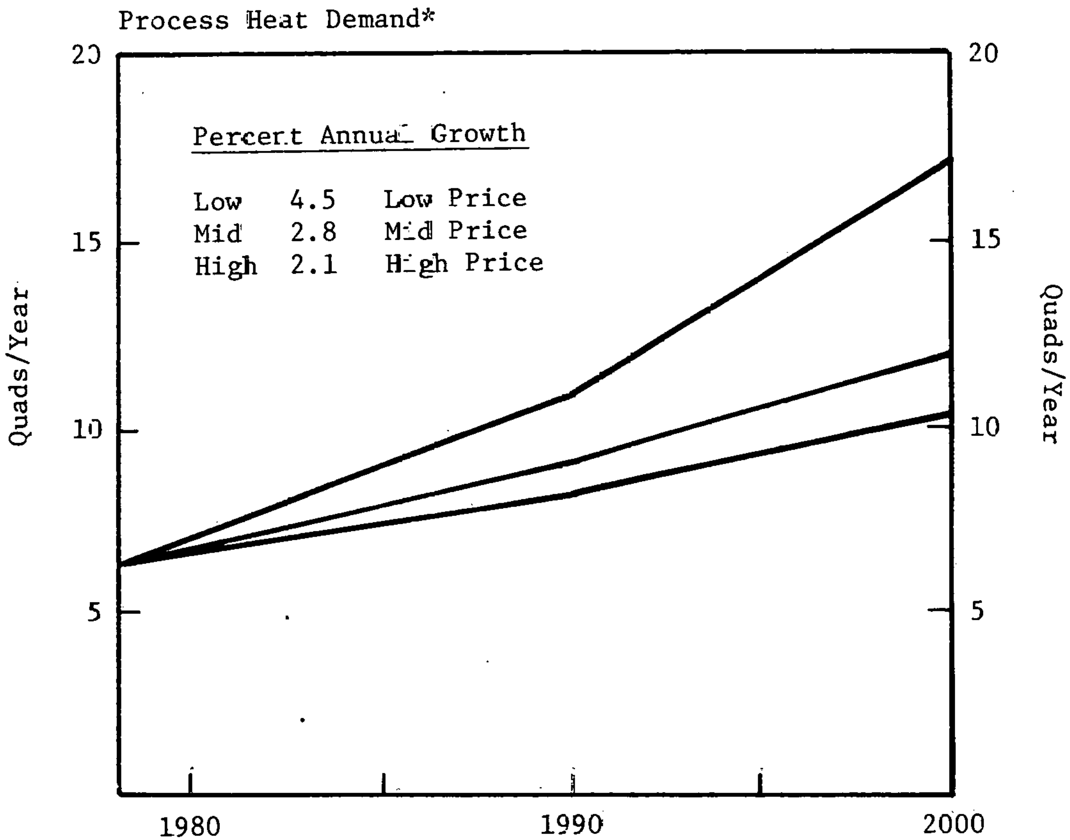
The Industrial Sector

Solar technologies are used in the industrial sector to produce heat (air, water and steam) for process heat applications and to generate electricity. The process heat demand is disaggregrated by temperature range as shown in Figure 16. This was necessitated because significantly different solar technologies are used in each temperature range--from a solar pond for low temperature water to tracking concentrator collectors for steam. Assumptions on the regional demand for process heat based on the nine census regions are shown in Figure 16. This represents the expected use in 1990 and indicates a shift of industry to the south.

Certain financial parameters are of importance when computing life cycle costs of solar systems. The before-tax weighted cost of capital varies between scenarios reflecting the general inflation rate. Inflation is assumed to be four, five and seven percent in the low-, mid- and high-price scenarios, respectively. In addition, the National Energy Act allows an additional ten percent investment tax credit, over the usual ten percent, for solar process heat equipment including equipment using biomass as a fuel. This tax credit expires at the end of 1982.

The Electric Sector

The demand for electricity is expected to grow at a faster rate than the overall demand for energy. Central utility solar technologies are configured differently--for example with varying amounts



*Service Demand or Demand to Process; not Demand for Primary Fuel

Regional Breakout

New England	2.9%
Mid Atlantic	14.3%
South Atlantic	11.4%
East North Central	22.9%
East South Central	8.6%
West North Central	5.7%
West South Central	22.9%
Mountain	2.9%
Pacific	8.4%
	100.0%

Breakout by Temperature Range

Air	50-100°C	2.9%
Air	100-150°C	4.2%
Air	>150°C	21.0%
Water	40-60°C	1.3%
Water	60-80°C	1.7%
Water	80-100°C	1.7%
Steam	100-150°C	30.2%
Steam	>150°C	37.0%
		100.0%

Weighted Cost-of-Capital

Low Price	8.5%
Mid Price	12.0%
High Price	18.0%

FIGURE 16
INDUSTRIAL PROCESS HEAT DEMAND

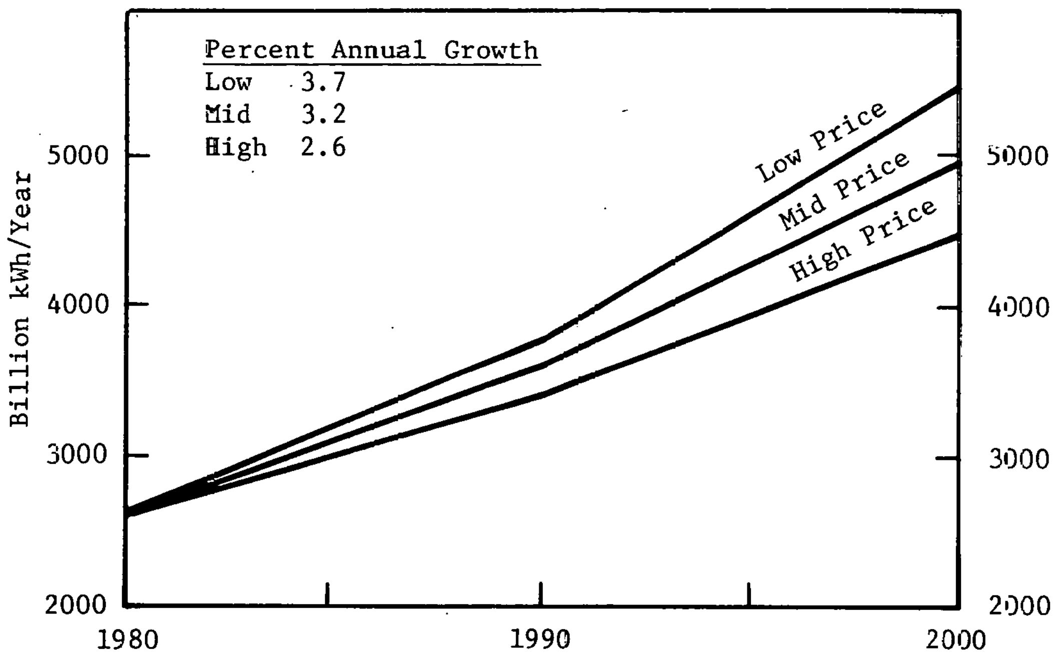
of storage--to operate at different capacity factors. Therefore, it is necessary to specify how much of the total electric demand will be generated by plants at varying capacity factors. These assumptions, as well as the regional breakouts, are given in Figure 17.

The weighted cost of capital for centralized electric utilities, shown in Figure 17, incorporates common and preferred equity as well as straight debt. This includes the return on investment to share holders. There are no solar tax credits for electric utilities in the National Energy Act.

PRELIMINARY SOLAR PROJECTIONS

Projections of solar utilization to the year 2000 have been made for the mid-price scenario. These projections and associated impacts are based on the solar commercialization incentives in the National Energy Act (Table VIII) and are breifly summarized here. For further detail, the reader is referred to two MITRE documents which report the results of the first phase of the solar commercialization study. The first is titled Toward a National Plan for the Accelerated Commercialization of Solar Energy--Phase One: The Implications of a National Committment, MTR-79W00004, Volume I and contains national and regional impacts of accelerated levels of solar utilization. The second report is directed toward regional planners and contains detailed regional impacts and guidelines for regional implementation planning. It is titled Toward a National Plan for the

Electricity Demand



Regional Breakout

New England	4%
Mid Atlantic	15%
South Atlantic	18%
East North Central	18%
East South Central	10%
West North Central	7%
West South Central	11%
Mountain	5%
Pacific	12%

Weighted Cost-of-Capital

Low Price	10.02%
Mid Price	10.16%
High Price	13.72%

DEMAND BREAKOUT BY LOAD TYPE

Type	Percentage	Average Capacity Factor
Baseload	65	0.70
Intermediate	22	0.45
Semi-Peaking	11	0.25
Peaking	2	0.03

FIGURE 17
DEMAND FOR ELECTRICITY

Accelerated Commercialization of Solar Energy--Guidelines for Regional Planning, MTR-79W00004, Volume II.

TABLE VIII

SOLAR TAX INCENTIVES OF THE NATIONAL ENERGY ACT

SECTOR	TAX CREDIT
Residential	30% of the first $2000; 20% of the next $8000; maximum of $2200; through 1985.
Commercial	10%; through 1982
Industrial	10%; through 1982
Utility	None

Conceptual Framework

A broad definition of solar technologies is used which includes wind, hydroelectric and the use of biomass for heat, fuels and electricity. The technologies and the applications to which they can be used are summarized in Table IX.

The projections were developed, for the most part, from computer market penetration models[1] which simulate on a year-by-year basis market decision to purchase solar and conventional technologies in each market sector to satisfy a given energy demand. The market penetration models require data (both current and future) on the following:

[1]Rebibo, K., et al. A System for Projecting the Utilization of Renewable Resources: SPURR Methodology. MTR-7570. The MITRE Corporation, McLean, VA. September 1977.

TABLE IX

SOLAR TECHNOLOGIES BY MARKET SECTOR

MARKET SECTOR/APPLICATION	Animal Waste	Wood Conversion	Biomass Electric	OTEC	Hydro Electric	Solar Total Energy Systems	Biomass Thermal	Solar Thermal Electric	Photovoltaics	Wind	Passive	Thermal
RESIDENTIAL												
Hot Water												x
Heating			x								x	x
Cooling												x
Electricity									x	x		
COMMERCIAL												
Hot Water												x
Heating			x								x	x
Cooling												x
Electricity									x	x		
INDUSTRIAL												
Low Temp. (To 100°C)												x
Med. Temp. (100-350°C)						x	x					x
High Temp. (Over 350°C)						x	x					x
Electricity					x	x		x	x	x		
UTILITY												
Base			x	x	x					x		
Intermediate			x		x			x	x	x		
Semi-peaking								x	x			
Peaking												
Fuel Savers								x	x	x		
SYNTHETIC FUELS												
Methanol		x										
Synthetic Crude Oil		x										
Ammonia		x										
Synthetic Natural Gas	x	x										

- size of the potential market
- solar technology costs and expected cost reductions (learning 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

Clearly there is a great deal of uncertainty in these data which carries over into the solar market penetration estimates. However, these estimates are useful in improving our understanding of the solar commercialization process and in providing information for mid- and long-range planning. Because a consistent analytical framework is used, the sensitivity of the market penetration projections to various levels of commercialization can easily be compiled.

The estimates of solar market acceptance discussed here are based on the current level of national commitment and do not assume accelerated levels of commercialization.

The annual energy savings from solar technologies in the year 2000 are expected to be about 14.5 quads. This includes 4.9 quads of hydroelectric and biomass combustion currently in place. This is a success-oriented scenario based on the following:

- existing federal and state financial incentives including those of the recently enacted National Energy Act

- current technology development programs, program cost goals, and commercial availability dates

- the current level of non-financial commercialization programs directed toward obtaining public visibility, information exchange and dissemination, and the removal of legal and institutional barriers extended to each technology as it matures

- a willingness by industry to produce and market the systems in a timely fashion

- market acceptance of solar technologies based on the competitive economic position of the technologies tempered by a market lag function

Current State of Solar Industry

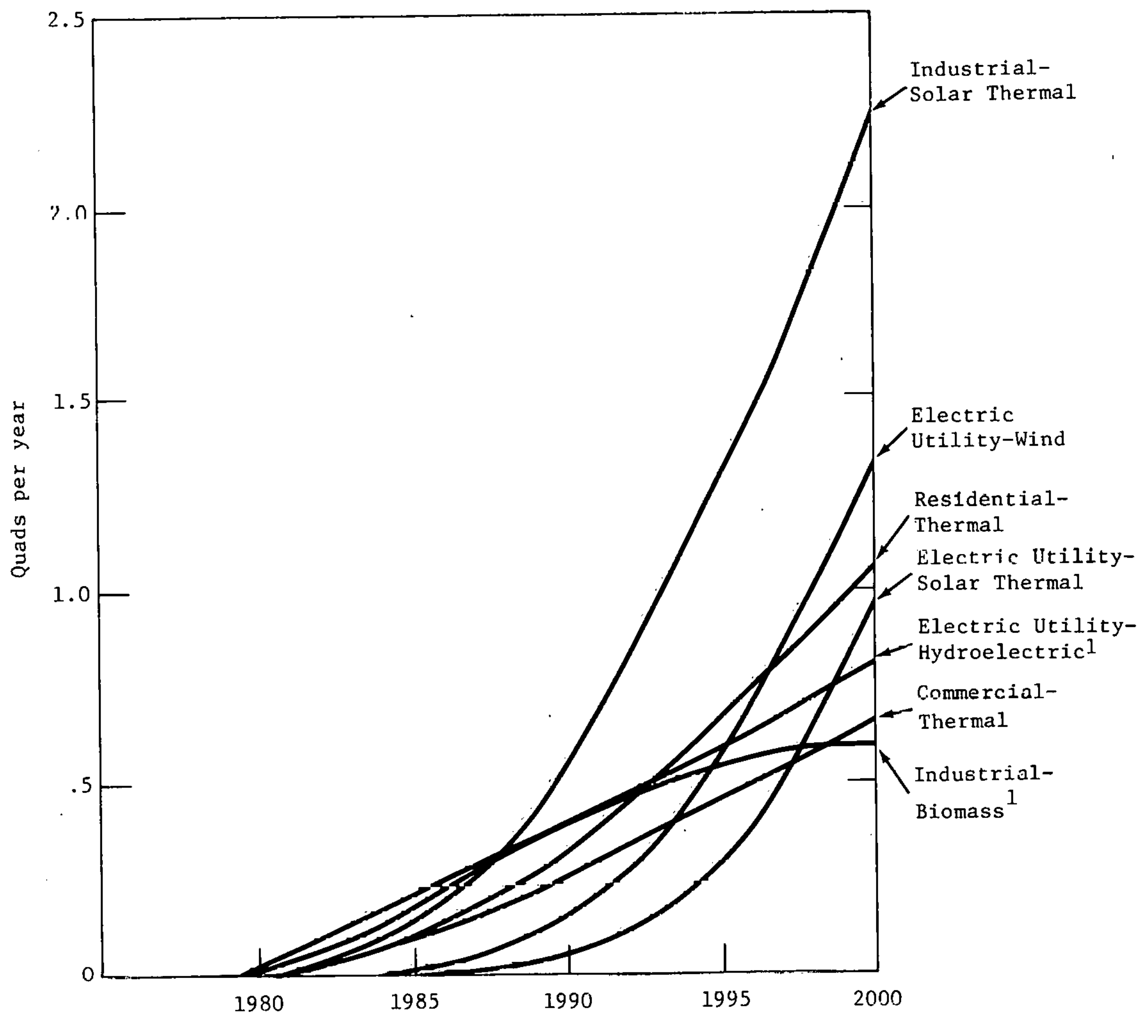
In terms of energy savings, hydroelectric is today's largest solar technology. It is supported by a mature industry with considerable federal assistance (approximately $1 billion in 1977 including pro-rated electricity subsidies). The other major solar technology today is the use of biomass by industry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

Although still small in terms of national energy savings, new solar industries are beginning to establish commercial markets for solar hot water and space heating systems, buildings designed with passive solar systems, and small-scale wind machines. There are currently approximately 60,000 buildings with active solar thermal systems (excluding swimming pool heaters), about 90 percent of which are hot water systems. 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 enjoyed commercial success in the past, is showing 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 2000 to 3000 per year. In addition, there are approximately 1000 wind generators in place producing electricity. About 100 to 200 are added each year.

Projections of National Impacts

Significant new energy savings are expected to begin around 1985 and escalate rapidly through the turn of the century (see Figure 18 and Table X). Near-term (1985) new 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.

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 machines and passive solar building designs are expected. In the industrial sector, solar process heat systems will contribute 0.5 quads and biomass utilization for process heat will increase about 0.4 quads over the 1.6 quads currently used. Central electric utility technologies will begin to come on line around 1986.



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

FIGURE 18
GROWTH OF MAJOR SOLAR TECHNOLOGIES—REFERENCE CASE

TABLE X

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 Elec.	--	--	--	0.02
	Total Energy	--	--	--	0.01
	S.S. Hydro.	--	--	--	0.15
Electric Utility	Wind	--	--	0.15	1.32
	Solar Thermal	--	--	0.05	0.96
	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

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, some of which will be small-scale systems (less than 15 MW) at existing dams, will increase by 0.4 quads over the present level of 3.0 quads.

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

These projections imply that 12 percent of our nation's energy will be provided by solar energy in the year 2000. This will require a significant national investment in capital and resources. It is estimated that private and federal expenditures of about $330 billion (1976$) will be required between 1980 and 2000. The manufacture and installation of solar technologies will represent a significant portion of the U.S. industrial activity. Approximately one million persons will be employed by the turn of the century in the production of steel, glass, aluminum, copper and concrete and the manufacture,

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[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.

installation and maintenance of the solar systems. Annual sales of the new solar industries (excluding hydroelectric and industrial biomass) are expected to increase rapidly (Figure 19) to approximately $35 billion in the year 2000. Current annual sales for General Motors are approximately 55 billion dollars. This will represent an approximately 70-fold increase over current solar sales and result in the creation of a significant industry. The numbers of systems operating in 1985, 1990 and 2000 are shown in Table XI.

Projections of Regional Impacts

Regional utilization of solar technologies varies because of differing fuel prices, energy demand, climate, availability of biomass and hydro resources, and local incentive programs. Solar projections have been disaggregrated to the Census Regions, displayed earlier in Figure 9. Greater market penetration is generally expected in southern and western regions where insolation and hydro resources are greater. The regional projections for the year 2000 are summarized in Figures 20 and 21. Additional detail on the expected energy savings and numbers of systems on technology can be found in the Appendix.

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. Wind and biomass are important renewable resources in this region. Over 35 electric util-

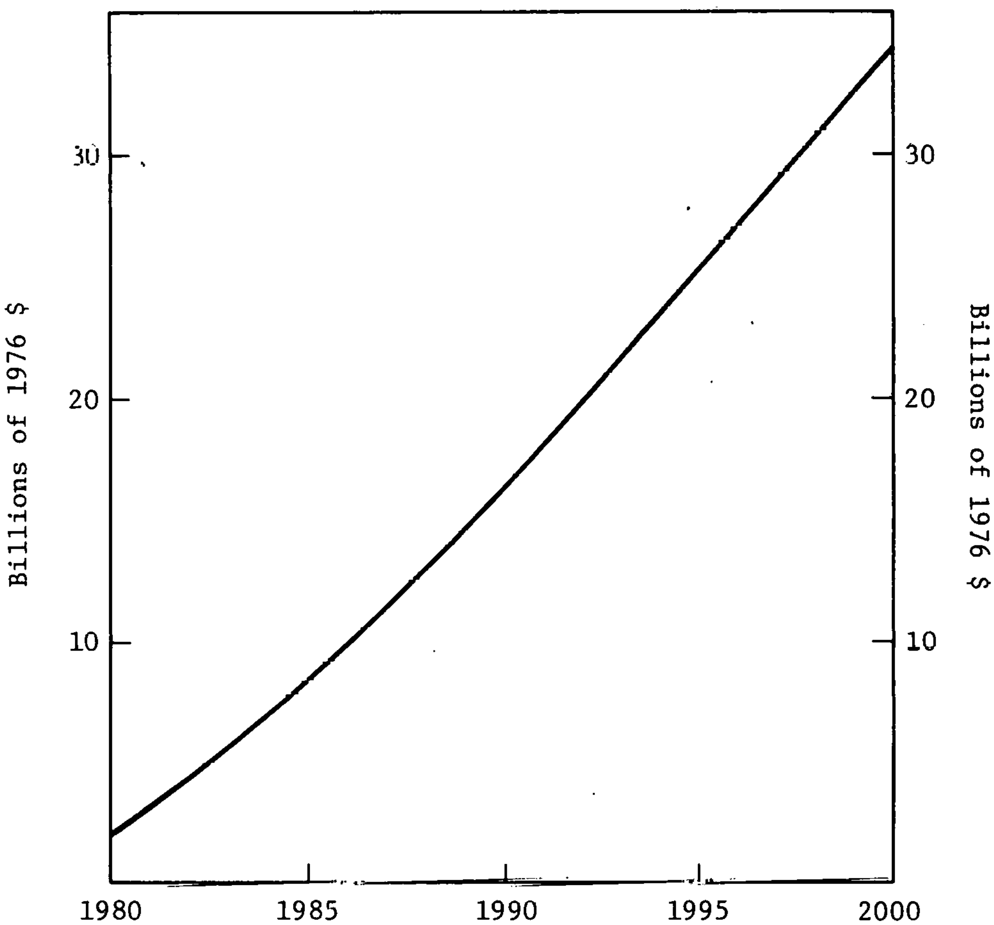


FIGURE 19
ANNUAL SOLAR SALES

TABLE XI

NUMBER OF SOLAR ENERGY SYSTEMS SOLD BY THE YEAR 2000

TECHNOLOGY	MARKET SECTOR	SYSTEM SIZE	1985	1990	2000
Thermal hot water	Residential	35-50 sq. ft.	4,170,000	9,350,000	25,550,000
	Commercial	160-175 sq. ft.	150,000	360,000	810,000
Thermal heating and hot water	Residential	115-130 sq. ft.	1,320,000	2,600,000	6,690,000
	Commercial	1115-1250 sq. ft.	130,000	290,000	600,000
Thermal cooling, heating, and hot water	Residential	120-240 sq. ft.	170,000	300,000	950,000
	Commercial	1835-1920 sq. ft.	90,000	170,000	380,000
Passive heating	Residential	150-350 sq. ft.	150,000	970,000	4,870,000
	Commercial	700-2600 sq. ft.	10,000	40,000	130,000
Small-scale wind	Residential	4 kWe	154,000	1,040,000	6,350,000
	Commercial	40 kWe	290	5,000	26,000
	Industrial	200 kWe	3	590	3,915
Large-scale wind	Industrial	5 modules of 2.5 MW	0	25	84
	Utility	100 MWe	0	21	358
Solar Thermal Electric	Industrial	500-750 kWe and	0	107	827
		14 MWe	0	36	261
	Utility	100 MWe	0	11	285
Photovoltaics	Residential	3.4 kWe	21,000	700,000	6,000,000
	Commercial	54-66 kWe	0	2,960	32,135
	Industrial	460-540 kWe and	0	0	655
		13-15 MWe	0	0	145
	Utility	100 MWe	0	0	6
Ocean Thermal	Utility	400 MWe	0	0	3
Biomass Electric	Utility	46 MWe	0	6	13
Thermal low temperature[1]	Industrial	100,000 sq. ft.	161	620	3,669
Thermal medium temperature[1]	Industrial	100,000 sq. ft.	2,740	10,396	25,166
Thermal high temperature[1]	Industrial	100,000 sq. ft.	392	1,479	12,703
Solar Total Energy Systems	Industrial	500,000 sq. ft.	0	1	48

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

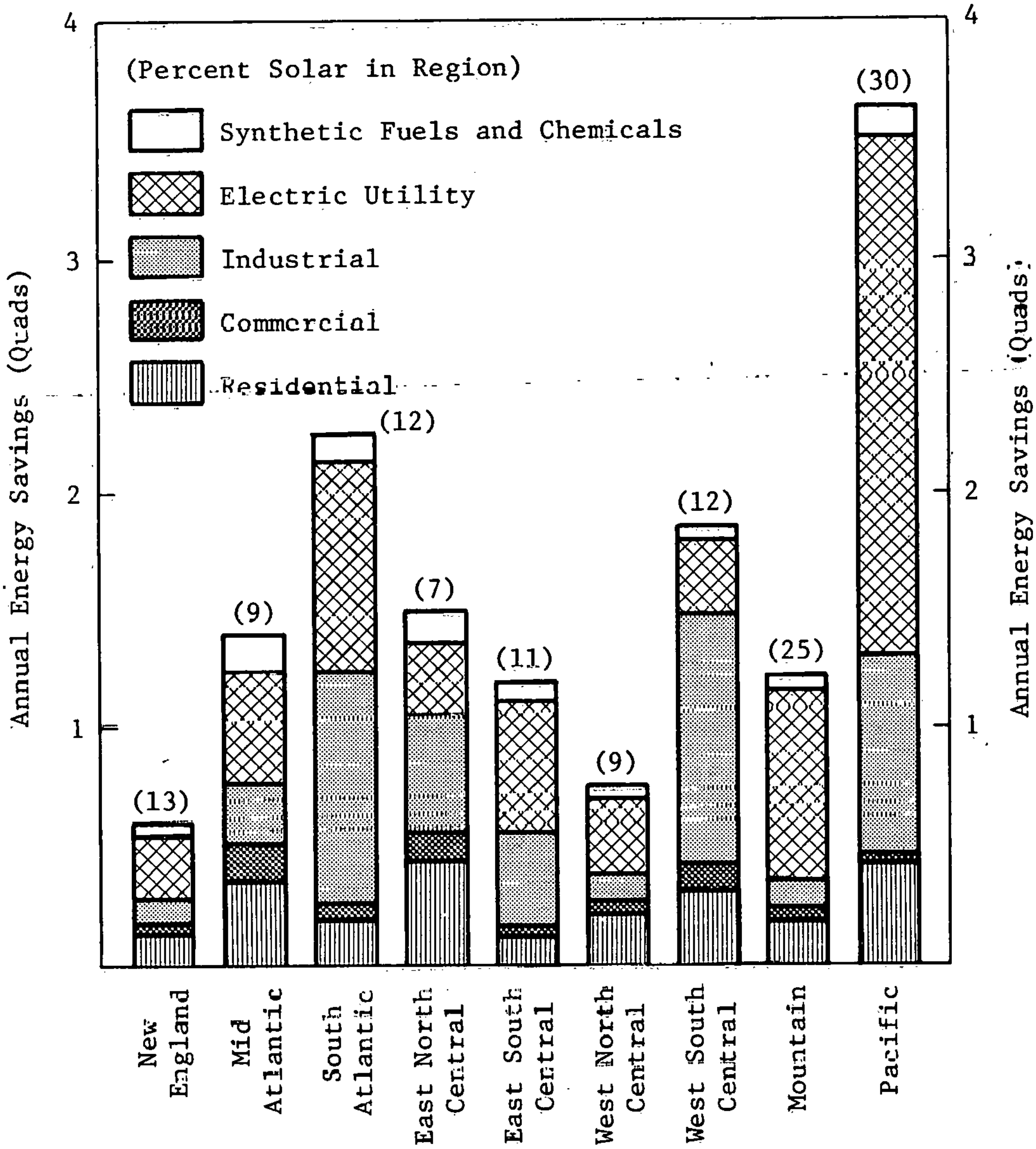


FIGURE 20
REGIONAL SOLAR MARKET PENETRATION BY MARKET SECTOR IN THE YEAR 2000

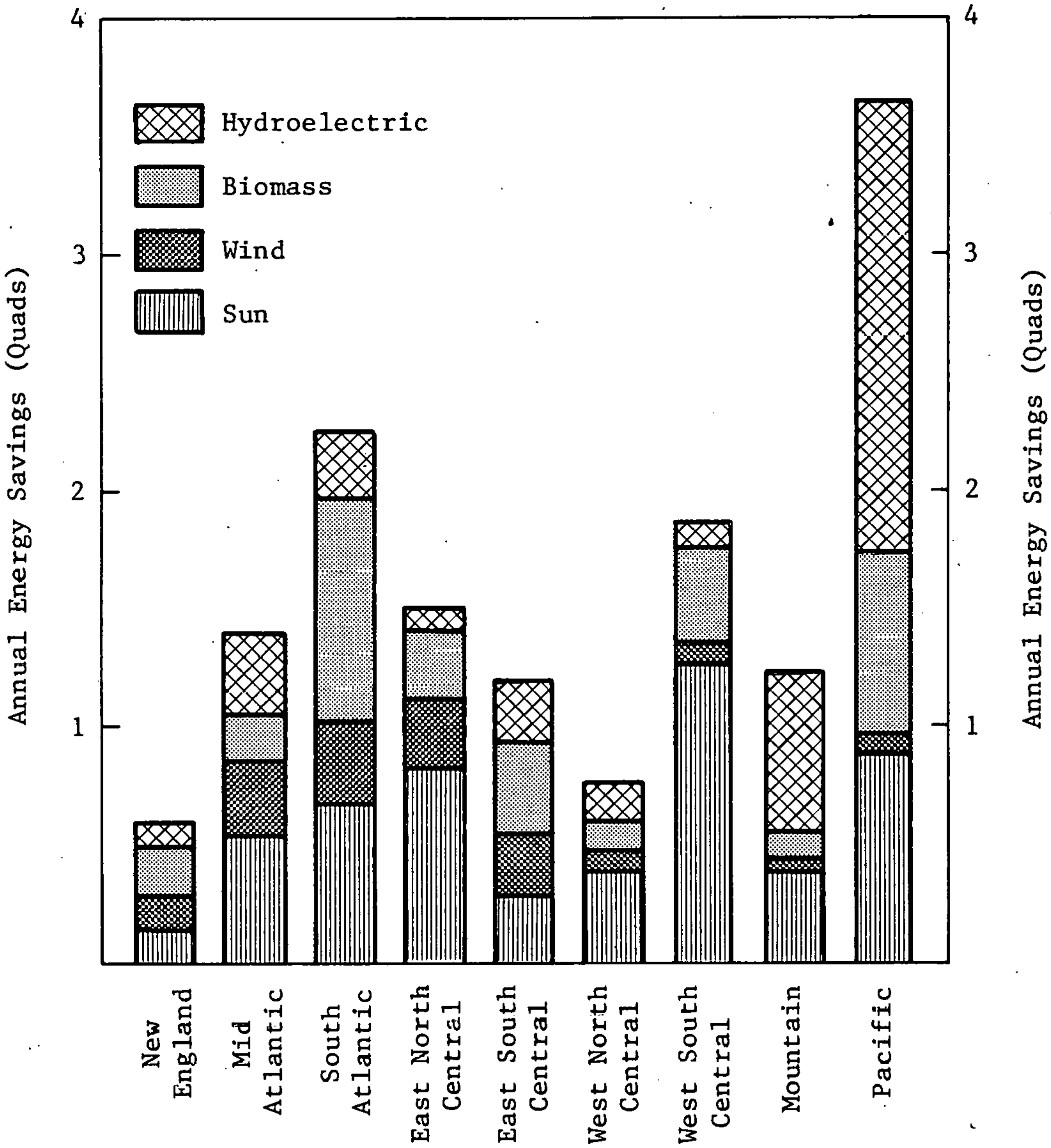


FIGURE 21
REGIONAL SOLAR MARKET PENETRATION BY RESOURCE IN THE YEAR 2000

ity 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 eight percent of the energy needs in the Mid Atlantic Region in the year 2000 with the National Energy Act incentives. Solar heating and cooling of buildings and wind systems are expected to displace sizeable amounts of energy in this region. It is estimated that there will be over five million homes with active solar systems and about 65 100-MWe wind systems installed by the year 2000.

The South Atlantic Region. The South Atlantic Region will be the second largest user of solar energy. Every solar technology shows promise, partly because of high fuel prices and partly because of 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 purposees 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. It is expected, however, to use more square feet of solar collectors for heating and cooling of buildings than any other region with almost five million systems in place by 2000.

[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.

Agricultural and industrial process heat and wind energy conversion system will also be important with about eight thousand process heat systems and 66 utility sized wind systems 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 the year 2000. The major contributors are wind, biomass and hydroelectric with approximately 69 large-scale wind systems and energy savings of 0.4 quads from biomass and 0.25 quads from hydroelectric.

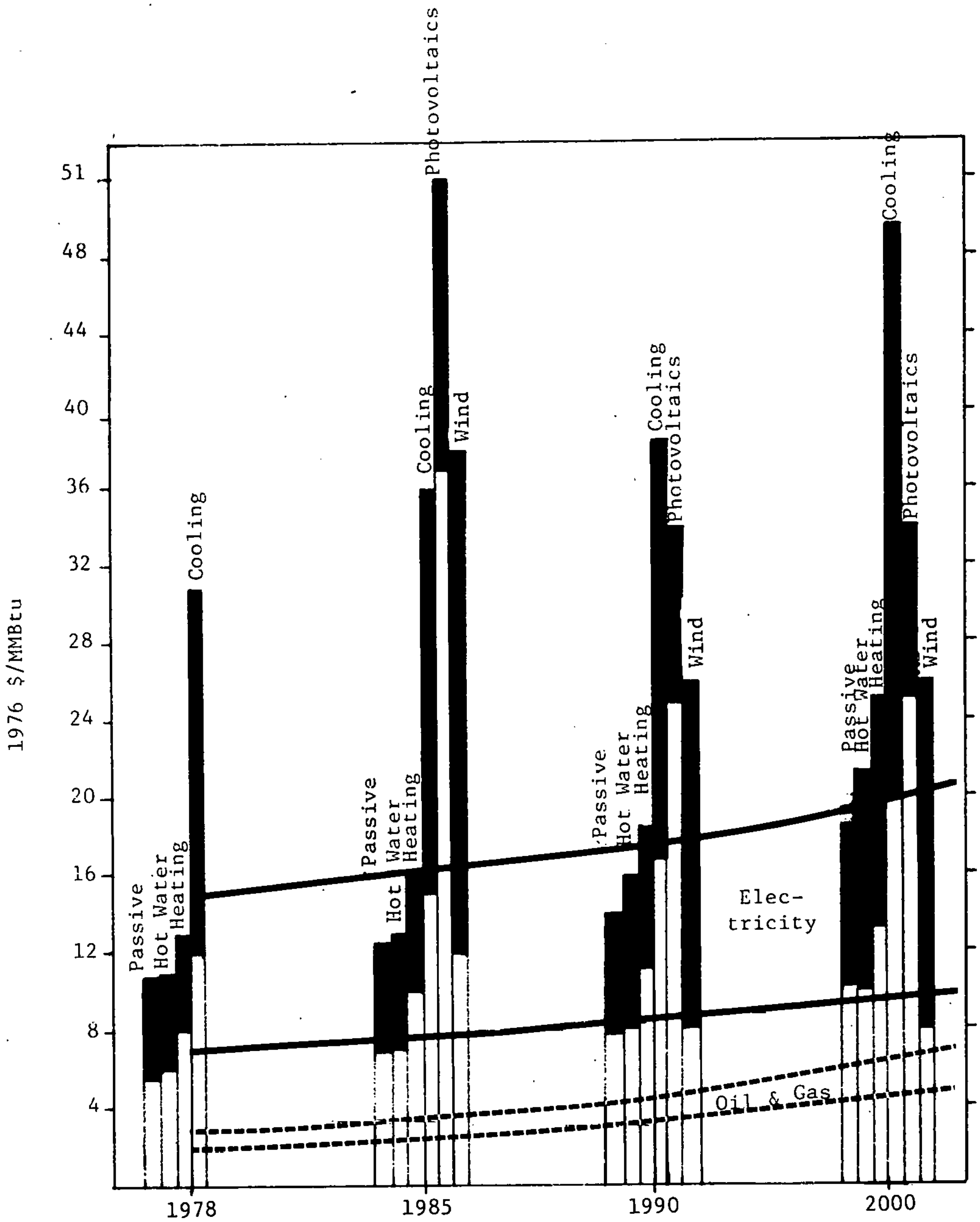
The West North Central Region. It is estimated that solar technologies will satisfy about 12 percent of the energy demand in the West South Central Region by the turn of the century. Large industrial energy demand and good insolation are responsible for making this region the largest user of solar process heat technologies with over 17,000 systems expected to be operating by the year 2000. Other large contributors include biomass, heating and cooling of buildings (4 million systems) and central utility solar thermal electric (63 systems each 100 MWe).

The Mountain Region. In spite of low prices for coal and electricity, solar technologies are expected to supply 25 percent of this region's energy requirements in the year 2000. Projections indicate that hydroelectric (0.5 quads) and central utility solar thermal electric with 35 systems will be major contributors.

The Pacific Region. The Pacific Region is the most favorable for solar energy with 30 percent of the region's energy needs expected to come from solar in the year 2000. Most of this is from hydroelectric. Out of the estimated 3.4 quads of solar, 1.9 quads are hydroelectric. Other solar technologies are expected to do well as this region has an ample supply of biomass, wind and sun. The year 2000 projections include 4.8 million residential and commercial buildings with active or passive solar systems, almost 10,000 industrial process heat systems, 17 utility sized wind systems and 75 utility solar thermal electric systems.

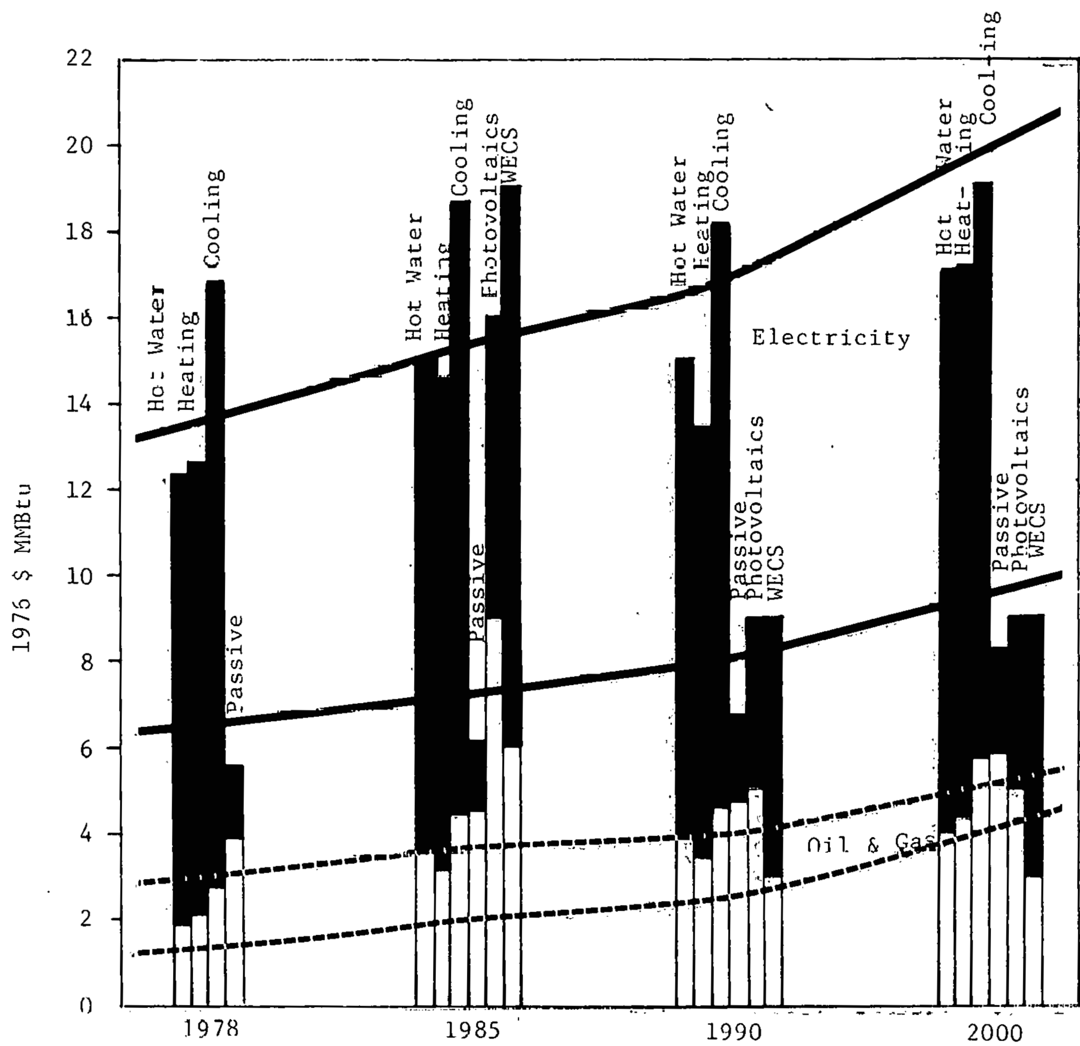
Comparative Energy Costs

The competitive position of solar technologies relative to alternative conventional technologies is shown in Figures 22 through 26 for the various market sectors. In general, solar technologies become increasingly competitive as cost reductions in solar manufacturing reduce solar system costs and as the costs of competing fossil fuels increases. In the near-term, active and passive heating and hot water systems compare favorably with electricity for residential and commercial applications. Industrial solar process heat systems are competitive with electric and oil systems. By 1990, wind and solar thermal systems for utility applications are expected to be cost-competitive with coal generation technologies in several regions of the U.S. The electric utility solar technologies shown in Figure 25 are configured with storage or backup to compete with conventional intermediate load systems. Solar electric technologies without storage or backup used as fuel savers are more cost competitive.



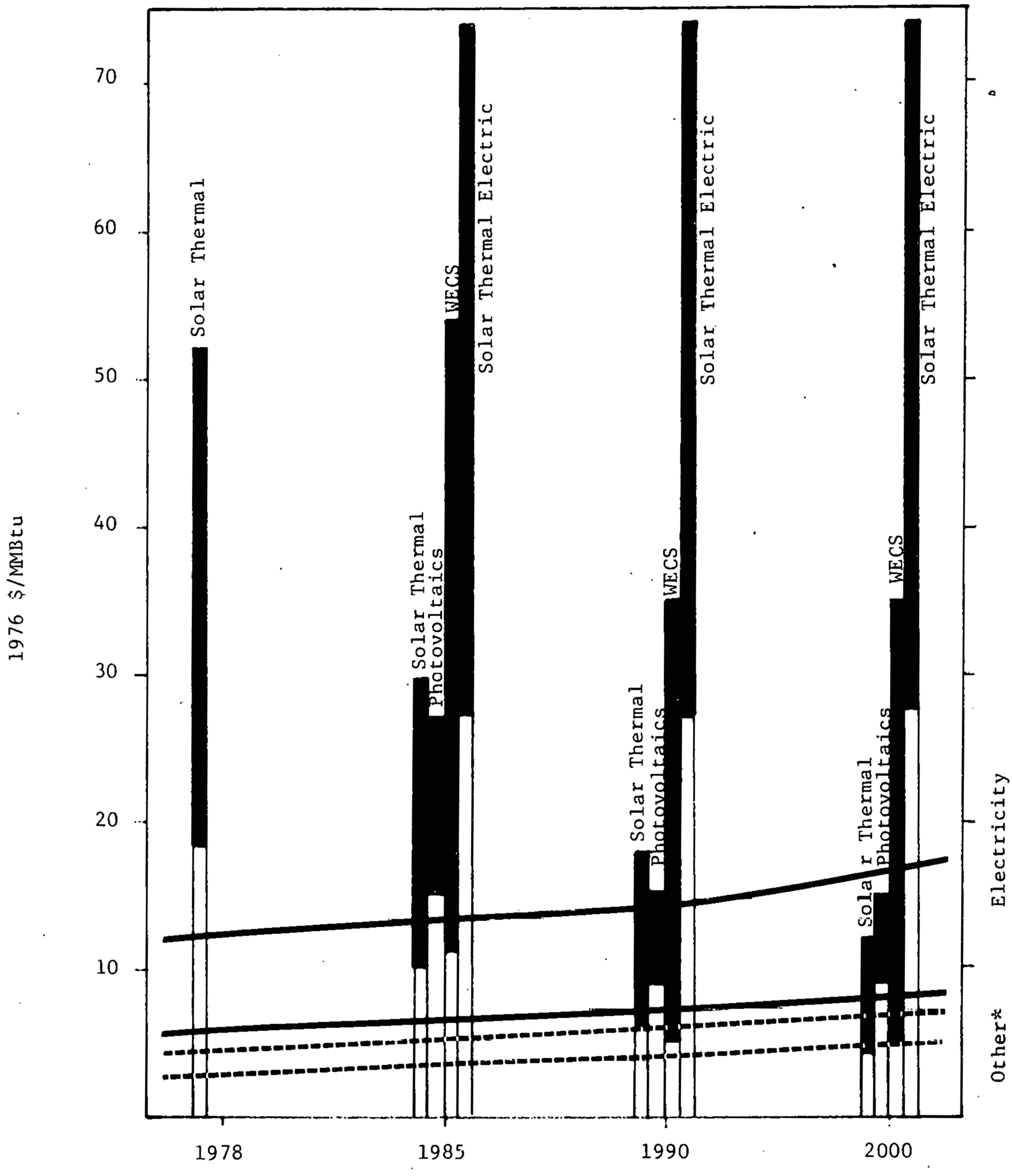
Note: Shaded areas represent regional ranges. Heating includes hot water. Cooling includes hot water and heating.

FIGURE 22
COST OF DELIVERED ENERGY IN THE RESIDENTIAL SECTOR



Note: Shaded areas represent regional ranges. Heating includes hot water. Cooling includes heating and hot water.

FIGURE 23
COST OF DELIVERED ENERGY IN THE COMMERCIAL SECTOR



*Average fuel cost for heat pump, oil, gas, coal and syn fuels.

Note: Shaded areas represent regional ranges.

FIGURE 24
COST OF DELIVERED ENERGY IN THE INDUSTRIAL SECTOR

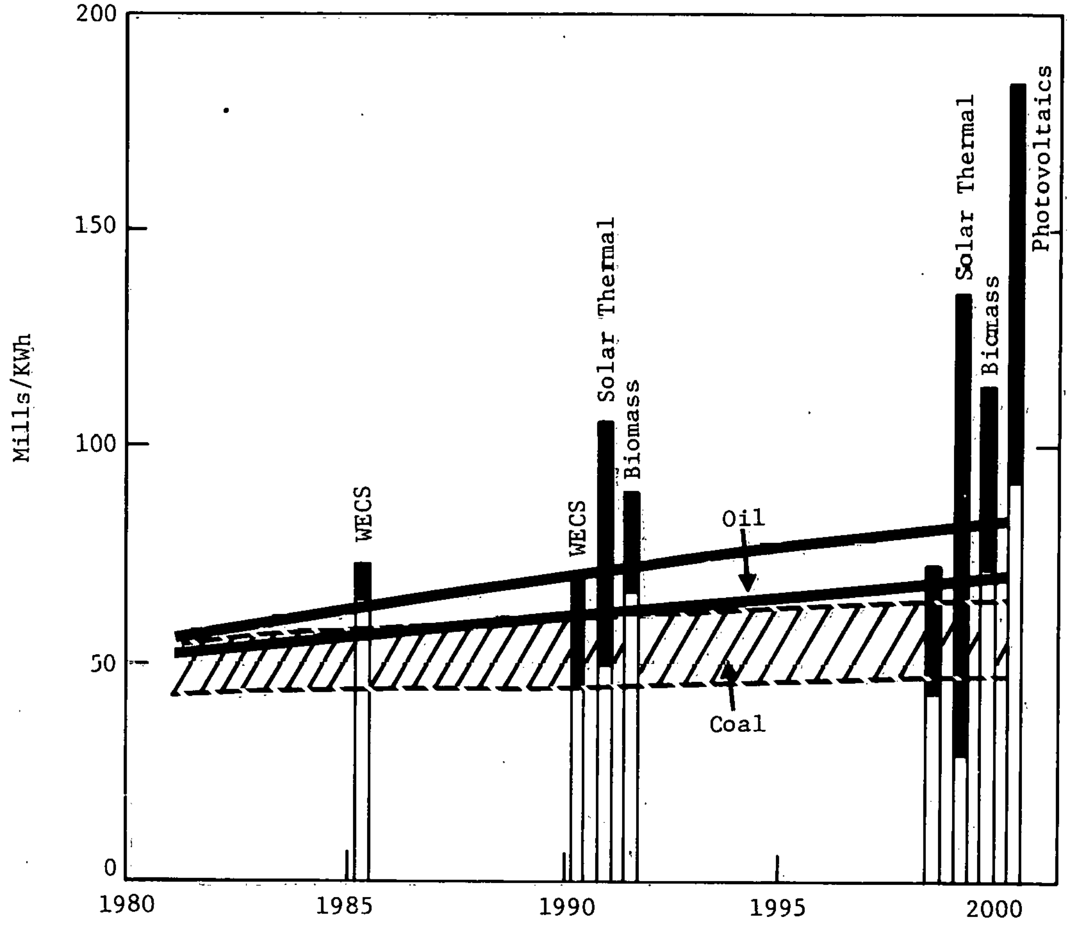
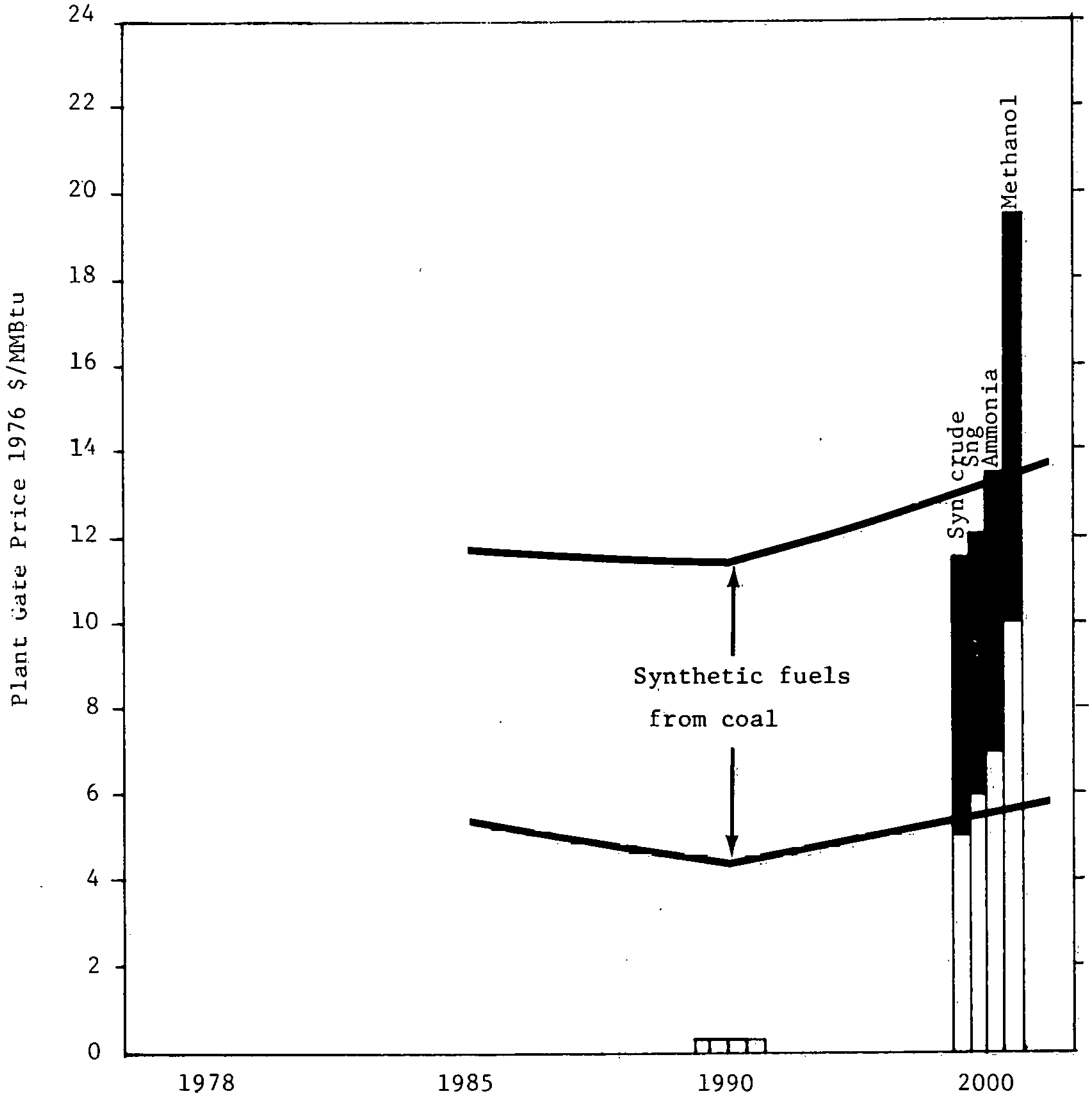


FIGURE 25
BUSBAR COST OF ELECTRICITY IN THE UTILITY SECTOR[1]

[1]Intermediate electric systems only. Range of costs represents regional variations in prices of fuels, variations by application type, and regional variation of system output.



Note: Shaded areas represent regional ranges.

FIGURE 26
COST OF DELIVERED ENERGY IN
THE SYNTHETIC FUELS AND CHEMICALS SECTOR

APPENDIX

DETAILED CHARTS AND TABLES

U.S. ENERGY DEMAND DATA FOR THE YEAR 1977
QUADS - PRIMARY FUEL

USES / FUELS	END-USES			INTERMEDIATE USES		GROSS ENERGY USE	PERCENT
	Residential & Commercial	Industrial	Transportation	Electric Utility	Synthetic Fuels		
PRIMARY							
Oil	7.1	7.0	19.1	3.8	-	37.0	47.5
Gas	7.5	8.3	0.6	3.2	-	19.6	25
Coal	0.2	3.7	-	10.4	-	14.3	18.5
Nuclear	-	-	-	2.7	-	2.7	3.5
Hydro	-	-	-	2.4	-	2.4	3
Solar	-	-	-	-	-	-	-
Geothermal	-	-	-	-	-	-	-
Biomass	0.3	1.6	-	-	-	1.9	2.5
INTERMEDIATE							
Electricity	13.3	9.0	0.2	22.5			
Synthetic Fuels	-	-	-		0.0		
TOTAL	23.1	29.6	19.9			77.9	100

SCENARIO: MID PRICE

U.S. ENERGY DEMAND DATA FOR THE YEAR 1990
QUADS - PRIMARY FUEL

FUELS \ USES	END-USES: Residential & Commercial	END-USES: Industrial	END-USES: Transportation	INTERMEDIATE USES: Electric Utility	INTERMEDIATE USES: Synthetic Fuels	GROSS ENERGY USE	PERCENT
PRIMARY							
Oil	6.4	6.9	19.4	3.0	-	35.7	37
Gas	8.9	9.1	0.6	1.0	-	19.6	20
Coal	0.1	5.4	-	19.2	1.5	26.2	27
Nuclear	-	-	-	9.4	-	9.4	10
Hydro	-	-	-	3.4	-	3.4	3
Solar	0.7	0.5	-	0.2	-	1.4	1
Geothermal	0.5	-	-	0.1	-	0.1	-
Biomass	-	2.0	-	-	-	2.5	3
INTERMEDIATE							
Electricity	18.1	17.8	0.4	36.3			
Synthetic Fuels	0.2	0.5	0.8		1.5		
TOTAL	34.9	42.2	21.2			98.3	100

NATIONAL AVERAGE FUEL PRICES IN 1976 $/MMBtu

	1976	LOW PRICE 1985	LOW PRICE 1990	LOW PRICE 1995	LOW PRICE 2000	MID PRICE 1985	MID PRICE 1990	MID PRICE 1995	MID PRICE 2000	HIGH PRICE 1985	HIGH PRICE 1990	HIGH PRICE 1995	HIGH PRICE 2000
RESIDENTIAL													
Electric	11.40	11.80	12.10	12.40	12.71	12.56	13.46	14.43	15.46	13.45	15.14	17.04	19.18
Gas	2.27	2.70	3.06	3.47	3.93	2.94	3.54	4.26	5.13	3.12	3.91	4.90	6.15
Oil	3.00	3.34	3.60	3.89	4.20	3.65	4.20	4.83	5.55	3.91	4.72	5.70	6.89
COMMERCIAL													
Electric	10.43	11.11	11.62	12.15	12.71	11.82	12.93	14.14	15.46	12.66	14.54	16.70	19.18
Gas	1.57	2.02	2.43	2.91	3.49	2.20	2.81	3.57	4.55	2.33	3.10	4.11	5.46
Oil	2.96	3.19	3.36	3.54	3.73	3.48	3.91	4.39	4.93	3.73	4.40	5.18	6.11
INDUSTRIAL													
Electric	9.28	9.63	9.97	10.27	10.59	10.30	11.10	11.95	12.88	11.03	12.48	14.12	15.98
Gas	1.42	2.63	2.78	2.93	3.10	3.20	3.55	3.94	4.37	3.13	3.72	4.41	5.24
Oil	2.17	2.78	2.91	3.04	3.18	3.33	3.68	4.06	4.48	3.47	4.06	4.75	5.56
Coal	1.10	1.32	1.38	1.44	1.51	1.70	1.83	1.97	2.13	1.75	1.97	2.22	2.49
Synfuels	3.60	3.85	4.06	4.26	4.48	4.14	4.57	5.05	5.57	4.43	5.13	5.95	6.90
UTILITY													
Coal	0.90	0.90	0.99	1.01	1.04	1.31	1.41	1.52	1.64	1.39	1.56	1.76	1.98
Gas	1.35	2.63	2.78	2.93	3.10	3.29	3.63	4.01	4.43	3.43	4.07	4.84	5.75
Oil	2.08	2.73	2.86	2.99	3.12	3.27	3.61	3.99	4.40	3.45	4.03	4.71	5.50
Nuc-Lwr	0.48	0.56	0.58	0.61	0.63	0.61	0.69	0.78	0.88	0.63	0.73	0.85	0.98
Nuc-Adv	0.33	0.38	0.40	0.41	0.43	0.41	0.46	0.52	0.59	0.42	0.49	0.56	0.65

REGIONAL FUEL PRICE VARIATIONS

		New England	Mid Atlantic	South Atlantic	East North Central	East South Central	West North Central	West South Central	Mountain	Pacific
GAS	INDUSTRIAL	1.10	1.02	0.94	1.00	0.92	0.97	1.01	0.96	1.07
	SYNFUELS	1.01	1.01	1.01	1.01	1.06	1.01	0.96	1.01	1.01
	RESID	1.20	1.14	0.87	0.98	0.85	0.89	1.01	0.87	1.07
	COMM	1.17	1.12	0.92	1.01	0.90	0.93	0.97	0.91	1.08
OIL	INDUSTRIAL	1.00	0.97	0.98	0.98	0.97	1.03	0.84	1.05	0.98
	UTILITY	0.99	0.97	0.97	0.98	0.97	0.99	0.96	1.06	1.10
	RES/COMM	1.03	0.99	1.00	1.00	0.99	1.03	0.95	1.04	0.96
COAL	INDUSTRIAL	1.15	0.90	1.05	0.87	0.98	0.82	0.85	0.68	1.01
	UTILITY	1.21	1.01	1.12	0.98	1.05	0.82	0.66	0.64	0.82
ELECT.	ALL SECTORS	1.17	1.30	0.97	1.07	0.85	1.20	1.14	1.28	0.62

Regional factors are multiplied by national average price to get price in the region. Factors are taken from 1990 projections by the American Gas Association Model TERA-II.

DISTRIBUTION OF FUELS DISPLACED BY SOLAR AS
SOLAR INCREASES ABOVE 14 QUADS

(Percent displaced by 2000)

Distributed Sectors	Elec.	Gas	Oil	Coal
Buildings	57	32	11	0
Industrial				
Biomass	-	70	30	-
Other	51	24	8	17

Utility Sector	Gas	Oil	Coal	Nuclear
Electricity Demand Reduction from Distributed Solar[1]	3	4	79	14
Base Solar Electric[1]	-	-	75	25
Intermediate Solar[1]	4	6	90	-
Solar Fuel Savers[1]	4	6	90	-
Synfuels	-	-	100	-

National Average	Gas	Oil	Coal	Nuclear
	25	11	57	7

[1]Assumes that electric utilities have pretty much switched from gas and oil to coal. Coal-fired plants with storage are used for intermediate load following.

BUILDING SECTOR DEMAND RELATIONSHIP

	PRIMARY ENERGY DEMAND	END USE DEMAND	BUILDING DEMAND	COEFFICIENT OF PERFORMANCE
1976				
Oil	14.0	14.0	7.7	0.55
Gas & SNG	6.2	6.2	3.4	0.55
Electricity	7.6	2.5	2.5	1.02
Solar	0.0	0.0	0.0	-
Total	27.8	22.7	13.6	
2000 Low Price				
Oil	3.0	3.0	2.1	0.70
Gas & SNG	7.2	7.1	5.0	0.70
Electricity	16.7	5.6	10.5	1.87
Solar	1.4	0.6	0.9	-
Total	28.3	16.3	18.5	
2000 Mid Price				
Oil	2.0	2.0	1.4	0.72
Gas & SNG	6.6	6.4	4.7	0.74
Electricity	16.1	5.4	10.4	1.89
Solar	2.6	1.0	1.7	-
Total	27.3	14.8	18.2	
2000 High Price				
Oil	1.1	1.1	0.9	0.82
Gas & SNG	6.9	6.5	5.4	0.83
Electricity	14.1	4.7	9.6	2.04
Solar	3.1	1.2	2.2	-
Total	25.2	13.5	18.1	

NOTE: There is 0.3 quads of building demand savings from conservation in the Mid price case and 0.4 quads in high-price scenario.

REGIONAL ANNUAL SOLAR SAVINGS IN THE YEAR 2000
(Quads of Primary Fuel Displaced)

SOLAR APPLICATION		TOTAL	NEW ENGLAND	MID ATLANTIC	SOUTH ATLANTIC	EAST NORTH CENTRAL	EAST SOUTH CENTRAL	WEST NORTH CENTRAL	WEST SOUTH CENTRAL	MOUNTAIN	PACIFIC
Residential	Thermal	1.053	0.043	0.221	0.055	0.238	0.051	0.090	0.172	0.071	0.113
	Passive	0.200	0.020	0.040	0.011	0.043	0.009	0.017	0.022	0.014	0.022
	Wind	0.31	0.02	0.05	0.04	0.05	0.02	0.05	0.07	0.01	0
	Photovoltaics	0.18	0.003	0.023	0.023	0.018	0.008	0.019	0.041	0.037	0.008
	Biomass	0.60	0.04	0.04	0.06	0.08	0.02	0.03	0	0.06	0.27
Commercial	Thermal	0.664	0.027	0.138	0.034	0.149	0.032	0.056	0.111	0.044	0.073
	Passive	0.022	0.001	0.004	0.002	0.005	0.001	0.002	0.003	0.001	0.002
Industrial	Solar Thermal	2.182	0.038	0.123	0.223	0.343	0.164	0.055	0.694	0.102	0.399
	Biomass	2.2	0.106	0.110	0.746	0.108	0.264	0.051	0.354	0.040	0.420
	S.S. Hydro	0.15	0.02	0.03	0.04	0.02	0.01	0.01	0.02	0	0
Electric Utility	Wind	1.315	0.129	0.240	0.327	0.244	0.249	0.027	0.005	0.034	0.062
	Solar Thermal	0.962	0	0	0.214	0.009	0.012	0.134	0.215	0.118	0.261
	Photovoltaics	0.014	0	0	0.005	0	0	0	0.009	0	0
	OTEC	0.10	0	0	0.10	0	0	0	0	0	0
	Biomass Elec.	0.025	0.006	0.003	0.010	0	0.006	0	0	0	0
	Hydro	3.80	0.10	0.34	0.26	0.07	0.26	0.15	0.09	0.65	1.88
Synthetic Fuels and Chemicals	Wood	0.447	0.047	0.042	0.094	0.070	0.075	0.011	0.028	0.015	0.065
	Animal Waste	0.20	0.009	0.009	0.012	0.045	0.010	0.044	0.025	0.018	0.028
TOTAL		14.43	0.61	1.41	2.26	1.49	1.19	0.75	1.86	1.21	3.60

NUMBER OF SYSTEMS BY REGION IN THE YEAR 2000

MARKET SECTOR TECHNOLOGY	SYSTEM SIZE	TOTAL	NEW ENGLAND	MID ATLANTIC	SOUTH ATLANTIC	EAST NORTH CENTRAL	EAST SOUTH CENTRAL	WEST NORTH CENTRAL	WEST SOUTH CENTRAL	MOUNTAIN	PACIFIC
Residential											
Hot Water	35- 50 sq.ft.	25,545,904	766,377	5,364,640	1,021,836	4,598,263	2,043,672	2,299,131	4,087,345	1,277,295	4,087,345
Heating + HW	115-130 sq.ft.	6,688,810	535,141	1,739,208	468,248	1,672,316	133,782	535,141	534,692	334,463	735,819
Cooling + H + HW	120-240 sq.ft.	948,495	9,485	18,970	740	237,124	9,485	151,759	444,322	75,880	730
Passive Heat	150-350 sq.ft	4,866,850	389,600	1,266,200	340,900	1,217,500	97,400	389,600	386,450	243,500	535,700
Wind	4kW	6,350,984	285,794	1,143,177	1,022,508	1,177,773	482,675	889,138	1,200,336	177,828	31,755
Photovoltaics	3.4kWe	6,009,783	126,079	1,038,654	780,491	738,465	300,189	684,431	1,242,782	816,514	282,178
Commercial											
Hot Water	160-175 sq.ft.	812,845	24,385	130,055	65,028	178,826	65,028	65,028	97,541	56,899	130,055
Heating + HW	1115-1250sq.ft.	597,118	41,798	131,366	65,683	107,481	41,798	29,856	35,827	17,914	125,395
Cooling + H +HW	1835-1920sq.ft.	375,612	3,756	52,586	48,829	60,098	33,805	37,561	60,098	22,537	56,342
Passive Heat	700-2600sq.ft	127,000	8,890	27,940	13,970	22,860	8.890	6,350	7,620	3,810	26,670
Industrial											
Solar Thermal	100,000sq.ft.	52,544	919	2,924	5,440	8,446	4,043	1,529	17,168	2,528	9,547
Electric Utility											
Wind	100 MWe	358	35	65	89	66	68	7	2	9	17
Solar Thermal	100 MWe	285	0	0	63	3	4	40	63	35	77
Photovoltaics	100 MWe	6	0	0	2	0	0	0	4	0	0
Ocean Thermal	400 MWe	3	0	0	3	0	0	0	0	0	0
Biomass	46 MWe	13	3	1	6	0	3	0	0	0	0