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OFFICE OF PLANNING AND POLICY EVALUATION
ASSISTANT SECRETARY FOR CONSERVATION AND SOLAR APPLICATIONS
By the
ECONOMIC ANALYSIS DIVISION
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ABSTRACT

Economic impacts of sharply higher oil and gas prices in the eighties are estimated using a combination of optimization and input-output models. A 1985 Base Case is compared with a High Case in which crude oil and crude natural gas are, respectively, 2.1 and 1.4 times as expensive as in the Base Case. Impacts examined include delivered energy prices and demands, resource consumption, emission levels and costs, aggregate and compositional changes in Gross National Product, balance of payments, output, employment, and sectoral prices.

Methodology is developed for linking models in both quantity and price space for energy service - specific fuel demands. A set of energy demand elasticities is derived which is consistent between alternative 1985 cases and between the 1985 cases and an historical year (1967).

A framework and methodology are also presented for allocating portions of the DOE Conservation budget according to broad policy objectives and allocation rules.

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EXECUTIVE SUMMARY

One of the principal issues facing energy planners is the possibility of major increases in the price of oil sometime in the next decade. Although we cannot assess the likelihood of this with a high degree of confidence, it is possible to analyze the impact of such a price increase were it to occur. This analysis uses combined optimization and input-output models to assess GNP, employment, output, balance of payments, energy, investment, and environmental impacts of a doubling of real oil prices from 1975 levels of $13 per barrel to $26 per barrel by 1985. It is assumed that this price increase occurs smoothly over the period of analysis rather than abruptly.

The major impacts of this price increase by 1985 are compared with those of a base case in which GNP grows at 3.7% per annum through 1985 and oil prices increase by 1% per annum in real terms to $14.50 per barrel by 1985. The impacts are as follows:

- Total annual energy system costs increase by about 12%, while resource consumption falls 12.5% from 96.75 x 10^{15} Btu to 84.68 x 10^{15} Btu.
- Annual capital investment by the energy sector increases slightly, about 2%; but investment in coal mining and fossil electric facilities increase 50% and 14%, respectively.
- The change in pollution emissions between the two scenarios is significant for particulates (20% increase), but negligible for sulfur oxides.
- GNP falls by 2.1% with a 68% increase in GNP purchases of energy more than offset by decreases of from 3.9% in purchases from the transportation sector to negligible change in purchases from the mining sector.
- Personal consumption falls by 4%, marked by a 16.4% decrease in energy consumption and up to a 4.5% decline in purchases from the nonenergy sectors.
- Net imports of energy drop by $11.2 billion and are almost matched by a drop in nonenergy net exports of $8.2 billion.
- The value of total system output increases by 1.8% reflecting the inflationary impact of more expensive energy. This is made up of a 31.8% increase in the value of energy output, partially offset by a 1.1% decrease in the value of nonenergy output.
- Total employment falls by about 2.8% with an increase of 0.7% in the energy sector more than offset by decreases in the nonenergy sectors.
- Energy price differences vary from increases of a few percent for coal-, nuclear-, and hydro-produced electricity to 31% for pipeline gas and 82.4% for refined oil products.
- Nonenergy price increases are closely tied to the cost of oil as an input. Petrochemicals, transportation, asphalt, and plastics all show large price increases. Industries such as machinery, autos,

television, and mechanical services show much lower price increases. The price increases are even less for service industries such as radio and television.

Thus, we see that major increases in oil prices will have widespread and for the most part undesirable impacts on the economy. These impacts will be felt far more severely in sectors that are heavily dependent upon oil rather than on other forms of energy. At the same time, we see that under our assumption of a smooth transition to higher price levels, there are major opportunities for conservation and fuel switching which limit losses in output and employment to a few percent despite the doubling of oil prices. Although it is beyond the scope of this analysis, these impacts would probably be greater if the doubling of oil price were to occur abruptly - in a single year, for example - rather than over a decade as assumed here.

The implications of this analysis for Conservation and Solar policy and planning are several. First, we see that improved efficiency and fuel substitution have a major impact in reducing energy requirements in response to higher oil prices. Much of this will occur through normal market forces; government activity will be most effective where market failures have been identified. Finally, though higher priced energy results in negative economic impacts, this analysis must not be construed as supporting low prices which are kept below marginal cost through subsidy, regulation, or other means. While such policies produce the appearance of low energy prices, they introduce additional costs elsewhere in the system more severe than the impacts of higher energy prices. Considerations dealing with allocation of resources are addressed in the most efficient manner by correct marginal pricing of resources in the marketplace. Distribution considerations, those dealing with transfers of income or wealth which may arise from energy pricing policy, are best dealt with through specific policy measures separate from pricing policy such as direct payments to impacted groups or taxes on windfall profits.

1.0 INTRODUCTION

One of the principal uncertainties in energy policy planning is possible scarcity of oil and resulting higher oil prices in the eighties. Scarcity could arise from a combination of factors - slow expansion of crude oil production by non-OPEC nations, slow development of alternative energy supplies, and a constraint imposed by OPEC on production for political reasons. Although the probability of such events occurring is unknown, it is important to assess the economic impacts of such a possibility and weigh them along with other aspects of national energy policy planning.

This paper presents the results of applying the combined Brookhaven Input-Output and Energy System Optimization Models and the Hudson-Jorgenson (LITM) Model (Jorgenson and Hudson, 1974) to this issue. The cases compared are the Base Case which presents an optimistic oil supply scenario with relatively small increases in domestic and imported fuel prices, and a High Case with a pessimistic scenario which assumes that high prices result from low finding rates of energy sources worldwide (including the U.S.) as well as a political upper bound set on Saudi Arabian production. The price paths studied in the two scenarios from 1975 to the year 2000 are shown in Table 1.

Table 1

Prices of Primary Resources (1975 $\$/10^6$ Btu)

	1975 Current	1985		2000	
		Base	High	Base	High
Coal (minemouth)	0.60	1.02	1.05	1.18	1.21
Domestic oil (wellhead)	1.38	1.85	4.45	2.88	5.92
Imported oil (crude)	2.26	2.50	4.45	3.21	5.92
Domestic gas (wellhead)	0.45	2.20	3.11	2.82	3.90
Imported gas (processed)	1.19	2.60	3.51	3.10	4.18

One of the principal concerns - probably the most important single concern - of the policy maker considering higher energy prices such as these is their possible effect on the economy. The greatest threat to the economy would come, as in 1973-74, from *sudden* and *large* price increases which dislocate normal economic patterns. On the other hand, our work indicates that incremental changes in energy prices, even if the cumulative effect is large over a period of years, have very slight effect on the economy because many small incremental adjustments are made to reduce energy consumption. These adjustments, if they are begun in time, permit substitutions to take place which largely offset the higher prices (Energy Modeling Forum, 1977; Hogan and Manne, 1977).

Of course, the economy would benefit greatly (all else being equal) from having inexpensive energy sources, provided of course the real costs were low and the energy was not simply low priced by virtue of a subsidy from elsewhere in the economy. If a technological breakthrough results in environmentally benign low cost energy, the authors would be the first to urge its implementation on economic and other grounds.

However, in view of the high cost of known alternatives to declining conventional petroleum availability and the grave economic consequences of a *sudden* and *unexpected* need to shift to these sources, we have explored the implications of a deliberate phased shift to higher cost energy forms.

2.0 ANALYTICAL FRAMEWORK

The national macroeconomic and interindustry energy model (LITM) provides useful information to the conservation and solar policy maker. The macroeconomic model is fed with energy prices, population growth, labor force participation, and a rate of technological progress (Jorgenson, 1974). It produces an output of energy and nonenergy demands. The energy demands are expressed in physical and dollar terms and represent fuel requirements. These can be partitioned into direct fuel demands that appear as components of the GNP (gasoline at the pump, electricity at the meter in the home) and indirect fuel demands that are a part of total output but are used by the purchaser to produce other goods and services. These are energy demands that appear in GNP as embodied energy in other components (e.g., energy in steel used in autos, or energy in glass used for bottles, etc.).

The energy requirements generated by the macroeconomic model are fed into an engineering process model of the energy system (BESOM)* as energy demands that must be satisfied (Cherniavsky, 1974). The model selects the supply and end-use conversion technologies that optimally meet these requirements subject to exogenously imposed supply limitations. The output of this model is a set of energy prices, the preferred fuel mix, and a set of identified preferred supply technologies. The prices and fuel mix from BESOM is fed back into LITM, and convergence is attained between the linked models through iteration (Behling et al., 1976). Thus the aggregated economic effects of energy prices, technology alternatives, energy policies, regulations and standards, and resource supply scenarios are studied in detail at the level of an integrated energy system coupled with the interaction of that system and the rest of the economy. This concept of linking analytical tools at the proper level of aggregation is discussed in Hogan (1977) and Behling (1978).

To fully understand the effect of conservation and solar policies one wishes to know their impact on employment, consumption, balance of payments, prices, investment, and total output. Ideally, we would like this information for each industry, occupation, and geographical area, perhaps at the county level. The methdology currently exists at Brookhaven to provide sectoral output, employment, price, consumption, and investment information for 12 energy and 90 nonenergy sectors. This linkage is described in Tessmer et al. (1975). This highly disaggregated, very rich level of detail model is capable of further disaggregation by occupation for employment, and by region (state and even possibly county) for output as well as employment. In addition, a model that disaggregates the energy system to nine census regions is currently being tested (Goettle, 1977) and when operational will be hierarchically linked with the three models described above.

Operationally, this analysis is performed by first operating the national macroeconomic and interindustry models and the energy system process model iteratively. Aggregated GNP and fuels delivered to consumers from this solution are used by the disaggregated combined linear programming/input-output model to calculate the detailed estimate of output, employment, prices, consumption, and investment. This procedure is described in Appendix A and is used to portray the economic impact of alternative energy price levels.

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*BESOM can be run with and without end-use capital costs. The version used for this analysis incorporated end-use capital costs, and optimization was performed on this basis.

Other Brookhaven analyses pursue this to one more level of detail, namely the analysis of technology penetration in individual energy consuming sectors (Carhart et al., 1978) (Pilati and Rosen, 1978). It is this level of detail which is required to examine the role of specific federal conservation and solar programs as distinct from economy-wide policies such as those of pricing. Individual sector models are run using product demands calculated by the economic models and energy prices consistent with those cases.

The analytic techniques involve an integration of engineering process analysis and econometrics. The econometric component is utilized to model the response of consumers and producers to changes in relative prices of labor, capital, energy, and materials. Modeling the use of energy by end-use conversion devices involves energy flow and system cost analysis and lies in the jurisdiction of engineering and microeconomics. Analysis of the determination of the economy's market basket of goods and services that generate the demand for energy services is subject matter for micro- and macroeconomics.

Fuel demands, both directly as personal consumption and indirectly as energy embodied in purchased goods and services, are the substance of the conservation program. However, to understand the role of conservation, it is necessary to convert these fuels to "energy services." Consumers do not buy gasoline to eat or drink or electricity to look at. Individuals purchase fuel to provide comfort or mobility, and business and industry purchase fuel to provide steam, heat, electrolytic services, or mechanical work. By defining energy demands in this manner, decreased energy use can be broken down into two components:

1. a decrease in the energy *service* per capita or per unit of output demanded;
2. an improvement in the *efficiency* by which fuel is converted to supply the service.

Existing methodology (see Appendix A) does not permit us to differentiate between these two effects. It does allow us to identify the combined effects by generating the total fuel requirements. In the analysis presented below, we identify the effect of differential prices on fuel use by the energy service sector. From the point of view of conservation policy this is valuable because:

1. it identifies the effect of price policies (incentives, taxation) on energy fuel demands for each particular energy service;
2. it identifies the effect of changing efficiencies (standards regulations, new RD & D options) on energy fuel demands;
3. it facilitates a comparison of the level of energy demands resulting from people acting on the basis of one set of prices with what the level of energy demands would have been if decisions had been made on the basis of a different set of prices.

The results shown in this paper are directed primarily to the last point. Specifically, they show the decrease in fuel use by each end-use demand associated with higher fuel prices. Three cases are examined and compared:

1. demands if decisions were made on the basis of 1975 prices (CURRENT):
2. demands if decisions were made on a typical energy price projections (BASE*):
3. demands if decisions were made on a high energy price projection (HIGH).

3.0 ENERGY AND ECONOMIC IMPACTS

The combined set of energy-economic models provides information to the policy maker on the nature and cost of the nation's energy system, GNP, output, employment, consumption, investment, environmental effects, and costs, and on the balance of payments impacts. To demonstrate the analytic capability of these models, a limited set of the available model results are presented. Results are shown for the 1985 Base and High price cases and are indicative of the effects of carrying out a conservation policy including higher prices and regulation to achieve the HIGH energy use pattern, as opposed to business as usual which would result in the Base outcome. Similar calculations can be made for other time periods.

3.1 Energy Prices

Table 2 presents energy price assumptions for the analysis. For comparison purposes, column (1) shows 1967 prices and column (2), 1975 (CURRENT) prices. Columns (3) and (5) show the BASE price path while columns (4) and (6) show the HIGH price path. Section A of the table is the delivered price of fuels. Section B presents the average delivered price of the combination of fuels to each end use. The prices in section B change across scenarios both as individual fuel prices change and as the mix of fuels to a given end use shifts. For example, with higher oil prices, less oil and more electricity will be used for space heat and the average price will reflect not only the higher oil price but also the new fuel mix. There is still another price which we would like to know--that of meeting a unit of end-use demand. This price depends on the average price of fuel, the cost of end-use equipment, and the conversion efficiencies of the fuels to end uses. The methodology is being developed to relate changes in fuel price to changes in the level of end-use demand and in efficiency of the end-use energy equipment. This will be incorporated in individual process models, with the primary problem being one of parameter specification from historical data.

*The base case prices are those that were generated for an early version of FY 77 ERDA RD & D Plan.

Table 2
Real Delivered Energy Prices*
1967 $/$10^6$ Btu

	1967	1975 Current	1985 Base	1985 High	2000 Base	2000 High
A. Fuel prices (producer prices)						
Coal	0.18	0.38	0.64	0.66	0.74	0.76
Refined oil	0.97	1.49	1.82	3.26	2.39	4.28
Pipeline gas	0.61	0.81	1.94	2.51	2.33	3.01
Electricity	4.16	4.52	6.15	6.25	6.05	6.15
B. Average delivered fuel price to energy service						
Coke	0.18	0.38	0.64	0.66	0.74	0.76
Petrochemicals	0.90	1.36	1.80	2.89	2.30	3.69
Motive power	0.98	1.49	1.82	3.28	2.40	4.32
Process heat	0.69	0.96	1.90	2.40	2.30	2.90
Water heat	1.13	1.37	3.09	3.42	3.33	3.69
Space heat	0.72	1.14	2.17	4.30	2.62	5.19
Air conditioning	4.16	4.52	6.15	6.25	6.05	6.15
Electric power	4.16	4.52	6.15	6.25	6.05	6.15

*Real prices are shown under the assumption that the average price of all nonenergy goods and services is the same across all years and cases. To convert to 1975 dollars, multiply all prices by 1.585.

3.2 Energy Demands

The fuel demands associated with the prices in Table 2 are shown in Tables 3 and 4. Table 3 shows the demands by consumers for fuels to supply energy services. Table 4 shows the demands by business, industry, and government for fuels to supply energy services. At present the methodology is not available for separating government, business, and industrial demands.

Tables 3 and 4 show quite clearly the differences in the mix of fuels that result from the various price paths. They also show the difference in quantities. Column (1) describes the quantities and mix projected for 1985 if 1975 prices were to remain in force. Column (2) indicates the decrease in requirements and the difference in mix with the BASE 1985 prices. Column (3) indicates the further reductions in quantities of fuel and the change in fuel mix if decisions were made based on the HIGH price projection. For example, in Table 4 under process heat we see that if current prices are maintained the demand will be met by almost 3 quads of coal,

Table 3
1985 Energy Demand
Personal Consumption Purchases, 10^{15} Delivered Fuel Btu*

Fuel type by energy service	Level of demand at 1975 (CURRENT) prices	Decrease (increase) in demand with: 85 BASE vs 75 prices	85 HIGH vs 85 BASE prices
Motive power			
Refined oil	12.53	1.37	2.75
Electricity	0.03	0.00	(-0.03)
Subtotal	12.56	1.37	2.72
Process heat			
Refined oil	0.41	0.06	0.17
Pipeline gas	0.43	0.06	0.04
Electricity	0.11	0.00	(-0.06)
Subtotal	0.95	0.12	0.15
Water heat			
Refined oil	0.15	0.03	0.00
Pipeline gas	1.27	0.22	0.09
Electricity	1.49	0.28	0.14
Solar direct	0.02	(-0.01)	(-0.07)
Subtotal	2.93	0.52	0.16
Space heat			
Refined oil	5.36	0.91	1.81
Pipeline gas	3.52	0.59	0.36
Electricity	1.85	0.30	(-0.50)
Direct solar, geo.	0.07	(-0.03)	(-0.10)
Subtotal	10.80	1.77	1.57
Air conditioning			
Electricity	1.54	0.14	0.17
Electric power			
Electricity	4.41	0.06	0.19
Total:	33.19	Total decrease: 3.98	4.96

*Electricity and direct solar/geothermal are converted to equivalent refined oil Btu.

Table 4
1985 Energy Demand
Business, Industrial, Government Purchases, 10^{15} Delivered Fuel Btu*

Fuel type by energy service	Level of demand at 1975 (CURRENT) prices	Decrease (increase) in demand with: 85 BASE vs 75 prices	85 HIGH vs 85 BASE prices
Ore reduc. feedstocks			
Coal	2.43	0.25	(0.00)
Petrochemicals			
Coal	0.29	0.04	(-0.05)
Refined oil	4.65	0.58	0.98
Pipeline gas	1.71	0.21	0.16
Subtotal	6.65	0.83	1.09
Motive power			
Refined oil	8.51	0.89	1.81
Electricity	0.03	0.00	(-0.03)
Subtotal	8.54	0.89	1.78
Process heat			
Coal	2.93	0.62	(-1.81)
Refined oil	8.56	1.90	3.48
Pipeline gas	8.81	1.88	0.89
Electricity	2.54	0.55	(-1.30)
Direct solar, geo.	0.17	(-0.05)	(-0.28)
Subtotal	23.01	4.90	0.98
Water heat			
Refined oil	0.10	0.02	(-0.01)
Pipeline gas	0.91	0.19	0.07
Electricity	1.08	0.22	(-1.30)
Subtotal	2.09	0.43	0.20
Space heat			
Refined oil	4.29	0.87	1.46
Pipeline gas	2.78	0.56	0.35
Electricity	1.49	0.30	(-0.33)
Subtotal	8.56	1.73	1.48
Air conditioning			
Electricity	0.88	0.14	0.14

Table 4 (Cont'd)
1985 Energy Demand
Business, Industrial, Government Purchases, 10^{15} Delivered Fuel Btu*

Fuel type by energy service	Level of demand at 1975 (CURRENT) prices	Decrease (increase) in demand with: 85 BASE vs 75 prices	85 HIGH vs 85 BASE prices
Electric power			
Electricity	15.95	1.39	0.55
Solar, geo.	0.14	(-0.05)	(-0.09)
Subtotal	16.09	1.34	0.46
Total:	68.25	Total decrease: 10.51	6.13

*Electricity and direct solar/geothermal are converted to equivalent refined oil Btu.

8-1/2 quads of oil, almost 9 quads of gas, and about 0.9 quad of electricity. If prices rise to the BASE level, the quantities of all four fuels will be reduced, about 0.6 quad for coal, 1.9 quads each for gas and oil, and 0.6 quad of electricity. If prices had risen more rapidly to the HIGH level, an additional 3.5 quads of oil and 0.9 quad of gas would be dispensed with, but coal and electricity use would increase over the BASE price scenario by 1.8 and 1.3 quads, respectively. A small amount of solar to process heat is competitive at the BASE price level. The HIGH price level increases the solar contribution almost five times, although the total contribution is still small at 0.13 quads. These data are of great importance to conservation policy. They indicate by sector (household, industrial, business, government), by end-use, and by fuel type a set of conservation goals. These goals are those that would arise if one expects energy decisions to be based upon a set of low energy prices (CURRENT or BASE), and the actual price turns out to be much higher (HIGH Case).

Given this set of goals, various energy policies can be analyzed and a set of policy actions chosen that will lead to the HIGH price energy consumption and fuel mix. Although this analysis has been carried out only for 1985, it can also be done for a more distant time horizon, for example, 1990 or 2000. In the longer time framework, the conservation planner can identify those RD & D options that would be attractive with the HIGH price structure but not with the BASE one. The RD & D activities thus identified are prime candidates for federal support. Appendix B addresses allocation of federal conservation monies in more detail and presents a methodology for allocation based on broad policy objectives and goals.

3.3 Energy Resources

Energy resource consumption for the BASE and HIGH cases is shown in Table 5. The HIGH price case shows a decrease in energy use of about 12 quads, a little over 12%. This substantial decrease is primarily in imported oil. In addition, there is over a 2-quad drop in natural gas usage, which is more than counterbalanced by the greater than 3-quad increase in coal and small absolute, but large relative, increases in use of geothermal, solar, and shale oil. Domestic production of oil and gas drops slightly because greater resource scarcity, the basis for higher oil and gas prices in the HIGH price case, is assumed worldwide.*

Table 5
Resource Consumption

	1985 Consumption (10^{15} Resource Btu)	
	BASE	HIGH
Hydroelectric	3.80	3.80
Geothermal	0.17	0.30
Solar	0.15	0.46
Nuclear	7.98	7.98
Domestic oil	22.40	21.64
Imported oil	22.04	9.20
Shale oil	0.30	0.40
Domestic natural gas	18.81	17.97
Imported natural gas	1.41	0.00
Coal	19.69	22.93
Total	96.75	84.68

3.4 Total Energy System Cost

The HIGH case results in total energy system annualized costs** that increase eighteen billion dollars above energy costs of $154 billion in the BASE case (1967 $). Perhaps more important is the differential level of investment since this represents the impact on the capital market (Table 6).

*The pessimistic scenario (HIGH) assumes both an upper bound on Saudi Arabian oil production plus a lower finding rate and more rapid exhaustion of non-OPEC oil than the optimistic scenario (BASE).

**Annualized costs include 1985 fuel and operating costs, plus capital costs of energy production and supply equipment which are annualized using appropriate equipment lives and discount rates.

Table 6
1985 Investment Requirements for the Energy Supply Sectors
(10^9 1967 $)

	Sectors	BASE	HIGH	% Change
1.	Coal	0.44	0.66	50.0
2.	Crude oil & gas	1.39	1.33	- 4.3
3.	Shale oil	0.51	0.70	37.3
4.	Methane from coal	0.37	0.37	0.0
5.	Coal liquefaction	--	--	--
6.	Refined oil products	1.63	0.33	-79.8
7.	Pipeline gas	0.48	0.42	-12.5
8.	Coal combined cycle electric	--	--	--
9.	Other fossil electric	10.01	11.37	13.4
10.	LWR electric	13.40	13.40	0.0
11.	HTGR electric	--	--	--
12.	Hydro, geothermal, & solar electric	2.26	2.44	8.0
	Total energy investment	30.49	31.02	1.7

This quantity is approximately five hundred million dollars per year which represents about 0.2% of total investment. Investment in coal mining and coal steam electric facilities increased by two hundred million dollars (50%) and 1.4 billion dollars (14%), respectively. This is offset by decreases in the other fuel sectors, primarily in oil refining. Investment in nuclear facilities is the same in both cases.

3.5 Emission Levels and Emission Costs

The HIGH case uses less energy resources but is characterized by a large shift from oil and gas to coal. The result is that if the same control technologies are applied, *the total emissions increase and the environment is degraded.* Some 42 air and water quality emission indices can be calculated. Only two were examined: those of particulates and SO_x. Emissions of particulates increase about 20% and emissions of SO_x increase about 1% in the HIGH price case.

The true costs of environmental damage are in health effects; property and crop damage; and effects on ecosystems, ambience, and aesthetics. These are almost impossible to measure but a surrogate measure can be supplied, namely, the cost of applying a more stringent level of control technologies such that the total emissions of the three pollutants would be controlled in the HIGH case to the level prevailing in the BASE case. These calculations suggest that the additional environmental degradation is not very great. The surrogate costs would be $160,000 additional for particulate abatement, and $210,000 additional for SO_x control. The basic data are shown in Table 7 and the incremental control costs were derived from

Hittman, 1976. The magnitude of these quantities suggests that the environmental degradation may in fact be negligible, especially if the new emissions are in less densely populated areas. They also suggest that the cost of restoring the environment, if the quantities are significant, is small.

Table 7
Calculation of Emission Cost Surrogates

	BASE control level, % removal	BASE emissions 10^3 tons	HIGH emissions 10^3 tons	Δ Emissions 10^3 tons	Δ Removal	$/Ton removed
Particulates	0.995	6,600	7,900	1,300	+0.001	0.02
SO_x	0.900	20,300	20,500	200	-0.0007	1.05

The $/ton removed are determined from the figures relating percentage removal to cost per ton of removal presented in Hittman, 1976. By entering these figures at the BASE case control level, a removal cost per ton can be read off the curves. One then calculates the control level that would equate emissions in the BASE case with that in the HIGH case. The cost per unit for the revised control level is read off the curve. The difference is the cost that would have to be applied to all of the emissions to bring about the equality.

3.6 GNP, Investment, and Personal Consumption

The data presented in Table 8 show that GNP in constant 1967 dollars declines from 1419 billion dollars for the BASE case to 1389 billion dollars for the HIGH case (2.1%). Investment also decreases but proportionately much less, from 214.6 to 212.2 billion dollars (1.1%). Personal consumption reflects the GNP decrease and falls from 935.4 billion dollars to 897.8 billion dollars (4.0%). If conservation policy could be applied to achieve a HIGH price scenario solution and in fact the HIGH prices did not materialize, an upper bound on its cost in personal welfare would be 4.0% of personal consumption.* This would be partly offset by the improvement in our international posture with imports of 9.2 quads as opposed to 23.4 quads and an increase in net exports of 11.8 billion dollars. The cost can also be considered as an insurance premium which would be paid if the HIGH price scenario did not materialize. If it is less than the product

*This is because the private sector could reduce energy consumption the requisite amount at this cost to personal consumption, without any new federal policies.

of the possibility that it would occur and the cost of the resultant domestic and international dislocations that would result, then it would be socially desirable. We do not at present have a methodology to calculate the cost of not anticipating the higher prices, but, given the extent of the potential implications, it could result in an impact greater than 4.0% of the 1985 GNP. To give the reader a sense of this magnitude, it is approximately the level of lost resources in a year such as 1976 due to the oil embargo two years before and other economic factors.

Table 8
The Effects of Higher Energy Prices
on GNP (10^9 1967 $)

Composition, by GNP purchaser	1976	1985 BASE	1985 HIGH
Personal consumption	679.2	935.4	897.8
Investment	139.1	214.6	212.2
Government	190.1	245.9	244.2
Net exports	17.7	23.0	34.8
Gross national product	1026.1	1418.9	1389.0

The data available from the model are rich in detail. Tables 9 to 11 show the change in GNP, investment, and consumption by major sectors within the economy. As can be readily seen, there is considerable difference between sectors. The marked difference between the energy sectors and each of the others is of interest. Variation among the nonenergy sectors is present, but greater disaggregation shows that these aggregates mask still larger changes between individual I-O sectors within the major sectors. The number of I-O sectors aggregated is indicated by the parentheses to the right of the major sector title in Tables 9 to 11. Disaggregated data are presented for total output and employment in Tables 16 and 18.

3.7 Balance of Payments Effects

The input-output model incorporates a balance of payments routine that generates the decrease in nonenergy net exports resulting from the decrease in payments for imported oil and gas. This is based upon historical demand elasticities for U.S. exports and foreign trade elasticities which reflect changes in the price of U.S. goods versus substitute foreign goods.

The lower cost of imported energy in the HIGH price case is reflected in Table 12, a total reduction of eleven billion dollars (1967 dollars) for net energy imports. This reduction has the greatest impact on net exports from the manufacturing sectors, as shown in Table 13. Reduction of capital goods exports is particularly large. Because exports of U.S. goods drop, another balance of payments effect is to shift domestic resources from use in the production of export goods to the production of domestic goods and services. Sectoral changes in the quantity of net exports (1967 dollars)

Table 9
Gross National Product Purchases
(10^9 1967 $)

Composition, by GNP purchase (No. of sectors)	BASE	HIGH	% Change
Energy (20)	18.2	30.6	68.1
Agriculture (4)	14.2	13.8	-2.8
Mining (4)	-0.4	-0.4	0.0
Construction (7)	163.8	162.9	-0.5
Manufacturing (52)	428.0	413.5	-3.4
Transportation (7)	36.0	34.6	-3.9
Services (10)	615.4	592.1	-3.8
Other purchases (3)	143.8	141.9	-1.3
Total GNP	1419.0	1389.0	-2.1

Table 10
Investment Goods Produced*
(10^9 1967 $)

Composition of Investment Goods	BASE	HIGH	% Change
Energy (20)	0	0	0.0
Agriculture (4)	0	0	0.0
Mining (4)	0	0	0.0
Construction (7)	124.0	124.0	0.0
Manufacturing (52)	70.8	69.1	-2.4
Transportation (7)	2.7	2.6	-3.7
Services (10)	10.3	9.6	-6.8
Other investment (3)	6.8	6.9	1.5
Total investment	214.6	212.2	-1.1

*This is the output of the sector sold for investment rather than purchased by the sector. It does not mean that there is no energy investment. In fact, a good portion of the sales of the construction and manufacturing sectors was for energy investment. Improvements are being made in the model that will permit a breakdown of investment by purchases.

Table 11
Personal Consumption Expenditures
(10^9 1967 $)

Composition of PCE goods/services	BASE	HIGH	% Change
Energy (20)	42.1	35.2	-16.4
Agriculture (4)	8.2	7.9	- 3.6
Mining (4)	0.0	0.0	0.0
Construction (7)	0.0	0.0	0.0
Manufacturing (52)	271.4	262.3	- 3.4
Transportation (7)	22.4	21.5	- 4.0
Services (10)	565.1	545.9	- 3.4
Other purchases (3)	26.2	25.0	- 4.6
Total consumption	935.4	897.8	- 4.0

Table 12
Energy Sector Net Exports

(Value at relative 1985 prices, 10^9 1967 $)

Sector	BASE	HIGH
Coal	1.4	2.0
Crude oil & gas	-18.2	-10.3
Refined oil products	- 8.6	- 9.5
Pipeline gas	- 3.6	0.0
Other fossil electric	- 0.1	- 0.1
Total	-29.1	-17.9

Table 13
Nonenergy Sector Net Exports

Quantity in 10^9 1967 $

Sector	BASE	HIGH
Agriculture	4.1	3.7
Nonfuel mining	-0.4	-0.5
Construction	*	*
Manufacturing	31.6	25.7
Transportation	5.6	4.8
Services	11.1	10.2
Total	52.1	43.9

*Less than 0.1.

and relative 1985 prices (1967 dollars) are shown in Table 14. Nonenergy sector quantities are measured in dollars, with historical 1967 sectoral prices all equal to $1. In 1985 the price of output from most nonenergy sectors is less than $1 (in 1967 dollars) because of productivity increases.

3.8 Output

Although GNP is used as a measure of welfare, a better indicator for energy studies is total output. Only energy used directly by an end user for consumption, e.g., heating oil in the home, gasoline in the car, is part of GNP. This comprises about 30% of total energy consumption in the Base Case. Gasoline used by trucks or taxis, electricity to illuminate a store, or coke to produce iron appears in GNP as embodied energy in a nonenergy purchase by a consumer. Since we are concerned with all energy (imported oil is the same whether we use it in industry or in our homes), total output is a more useful indicator of the relation of energy to the economy. Table 15 shows the value of total output by major sector. To indicate the richness of the I-O model outputs, Table 16 shows total output broken down into 12 energy and 90 nonenergy sectors. The energy sector output is presented in physical quantity (Btu) and value (at relative 1985 prices) terms. All nonenergy sectors are in quantity (1967 $) terms. In Table 15 one can readily see that the value of energy output increases dramatically while the changes in value of other sector outputs are relatively small. Value of total output increases 1.8%, which reflects the offsetting effects of a decrease in total output and higher prices plus changing composition of output.

A small set of interesting sectors was selected and the output of these sectors under the BASE and HIGH cases is shown in Table 17. The sectors were selected to illustrate the level of disaggregation existing in the model and the potential richness of interpretation of the model output.

Table 14
Net Exports and Relative Prices in Nonenergy Sectors

No.	Sector	BASE Quantity (10^9 1967 $)	BASE Relative 1985 price	HIGH Quantity (10^9 1967 $)	HIGH Relative 1985 price
	Agriculture				
21	Livestock and livestock products	- 0.09	0.91	- 0.11	0.94
22	Other agriculture products	4.55	0.91	4.23	0.94
23	Forestry and fishery products	- 0.40	0.95	- 0.44	0.97
24	Agriculture, forestry, and fishery services	0.06	0.92	0.05	0.93
25	Iron and ferroalloy ores mining	- 0.19	0.93	- 0.21	0.96
26	Nonferrous metal ores mining	- 0.14	0.97	- 0.18	0.99
27	Stone and clay mining, quarrying	0.12	0.89	0.09	0.91
28	Chemicals and fertilizer mineral mining	- 0.14	1.03	- 0.16	1.08
29	New construction, residential buildings	0	0.86	0	0.88
30	New construction, nonresidential buildings	0.01	0.86	0.01	0.88
31	New construction, public utilities	0	0.86	0	0.88
32	New construction, highways	0	0.84	0	0.87
33	New construction, all other	0	0.84	0	0.86
34	Maintenance and repair construction, residential	0	0.86	0	0.88
35	Maintenance and repair construction, all other	0	0.82	0	0.84
	Manufacturing				
36	Ordnance and accessories	0.50	0.78	0.44	0.79
37	Food and similar products	1.58	0.87	1.22	0.89
38	Tobacco manufactures	0.61	0.92	0.57	0.93
39	Broad and narrow fabrics, yarn and thread mills	- 0.30	0.85	- 0.37	0.88
40	Misc. textile goods and floor coverings	- 0.16	0.84	- 0.21	0.87
41	Apparel	- 0.90	0.80	- 0.95	0.82
42	Misc. fabricated textile products	- 0.04	0.83	- 0.05	0.85
43	Lumber and wood products, except containers	- 0.02	0.83	- 0.16	0.85
44	Wooden containers	- 0.02	0.76	- 0.02	0.78
45	Household furniture	- 0.29	0.82	- 0.29	0.84

Table 14 (continued)

No.	Sector	BASE Quantity (10^9 1967 $)	BASE Relative 1985 price	HIGH Quantity (10^9 1967 $)	HIGH Relative 1985 price
	Manufacturing				
46	Other furniture and fixtures	0.04	0.80	0.03	0.82
47	Paper and allied products, except containers and boxes	0.90	0.90	0.61	0.94
48	Paperboard containers and boxes	0.04	0.83	0.04	0.86
49	Printing and publishing	0.35	0.84	0.26	0.85
50	Chemicals and selected chemical products	3.30	0.98	3.00	1.06
51	Plastics and synthetic materials	1.90	0.87	1.69	0.94
52	Drugs, cleaning, and toilet preparations	0.91	0.86	0.81	0.88
53	Paints and allied products	0.08	0.86	0.08	0.90
54	Paving mixtures and blocks	- 0.01	1.19	- 0.01	1.47
55	Asphalt felts and coatings	- 0.01	1.10	- 0.01	1.35
56	Rubber and misc. plastics products	- 0.04	0.81	- 0.14	0.83
57	Leather tanning and industrial leather products	- 0.08	0.91	- 0.09	0.93
58	Footwear and other leather products	- 0.83	0.87	- 0.86	0.89
59	Glass and glass products	0.12	0.86	0.09	0.88
60	Stone and clay products	0.11	0.92	0.02	0.96
61	Primary iron and steel manufacturing	- 0.45	0.94	- 0.71	0.97
62	Primary nonferrous metals manufacturing	- 0.61	0.96	- 0.81	0.98
63	Metal containers	0	0.85	- 0.01	0.87
64	Heating, plumbing, and fabricated structural metal products	0.39	0.87	0.35	0.88
65	Screw machine prod., bolts, nuts, etc., & metal stampings	0.47	0.83	0.40	0.85
66	Other fabricated metal products	0.38	0.87	0.23	0.89
67	Engines and turbines	1.14	0.84	1.03	0.85
68	Farm machinery	0.22	0.83	0.15	0.84
69	Construction, mining, oil field machinery, equipment	2.12	0.89	1.98	0.90

Table 14 (continued)

No.	Sector	BASE Quantity (10^9 1967 $)	BASE Relative 1985 price	HIGH Quantity (10^9 1967 $)	HIGH Relative 1985 price
	Manufacturing				
70	Materials-handling machinery and equipment	0.19	0.82	0.17	0.83
71	Metalworking machinery and equipment	0.45	0.80	0.32	0.81
72	Special industry machinery and equipment	0.98	0.75	0.84	0.77
73	General industrial machinery and equipment	0.86	0.80	0.73	0.81
74	Machine shop products	0.03	0.82	0.02	0.83
75	Office computing and accounting machines	3.40	0.82	2.97	0.83
76	Service industry machines	1.01	0.85	0.93	0.87
77	Elec. trans. & dist. eq. & elec. industry apparatus	1.50	0.79	1.36	0.81
78	Household appliances	0.06	0.81	0.04	0.82
79	Electric lighting and wiring equipment	0.16	0.83	0.08	0.84
80	Radio, television and communications equipment	- 0.06	0.70	- 0.19	0.70
81	Electronic components and accessories	1.52	0.73	1.29	0.74
82	Miscellaneous elec. machinery, equipment & supplies	0.12	0.88	0.08	0.89
83	Motor vehicles and equipment	4.00	0.82	3.60	0.83
84	Aircraft and parts	3.69	0.76	3.40	0.77
85	Other transportation equipment	0.14	0.87	0.04	0.89
86	Professional, scientific, & controlling instr. & supplies	0.83	0.76	0.71	0.77
87	Optical, ophthalmic & photographic equip. & supplies	1.32	0.87	1.19	0.88
88	Miscellaneous manufacturing	0.01	0.76	- 0.18	0.78
89	Railroads and related services	0.65	0.73	0.54	0.77
90	Local, urban and interurban highway equip. & supplies	0	0.84	0	0.87
91	Motor freight transportation and warehousing	1.66	0.73	1.52	0.75
92	Water transportation	1.84	0.82	1.47	0.92
93	Air transportation	1.10	0.79	0.92	0.88
94	Pipe line transportation	.08	0.85	0.06	0.88
95	Transportation services	0.28	0.84	0.26	0.85

		BASE		HIGH	
No.	Sector	Quantity (10^9 1967 $)	Relative 1985 price	Quantity (10^9 1967 $)	Relative 1985 price
	Services				
96	Communications except radio & television broadcasting	0.65	0.81	0.60	0.82
97	Radio and TV broadcasting	0.07	0.91	0.07	0.92
98	Water and sanitary services	0.01	0.96	0	1.01
99	Wholesale and retail trade	6.10	0.91	5.64	0.92
100	Finance and insurance	0.18	0.90	0.16	0.91
101	Real estate and rental	1.40	0.96	1.30	0.97
102	Hotels & lodging; pers. & repair serv., except auto repair	0.99	0.94	0.94	0.97
103	Business services	1.06	0.92	0.98	0.93
104	Automobile repair & services	0.01	0.84	0.01	0.85
105	Amusements	0.69	0.97	0.63	0.98
106	Medical, educ. services, & nonprofit inst.	0.17	0.92	0.16	0.93
107	Federal government enterprises	0.17	1.02	0.16	1.04
108	State and local government enterprises	0	0.97	0	1.01
109	Business travel, entertainment, & gifts	- 0.38	0.86	- 0.43	0.89
110	Office supplies	0	0.84	0	0.86

Table 14 (continued)

Table 15
Value of Total Output
by Major Economic Sector, at 1985 Relative Prices

(10^9 1967 $)

	1985 BASE	1985 HIGH	% Change
Agriculture, mining, const.	273	275	0.7
Manufacturing	872	868	- 0.5
Transportation	71	72	1.4
Services	907	884	- 2.5
Energy supply	211	278	31.8
Total	2334	2377	1.8

Table 16
Quantity and Value of Output* (Energy Sectors)
and Quantity of Output* (Nonenergy Sectors)

No.	Sector	BASE	HIGH	% Change
	Energy total output, quantity (10^{15} Btu)			
1	Coal	21.68	26.24	21.0
2	Crude oil & gas	41.87	39.99	- 4.5
3	Shale oil	0.30	0.40	33.3
4	Methane from coal	0.21	0.21	0.0
5	Coal liquefaction	-	-	-
6	Refined oil products	35.72	24.90	-30.3
7	Pipeline gas	17.82	17.56	- 1.4
8	Coal combined cycle electric	-	-	-
9	Other fossil electric	6.89	7.20	4.5
10	LWR electric	2.71	2.71	0.0
11	HTGR electric	-	-	-
12	Hydro, geothermal & solar electric	1.43	1.50	4.9
	Energy total output, value (10^9 1967 $)			
1	Coal	12.1	15.5	28.1
2	Crude oil & gas	51.1	86.5	69.3
3	Shale oil	0.4	0.6	50.0
4	Methane from coal	0.4	0.4	0.0
5	Coal liquefaction	-	-	-
6	Refined oil products	56.8	72.4	27.5
7	Pipeline gas	30.5	39.3	29.9
8	Coal combined cycle electric	-	-	-
9	Other fossil electric	37.3	40.2	7.8
10	LWR electric	14.7	15.1	2.7
11	HTGR electric	-	-	-
12	Hydro, geothermal & solar electric	7.8	8.4	7.7
	Total	211.1	278.4	31.9
	Nonenergy total output, agriculture (10^9 1967 $)			
21	Livestock and livestock products	50.73	48.83	- 3.7
22	Other agriculture products	45.42	43.83	- 3.5
23	Forestry and fishery products	3.37	3.23	- 4.2
24	Agriculture, forestry, and fishery services	4.18	4.04	- 3.3
25	Iron and ferroalloys ores mining	2.92	2.83	- 3.1
26	Nonferrous metal ores mining	3.04	2.95	- 3.0
27	Stone and clay mining, quarrying	3.96	3.89	- 1.8
28	Chemicals and fertilizer mineral mining	1.69	1.63	- 3.6
29	New construction, residential buildings	43.08	43.08	0.0
30	New construction, nonresidential buildings	64.28	62.07	- 3.4

*Total output equals domestic production.

Table 16 (continued)

No.	Sector	BASE	HIGH	% Change
	Nonenergy total output, agriculture (10^9 1967 \$)			
31	New construction, public utilities	31.12	31.01	- 0.4
32	New construction, highways	6.34	6.34	0.0
33	New construction, all other	8.51	9.91	16.4
34	Maintenance and repair construction, residential	11.72	11.28	- 3.8
35	Maintenance and repair construction, all other	31.79	31.08	- 2.2
	Nonenergy total output, manufacturing (10^9 1967 \$)			
36	Ordnance and accessories	7.13	7.06	- 1.0
37	Food and similar products	142.50	137.04	- 3.8
38	Tobacco manufactures	9.86	9.49	- 3.8
39	Broad and narrow fabrics, yarn and thread mills	26.89	25.83	- 3.9
40	Misc. textile goods and floor coverings	7.98	7.67	- 3.9
41	Apparel	36.27	34.83	- 4.0
42	Misc. fabricated textile products	7.49	7.21	- 3.7
43	Lumber and wood products, except containers	23.97	23.51	- 1.9
44	Wooden containers	0.91	0.88	- 3.3
45	Household furniture	8.32	8.00	- 3.8
46	Other furniture and fixtures	4.80	4.56	- 5.0
47	Paper and allied products, except containers and boxes	31.06	29.93	- 3.6
48	Paperboard containers and boxes	11.04	10.63	- 3.7
49	Printing and publishing	39.57	38.24	- 3.4
50	Chemicals and selected chemical products	46.69	45.09	- 3.4
51	Plastics and synthetic materials	16.59	16.00	- 3.6
52	Drugs, cleaning, and toilet preparations	30.04	28.96	- 3.6
53	Paints and allied products	5.33	5.18	- 2.8
54	Paving mixtures and blocks	0.88	0.87	- 1.1
55	Asphalt felts and coatings	1.11	1.08	- 2.7
56	Rubber and misc. plastics products	26.90	25.96	- 3.5
57	Leather tanning and industrial leather products	1.25	1.18	- 5.6
58	Footwear and other leather products	4.67	4.45	- 4.7
59	Glass and glass products	6.58	6.36	- 3.3
60	Stone and clay products	20.53	20.16	- 1.8
61	Primary iron and steel manufacturing	56.55	55.20	- 2.4
62	Primary nonferrous metals manufacturing	40.08	39.17	- 2.3
63	Metal containers	5.77	5.52	- 4.3
64	Heating, plumbing and fabricated structural metal products	26.31	26.29	- 0.1

Table 16 (continued)

No.	Sector	BASE	HIGH	% Change
	Nonenergy total output, manufacturing (10^9 1967 $)			
65	Screw machine prod., bolts, nuts, etc. & metal stampings	15.98	15.51	- 2.9
66	Other fabricated metal products	23.25	22.61	- 2.8
67	Engines and turbines	8.49	8.79	3.5
68	Farm machinery	5.44	5.03	- 7.5
69	Construction, mining, oil field machinery, equipment	9.84	9.84	0.0
70	Materials-handling machinery and equipment	5.64	5.41	- 4.1
71	Metalworking machinery and equipment	12.01	11.59	- 3.5
72	Special industry machinery and equipment	10.01	9.49	- 5.2
73	General industrial machinery and equipment	13.24	12.82	- 3.1
74	Machine shop products	6.24	6.09	- 2.4
75	Office computing and accounting machines	15.00	14.24	- 5.1
76	Service industry machines	10.74	10.36	- 3.5
77	Elec. trans. & dist. eq. & elec. industry apparatus	17.21	16.96	- 1.4
78	Household appliances	11.70	11.25	- 3.8
79	Electric lighting and wiring equipment	8.54	8.34	- 2.3
80	Radio, television, and communications equipment	25.05	24.22	- 3.3
81	Electronic components and accessories	13.97	13.48	- 3.5
82	Miscellaneous elec. machinery, equipment & supplies	5.34	5.16	- 3.3
83	Motor vehicles and equipment	85.69	83.01	- 3.1
84	Aircraft and parts	19.15	18.84	- 1.6
85	Other transportation equipment	17.65	17.01	- 3.6
86	Professional, scientific & controlling instr. & supplies	9.66	9.40	- 2.7
87	Optical, ophthalmic & photographic equip. & supplies	8.35	8.05	- 3.6
88	Miscellaneous manufacturing	17.54	16.84	- 4.0
	Nonenergy total output, transportation (10^9 1967 $)			
89	Railroads and related services	23.98	23.33	- 2.7
90	Local, urban and interurban highway equip. & supplies	7.99	7.74	- 3.1
91	Motor freight transportation and warehousing	33.20	32.04	- 3.5
92	Water transportation	8.23	7.74	- 6.0
93	Air transportation	15.99	15.44	- 3.4
94	Pipe line transportation	1.58	1.22	-22.8
95	Transportation services	2.58	2.49	- 3.5

Table 16 (continued)

No.	Sector	BASE	HIGH	% Change
	Nonenergy total output, services (10^9 1967 $)			
96	Communications except radio & television broadcasting	40.94	39.54	- 3.4
97	Radio and TV broadcasting	5.94	5.74	- 3.4
98	Water and sanitary services	5.46	5.25	- 3.8
99	Wholesale and retail trade	301.20	290.02	- 3.7
100	Finance and insurance	89.91	86.49	- 3.8
101	Real estate and rental	214.96	206.77	- 3.8
102	Hotels & lodging; pers. & repair serv., except auto repair	35.10	33.84	- 3.6
103	Business services	102.12	98.74	- 3.3
104	Automobile repair & services	24.59	23.72	- 3.5
105	Amusements	14.93	14.38	- 3.7
106	Medical, educ. services, & nonprofit inst.	101.08	97.38	- 3.7
107	Federal government enterprises	14.42	13.99	- 3.0
108	State and local government enterprises	11.00	10.63	- 3.4
109	Business travel, entertainment & gifts	19.98	19.31	- 3.4
110	Office supplies	5.23	5.09	- 2.7

There is a marked contrast in the change of output between energy sectors: a 21% increase in coal, a 4 1/2% increase in electricity output, and a 30% decrease in refined oil products. Information on nonenergy sectors in Table 17 has been selected to illustrate the diffusion of the energy price changes through their effect on output of nonenergy sectors. In the construction sector this is reflected by a public utility construction output level which is almost unchanged, reflecting the opposite forces of greater electricity construction requirements on the one hand and the decreased gas utility and other construction because of gas prices and the lower GNP on the other. The nonresidential building construction sector is barely affected by either energy prices or changing energy production, and its output reflects the overall decrease in economic activity with a 3.4% decrease. In manufacturing, engine and turbine sales are affected much more by the increase in electricity production than by the decrease in GNP, as shown by the 3.5% increase in output for that sector. On the other hand, farm machinery with a 7.5% decrease in output reflects the reinforcing effect of a decrease in overall activity and the fewer agricultural exports needed to finance foreign oil. This same effect is seen in the differential between the decrease in output of office machinery (-5.1%), a major export product, and of machine shop products (-2.4%), a sector not greatly affected either by changes in the energy sector or in foreign trade. In the transportation sector the difference between the decline in air transport (3.4%) and pipeline transportation (22.8%) indicates that air transport is not too sensitive to price (see Table 16), but as might be expected, pipeline output is closely related to the use of oil and gas. The final entry, services, tends to show a fairly uniform 3.5 to 4% decrease in all sectors, which is consistent with, but slightly larger than, the decrease in GNP.

Table 17
Quantity of Total Output for Selected Sectors

(Energy in 10^{15} Btu; nonenergy in 10^9 1967 $)

	BASE	HIGH	% Change
Energy			
Coal	21.68	26.24	21.0
Refined oil products	35.72	24.90	-30.3
Fossil electric	6.89	7.20	4.5
Construction			
Public utility	31.12	31.01	- 0.4
Nonresidential buildings	64.28	62.07	- 3.4
Manufacturing			
Engines & turbines	8.49	8.79	3.5
Farm machinery	5.44	5.03	- 7.5
Office computing & accounting machines	15.00	14.24	- 5.1
Machine shop products	6.24	6.09	- 2.4
Transportation			
Air transport	15.99	15.44	- 3.4
Pipeline transportation	1.58	1.22	-22.8
Services			
Finance & insurance	89.91	86.49	- 3.8
Business travel, entertainment & gifts	19.98	19.31	- 3.4

3.9 Employment

Table 18 shows employment by sector. Unemployment is not specifically shown. The H-J model assumes full employment. The I-O model generates the number of workers required to produce the output. If the size of the labor force is postulated, then unemployment is the difference between the labor force and the level of employment. The I-O calculates the level of employment for each scenario. The difference between the low scenario and the high scenario can be determined, and in fact employment drops from about 100 million in the BASE case to 97.6 million in the HIGH case, a crop of 2.8%.

These calculations were made on the basis of assumed productivity increases in each sector. The same productivity increase was used for both scenarios. In fact, productivity in each scenario should be related to the rate of growth of the sector reflecting the turnover of capital stock. Since productivity would grow more slowly in the HIGH case, the differential is understated. On the other hand, the input-output model does not adjust the mix of labor and other factors of production as a function of prices. If it did, this would tend to increase employment for the HIGH case. Both of these refinements are possible for each sector for some 380 occupations. A sample of selected sectors and occupations is shown in Table 19. Employment grows substantially in both the coal mining and fossil electric sectors. The increased coal employment is half in operatives with most of the rest laborers and craftsmen. On the other hand, almost half the fossil electric increased employment consists of craftsmen with most of the remainder being professional, technical, or clerical.

Table 18
Employment

(1000 man-years)

No.	Sector	BASE	HIGH	% Change
	Energy			
1	Coal	132.0	159.8	21.1
2	Crude oil & gas	129.8	127.7	- 1.6
3	Shale oil	0.6	0.8	33.3
4	Methane from coal	0.6	0.6	0.0
5	Coal liquefaction	-	-	-
6	Refined oil products	120.7	84.2	-30.2
7	Pipeline gas	76.8	75.7	- 1.4
8	Coal combined cycle electric	-	-	-
9	Other fossil electric	387.9	405.4	4.5
10	LWR electric	193.2	193.2	0.0
11	HTGR electric	-	-	-
12	Hydro, geothermal & solar electric	34.2	35.9	5.0
	Total	1075.8	1083.3	0.7%
	Agriculture			
21	Livestock and livestock products	1389.0	1337.0	- 3.7
22	Other agriculture products	1711.4	1651.5	- 3.5
23	Forestry and fishery products	114.0	109.3	- 4.1
24	Agriculture, forestry, and fishery services	318.9	308.2	- 3.4
25	Iron and ferroalloy ores mining	42.7	41.3	- 3.3
26	Nonferrous metal ores mining	91.1	88.4	- 3.0
27	Stone and clay mining, quarrying	112.7	110.7	- 1.8
28	Chemicals and fertilizer mineral mining	25.6	24.7	- 3.5
29	New construction, residential buildings	1051.6	1051.6	0.0
30	New construction, nonresidential buildings	1536.3	1483.5	- 3.4
31	New construction, public utilities	745.0	742.4	- 0.3
32	New construction, highways	182.1	182.1	0.0
33	New construction, all other	265.2	308.8	16.4
34	Maintenance and repair construction, residential	380.5	366.3	- 3.7
35	Maintenance and repair construction, all other	1234.4	1206.8	- 2.2

Table 18 (continued)

No.	Sector	BASE	HIGH	% Change
	Manufacturing			
36	Ordnance and accessories	129.8	128.6	- 0.9
37	Food and similar products	1710.0	1644.5	- 3.8
38	Tobacco manufactures	58.2	56.0	- 3.8
39	Broad and narrow fabrics, yarn and thread mills	627.6	600.3	- 4.3
40	Misc. textile goods and floor coverings	133.7	128.5	- 3.9
41	Apparel	1513.5	1453.4	- 4.0
42	Misc. fabricated textile products	189.2	182.1	- 3.8
43	Lumber and wood products, except containers	722.4	708.6	- 1.9
44	Wooden containers	32.8	31.7	- 3.4
45	Household furniture	362.4	348.5	- 3.8
46	Other furniture and fixtures	144.5	137.2	- 5.0
47	Paper and allied products except containers and boxes	589.2	567.8	- 3.6
48	Paperboard containers and boxes	233.9	225.2	- 3.7
49	Printing and publishing	1344.6	1299.4	- 3.4
50	Chemicals and selected chemical products	435.2	420.2	- 3.4
51	Plastics and synthetic materials	174.8	168.6	- 3.5
52	Drugs, cleaning, and toilet preparations	320.2	308.7	- 3.6
53	Paints and allied products	72.2	70.1	- 2.9
54	Paving mixtures and blocks	10.7	10.5	- 1.9
55	Asphalt felts and coatings	19.9	19.4	- 2.5
56	Rubber and misc. plastics products	498.2	480.8	- 3.5
57	Leather tanning and industrial leather products	37.9	35.8	- 5.5
58	Footwear and other leather products	280.2	267.0	- 4.7
59	Glass and glass products	169.9	164.2	- 3.4
60	Stone and clay products	499.1	490.1	- 1.8
61	Primary iron and steel manufacturing	1241.8	1212.2	- 2.4
62	Primary nonferrous metals manufacturing	597.2	583.6	- 2.3
63	Metal containers	75.1	71.8	- 4.4
64	Heating, plumbing and fabricated structural metal products	727.2	726.0	- 0.1
65	Screw machine prod., bolts, nuts, etc., & metal stampings	373.0	362.0	- 2.9
66	Other fabricated metal products	608.7	591.9	- 2.8

Table 18 (continued)

No.	Sector	BASE	HIGH	% Change
	Manufacturing			
67	Engines and turbines	152.8	158.2	3.5
68	Farm machinery	111.1	102.7	- 7.6
69	Construction, mining, oil field machinery, equipment	246.6	246.6	0.0
70	Materials handling machinery and equipment	127.1	121.9	- 4.1
71	Metalworking machinery and equipment	322.8	311.5	- 3.5
72	Special industry machinery and equipment	195.2	185.0	- 5.2
73	General industrial machinery and equipment	294.4	285.1	- 3.2
74	Machine shop products	257.0	250.8	- 2.4
75	Office computing and accounting machines	382.6	363.3	- 5.0
76	Service industry machines	192.0	185.2	- 3.5
77	Elec. trans. & dist. eq. & elec. industry apparatus	424.0	417.9	- 1.4
78	Household appliances	193.2	185.7	- 3.9
79	Electric lighting and wiring equipment	250.3	244.4	- 2.4
80	Radio, television and communications equipment	467.4	451.9	- 3.3
81	Electronic components and accessories	340.6	328.6	- 3.5
82	Miscellaneous elec. machinery, equipment, & supplies	154.2	149.0	- 3.4
83	Motor vehicles and equipment	879.2	851.7	- 3.1
84	Aircraft and parts	452.5	445.2	- 1.6
85	Other transportation equipment	558.3	538.0	- 3.6
86	Professional, scientific & controlling instr. & supplies	246.7	240.1	- 2.7
87	Optical, ophthalmic & photographic equip. & supplies	193.4	186.4	- 3.6
88	Miscellaneous manufacturing	411.0	394.6	- 4.0
	Transportation			
89	Railroads and related services	580.3	564.6	- 2.7
90	Local, urban, and interurban highway equip. & supplies	371.0	359.4	- 3.1
91	Motor freight transportation and warehousing	992.3	957.7	- 3.5

Table 18 (continued)

No.	Sector	BASE	HIGH	% Change
	Transportation			
92	Water transportation	219.7	206.6	- 6.0
93	Air transportation	277.3	267.7	- 3.5
94	Pipe line transportation	18.2	14.0	-23.1
95	Transportation services	185.0	178.5	- 3.5
	Services			
96	Communications, except radio & television broadcasting	850.3	821.2	- 3.4
97	Radio and TV broadcasting	175.9	170.0	- 3.4
98	Water and sanitary services	55.4	53.2	- 4.0
99	Wholesale and retail trade	23514.7	22641.9	- 3.7
100	Finance and insurance	4158.3	4000.2	- 3.8
101	Real estate and rental	1150.0	1106.2	- 3.8
102	Hotels & lodging; pers. & repair serv., except auto repair	3790.8	3654.7	- 3.6
103	Business services	4142.0	4004.9	- 3.3
104	Automobile repair & services	474.1	457.3	- 3.5
105	Amusements	1099.3	1058.8	- 3.7
106	Medical, educ. services, & nonprofit inst.	9587.4	9236.5	- 3.7
107	Federal government enterprises	1514.5	1469.4	- 3.0
108	State and local government enterprises	584.1	564.4	- 3.4
109	Business travel, entertainment, and gifts	-	-	-
110	Office supplies	-	-	-
	Other government* employment	14100.0	14100.0	0.0
	Household employment	1448.8	1448.8	0.0
	Total Employment	100351.4	97571.0	- 2.8

*Growth rate in other government employment assumed to be 1.8% per year.

Table 19
Changes in Employment in Selected Occupations
for Selected Industries - 1985

(Thousands of man-years)

	1 Coal mining		9 Other fossil electric		30 New construction nonresidential buildings		33 New construction all other	
	BASE case	Change to HIGH	BASE case	Change to HIGH	BASE case	Change to HIGH	BASE case	Change to HIGH
Total employment	132	28	388	18	1536	-53	265	44
Prof., tech., kindred	4	1	52	2	37	- 1	29	5
Engineers, tech.	2	0	25	1	15	- 1	12	2
Computer spec.	1	0	2	0	1	0	1	0
Clerical workers	6	1	77	3	86	- 3	20	3
Secretaries, gen.	1	0	11	1	26	- 1	5	1
Crafts & kindred	44	9	182	8	826	-28	95	16
Carpenters	6	1	2	0	538	-18	6	1
Electricians	5	1	22	1	15	- 1	2	0
Mechanics	9	2	24	1	11	0	10	2
Operatives	66	14	22	1	76	- 3	28	5
Drill press oper.	-	-	-	-	-	-	-	-
Truck drivers	7	1	7	0	11	0	16	3
Nonfarm workers	8	2	19	1	249	- 9	62	10

	67 Engines & turbines		68 Farm machinery		75 Office computing & accounting machines	
	BASE case	Change to HIGH	BASE case	Change to HIGH	BASE case	Change to HIGH
Total employment	153	5	111	- 8	383	-19
Prof., tech., kindred	20	1	9	- 1	137	- 7
Engineers, tech.	8	0	3	0	38	- 2
Computer spec.	1	0	1	0	38	- 2
Clerical workers	21	1	14	- 1	71	- 4
Secretaries, gen.	4	0	3	0	21	- 1
Crafts & kindred	29	1	23	- 2	45	- 2
Carpenters	-	-	-	-	-	-
Electricians	1	0	1	0	1	0
Mechanics	9	0	5	0	3	0
Operatives	68	2	51	- 4	77	- 4
Drill press oper.	3	0	1	0	1	0
Truck drivers	-	-	2	0	-	-
Nonfarm laborers	7	0	3	0	3	0

The next sectors chosen for illustration are two construction sectors, nonresidential and all other. In this case decreased employment in nonresidential construction, 53,000 jobs, is almost compensated for by 44,000 new jobs in the all other construction sector. Differences in the mix of workers stand out. 28,000 fewer craftsmen are working in nonresidential construction, while 16,000 more are working in the other new construction sector. The opposite effect is seen in terms of professional workers, where additional employment in the expanding sector is five times as great as the reduction in the contracting one. Finally, employment of clerical workers and laborers between the two sectors is a standoff.

A similar comparison can be made between engines and turbines, where production increases because of the expansion of electric utilities, and farm machinery with a larger than average decrease in employment because of the decline in exports of both machinery and farm products that are no longer required to finance oil imports. For these two sectors there does not seem to be a sharp differential across occupations. However, the chances that the firms are geographically co-located is small, and therefore the workers laid off by one sector are not necessarily available for employment by the other. To analyze the geographical as well as the occupational impact of energy price or policy changes, geographical detail is needed. Fortunately the data exist, and if research support is available the tools can be sharpened to show occupational effects by almost 400 occupations and geographical impacts for states and, possibly, counties.

Employment impacts for still one more selected sector are shown. This sector, office computing and accounting machines, is a major, rapidly growing export sector. It is interesting in that the lower level of employment almost totally affects employment of professional and clerical workers, with no impact on nonfarm workers.

3.10 Prices

Energy prices have been discussed earlier. Other prices show how much a 1967 dollar can buy in 1985 under the new sets of relative prices. Since all nonenergy sector prices in 1967 were one dollar, a 1985 price of less than that shows that its real price has declined because of productivity increases. Likewise, a 1985 price greater than one dollar shows an increase in real price, the increased cost of energy more than offsetting productivity gains between 1967 and 1985. Estimation of current prices in 1985 dollars is not possible at this time because the BNL I-O model does not contain a monetary sector.

The change in energy prices in Table 20 was the input to the exercise. The changes in the nonenergy prices indicate how the energy price changes percolate through the economy. As one might expect, the price increases of products heavily dependent on energy input are much more relative to the Base Case than those that have little energy embodied in them. By and large, sectors in the chemical and transportation sectors show relatively large price increases and machinery and services relatively small increases. Some selected sectors are shown in Table 21. As can be clearly seen, items such as paving mixtures and asphalt, both heavily dependent on petroleum, have increased on the order of 25%. Water and air transportation, also heavily dependent on energy sources and petroleum, have increased by over 10%. Chemicals and plastics, similarly dependent, have increased on the order of 8%; paper and stone and clay, both large energy-using industries but with relatively smaller energy requirements than chemicals, about 4%. Highways requiring energy for paving and hotels and lodging for space conditioning, increase between 3% and 4%, and residential construction prices increase somewhat less, at about 2%. Finally, sectors such as printing and publishing, farm machinery, radio and television broadcasting, and medical services show quite small price increases, about 1%.

Table 20
1985 Prices Corrected for Comparability
with 1967 Nonenergy Prices

(Aggregate nonenergy price index: 1) 0.87809 BASE; 2) 0.89287 HIGH)

No.	Sector	BASE	HIGH	% Change
	Energy (price: 1967 $\$/10^6$ Btu)			
1	Coal	.56	.59	5.4
2	Crude oil & gas	1.22	2.16	77.0
3	Shale oil	1.39	1.41	1.4
4	Methane from coal	2.07	2.12	2.4
5	Coal liquefaction	-	-	-
6	Refined oil products	1.59	2.90	82.4
7	Pipeline gas	1.71	2.24	31.0
8	Coal combined cycle electric	-	-	-
9	Other fossil electric	5.42	5.58	3.0
10	LWR electric	5.42	5.58	3.0
11	HTGR electric	-	-	-
12	Hydro, geothermal & solar electric	5.42	5.58	3.0
	Agriculture (price: 1967 $/unit output)			
21	Livestock and livestock products	0.91	0.94	3.3
22	Other agriculture products	0.91	0.94	3.3
23	Forestry and fishery products	0.95	0.97	2.1
24	Agriculture, forestry and fishery services	0.92	0.93	1.1
25	Iron and ferroalloys ores mining	0.93	0.96	3.2
26	Nonferrous metal ores mining	0.97	0.99	2.1
27	Stone and clay mining, quarrying	0.89	0.91	2.2
28	Chemicals and fertilizer mineral mining	1.03	1.08	4.8
29	New construction, residential buildings	0.86	0.88	2.3
30	New construction, nonresidential buildings	0.86	0.88	2.3
31	New construction, public utilities	0.86	0.88	2.3
32	New construction, highways	0.84	0.87	3.6
33	New construction, all other	0.84	0.86	2.4
34	Maintenance and repair construction, residential	0.86	0.88	2.3
35	Maintenance and repair construction, all other	0.82	0.84	2.4

Table 20 (continued)

No.	Sector	BASE	HIGH	% Change
	Manufacturing (price: 1967 $/unit output)			
36	Ordnance and accessories	0.78	0.79	1.3
37	Food and kindred products	0.87	0.89	2.3
38	Tobacco manufactures	0.92	0.93	1.1
39	Broad and narrow fabrics, yarn and thread mills	0.85	0.88	3.5
40	Misc. textile goods and floor coverings	0.84	0.87	3.6
41	Apparel	0.80	0.82	2.5
42	Misc. fabricated textile products	0.83	0.85	2.4
43	Lumber and wood products, except containers	0.83	0.85	2.4
44	Wooden containers	0.76	0.78	2.6
45	Household furniture	0.82	0.84	2.4
46	Other furniture and fixtures	0.80	0.82	2.5
47	Paper and allied products except containers and boxes	0.90	0.94	4.4
48	Paperboard containers and boxes	0.83	0.86	3.6
49	Printing and publishing	0.84	0.85	1.2
50	Chemicals and selected chemical products	0.98	1.06	8.2
51	Plastics and synthetic materials	0.87	0.94	8.0
52	Drugs, cleaning and toilet preparations	0.86	0.88	2.3
53	Paints and allied products	0.86	0.90	4.6
54	Paving mixtures and blocks	1.19	1.47	23.5
55	Asphalt felts and coatings	1.10	1.35	22.7
56	rubber and misc. plastics products	0.81	0.83	2.5
57	Leather tanning and industrial leather products	0.91	0.93	2.2
58	Footwear and other leather products	0.87	0.89	2.3
59	Glass and glass products	0.86	0.88	2.3
60	Stone and clay products	0.92	0.96	4.3
61	Primary iron and steel manufacturing	0.94	0.97	3.2
62	Primary nonferrous metals manufacturing	0.96	0.98	2.1
63	Metal containers	0.85	0.87	2.4
64	Heating, plumbing and fabricated structural metal products	0.87	0.88	1.1
65	Screw machine prod., bolts, nuts, etc. & metal stampings	0.83	0.85	2.4
66	Other fabricated metal products	0.87	0.89	2.3

Table 20 (continued)

No.	Sector	BASE	HIGH	% Change
	Manufacturing (price: 1967 $/unit output)			
67	Engines and turbines	0.84	0.85	1.2
68	Farm machinery	0.83	0.84	1.2
69	Construction, mining, oil field machinery, equipment	0.89	0.90	1.1
70	Materials handling machinery and equipment	0.82	0.83	1.2
71	Metalwork machinery and equipment	0.80	0.81	1.2
72	Special industry machinery and equipment	0.76	0.77	1.3
73	General industrial machinery	0.80	0.81	1.2
74	Machine shop products	0.82	0.83	1.2
75	Office computing and accounting machines	0.82	0.83	1.2
76	Service industry machines	0.85	0.87	2.4
77	Elec. trans. & dist. eq. & elec. industry apparatus	0.79	0.81	2.5
78	Household appliances	0.81	0.82	1.2
79	Electric lighting and wiring equipment	0.83	0.84	1.2
80	Radio, television and communications equipment	0.70	0.70	0.0
81	Electronic components and accessories	0.73	0.74	1.4
82	Miscellaneous elec. machinery, equipment & supplies	0.88	0.89	1.1
83	Motor vehicles and equipment	0.82	0.83	1.2
84	Aircraft and parts	0.76	0.77	1.3
85	Other transportation equipment	0.87	0.89	2.3
86	Professional, scientific & controlling inst. & supplies	0.76	0.77	1.3
87	Optical, ophthalmic & photographic equip. & supplies	0.87	0.88	1.1
88	Miscellaneous manufacturing	0.76	0.78	2.6
89	Railroads and related services	0.73	0.77	5.5
90	Local, urban and interurban highway equip. & supplies	0.84	0.87	3.6
91	Motor freight transportation and warehousing	0.72	0.75	4.2
92	Water transportation	0.82	0.92	12.2
93	Air transportation	0.79	0.88	11.4
94	Pipe line transportation	0.85	0.88	3.5
95	Transportation services	0.84	0.85	1.2

Table 20 (continued)

No.	Sector	BASE	HIGH	% Change
	Services (price: 1967 %/unit output)			
96	Communications except radio & television broadcasting	0.81	0.82	1.2
97	Radio and TV broadcasting	0.91	0.92	1.1
98	Water and sanitary services	0.96	1.01	5.2
99	Wholesale and retail trade	0.91	0.92	1.1
100	Finance and insurance	0.90	0.91	1.1
101	Real estate and rental	0.96	0.97	1.0
102	Hotels & lodging; pers. & repair serv., except auto repair	0.94	0.97	3.2
103	Business services	0.92	0.93	1.1
104	Automobile repair & services	0.84	0.85	1.2
105	Amusements	0.97	0.98	1.0
106	Medical, educ. services & nonprofit inst.	0.92	0.93	1.1
107	Federal government enterprises	1.02	1.04	2.0
108	State and local government enterprises	0.97	1.01	4.1
109	Business travel, entertainment & gifts	0.86	0.89	3.5
110	Office supplies	0.84	0.86	2.4

Note: There are Real Prices expressing how much a 1967 dollar can buy in 1985.

Table 21
Price Change between HIGH and BASE
Scenarios for Selected Sectors

Sector	% Increase over BASE
Coal	5.4
Refined oil products	82.4
Electricity	3.0
Pipeline gas	31.0
Paving mixtures & blocks	23.5
Asphalt felts & coatings	22.7
Water transportation	12.2
Air transportation	11.4
Chemicals & selected products	8.2
Plastics & synthetic materials	8.0
Paper & allied products	4.4
Stone & clay products	4.3
Highway construction	3.6
Residential construction	2.3
Printing & publishing	1.2
Farm machinery	1.2
Hotels & lodging	3.2
Radio & television broadcasting	1.1
Medical, educational services, nonprofit institutions	1.1

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APPENDIX A

MODELING FUEL-CONSUMING ACTIVITIES AND THE NATIONAL ECONOMY

A representation of the national economy with a detailed picture of fuel-consuming activities has been established using the DRI Long-term Interindustry Model (LITM) and the BNL Energy Input-output Model. The models are aligned to an exogenous set of base case assumptions regarding future years, usually 1985 to 2000. Assumptions are made for such items as factor productivity, energy resource consumption, energy service demands, and energy prices. The linked models can be solved to determine deviations from the base case, such as expectations of higher oil and gas prices. The models are used as planning, not forecasting, tools. They are general equilibrium models in that they assume sufficient time for the economy to fully adjust to changes in factor prices, resource constraints, etc.

A major factor which can induce energy conservation is the price of fuel (including electricity) to consumers. At equilibrium, the effects of the price of each fuel on each particular energy service for which fuels are demanded are incorporated. Energy-using capital stock differs by energy service, and cost of the capital stock is an important element in the user's fuel/end-use equipment decision. Although the BNL I-O model incorporates this within operating and capital coefficients and the structure of GNP, the DRI model does not identify energy services. A bridge is therefore necessary to translate DRI changes in fuel consumption and GNP into BNL changes in energy service-specific fuel and end-use equipment demands.

Linkages of the DRI and BNL models for previous policy studies have been in both quantity and price space for fuels. Adjustment of energy service demands in the BNL model were based on DRI fuel quantities and an exogeneously specified set of income and price elasticities of demand for each energy service. In this study, linkage has been established in both quantity and price space for energy service--specific fuel demands. A set of demand elasticities are determined within the model solution procedure that are consistent both with respect to fuel demands between alternative 1985 cases and between the 1985 cases and an historical year (1967).

A simple bridge model has been specified which relates fuel demand in the I-O for each particular energy service (the dependent variable) to GNP (or PCE) and to the average price of all fuels delivered to that energy service (the independent variables). This model is fully described by a set of price and GNP (or PCE) elasticities for residential consumers and for the set of all other consumers. These elasticities yield consistent changes in fuel demand, both when one looks at the 1985 Base Case versus historical 1967 data, and when one compares the 1985 Base Case with an alternative 1985 Case.

The basic model is as follows:

$$Q = Q(P,Y),$$

where Q = fuel demand for a particular energy service,
P = average fuel price to that energy service,
Y = PCE (for residential demand), or iron and steel output (for coke demand), or GNP (for all other demand).

Total differentiation of this equation shows the impact of changes in the independent variables:

$$dQ = \frac{\partial Q}{\partial P} dP + \frac{\partial Q}{\partial Y} dY,$$

or

$$\frac{dQ}{Q} = \frac{\partial Q}{\partial P} \frac{P}{Q} \frac{dP}{P} + \frac{\partial Q}{\partial Y} \frac{Y}{Q} \frac{dY}{Q},$$

or

$$\frac{dQ}{Q} = e_p \frac{dP}{P} + e_y \frac{dY}{Y}$$

where

e_p = fuel price elasticity,

e_y = PCE or GNP income elasticity,

$$\frac{dx}{x} = \frac{x_2 - x_1}{(x_1 + x_2)/2}, \text{ for } x = Q,P,Y.$$

To facilitate computation, energy service demand Btu (after end-use equipment efficiency is accounted for) were used for Q instead of delivered fuel Btu. This introduces the additional assumption that changes in the efficiency of end-use equipment are independent of fuel type for each energy service. This implies that improvements in end-use equipment over time for any energy service are independent of the fuel used in that equipment. In space heating, for example, any increased insulation would be applied to all buildings regardless of heating system type, and any efficiency improvement in furnaces would be matched by improvements in electrical heating systems.

In running the model to compare two policy cases, changes in energy service demand are directly proportional to changes in demand for delivered fuel. To avoid confusion, demand changes listed in the body of this report are tabulated in terms of delivered fuel quantities and prices, not in terms of final energy service quantities and prices. At the present stage of model development it is not possible to separate the two reasons for a change in fuel demand, a change in basic energy service demand (behavioral change), and a change in end-use equipment efficiency (technical change).

Several national scenarios for 1985 have been established for use with the combined BNL/DRI models. Each represents long-term equilibrium adjustment by the economy to the set of energy prices and other parameters assumed.

1985 Base Case (85B) - This is standard forecast 2 used by ERDA in early 1976 for internal planning purposes.* No proposals from the National Energy Plan are included in this forecast. Both the DRI and BNL energy and input-output models were calibrated to this forecast. As shown in Table A-1, real energy prices in 1985 are projected to be considerably higher than in 1975. Percentage change listed in the table is the energy price change between two cases, divided by the average energy price for the two cases.

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*ERDA, Administrator for Planning, Analysis and Evaluation, Approval of Energy Impact Numbers, internal memo, Washington, D.C. (Feb. 11, 1977).

Table A-1
Real Energy Prices (1967 $/10⁶ Btu)

I-O Sector	1967	1975	ΔP/Pave 75 vs 67	1985-B	ΔP/Pave 85-B vs 75	1985-HP	ΔP/Pave 85-HP vs 85-B	2000B	ΔP/Pave 00B vs 85B	2000HP	ΔP/Pave 00HP vs 00B
1. Coal	0.18	0.38	0.71	0.64	0.51	0.66	0.03	0.74	0.14	0.76	0.03
2. Crude oil	0.52	1.04	0.67	1.37	0.27	2.81	0.69	1.94	0.34	3.98	0.69
Crude gas	0.16	0.28	0.55	1.39	1.33	1.96	0.34	1.78	0.25	2.51	0.34
3. Shale oil				1.58		1.58	0.00				
6. Refined oil	0.97	1.49	0.42	1.82	0.20	3.26	0.57	2.39	0.27	4.28	0.57
7. Pipeline gas	0.61	0.81	0.28	1.94	0.82	2.51	0.26	2.33	0.18	3.01	0.02
9-12. Electricity	4.16	4.52	0.08	6.15	0.31	6.25	0.01	6.05	-0.02	6.15	0.02
13. Coke	0.80	1.64	0.69	2.66	0.47	2.74	0.03	3.09	0.15	3.18	0.03
14. Petrochemicals	0.90	1.36	0.41	1.80	0.28	2.89	0.46	2.30	0.24	3.69	0.46
15. Motive power	3.75	5.72	0.42	6.97	0.20	12.56	0.57	9.18	0.27	16.54	0.57
16. Process heat	1.01	1.41	0.33	2.78	0.65	3.51	0.23	3.36	0.19	4.24	0.23
17. Water heat	1.65	2.00	0.19	4.51	0.77	5.00	0.10	4.86	0.07	5.39	0.10
18. Space heat	1.32	2.09	0.45	3.99	0.63	7.90	0.66	4.82	0.19	9.54	0.66
19. Air conditioning	1.12	1.22	0.08	1.72	0.34	1.74	0.01	1.68	-0.02	1.70	0.01
20. Electric power	4.16	4.52	0.08	6.38	0.34	6.47	0.01	6.23	-0.02	6.32	0.01

Note: 1967 and 1975 energy service prices for sectors 13-20 ($ per Btu after end-use efficiency) are adjusted to 1985 end-use efficiencies so that price differences between cases are proportional to real fuel price differences.

1985 High Price Case (85HP) - This scenario assumes much scarcer oil and gas than the Base Case. The higher cost of finding and exploiting oil and gas reservoirs is arbitrarily reflected by a crude oil price that is 2.1 times that in the Base Case and a crude gas price that is 1.4 times the Base Case level. The scenario assumes that these prices are both expected and realized, and that there is sufficient time to fully adjust production and consumption activities to these prices. Government policies enacted to date are assumed.

1985 No New Government Case (85NG) - The same set of energy prices are assumed as for the Base Case. Government programs enacted since 1967 are not assumed; so energy consumption is greater than in the Base Case. The greatest increase in fuel consumption is to meet motive power demand because the government's automobile mileage standards are expected to have more impact on energy consumption than any other program enacted to date. This case is purely hypothetical, but it is necessary in order to estimate bridge model elasticities.

1985 With 1975 Energy Prices (85-75P) - In this scenario all energy prices are assumed to remain constant between 1975 and 1985. Decision makers, in this instance, expect market forces and/or government price controls to prevent energy price increases over this decade. Government policies enacted to date are assumed.

Input-output model solutions were obtained for only the first two cases (85B and 85HP) because of the project deadline on this study. It was necessary, however, to establish energy service consumption levels for the third case (85NG) in order to obtain energy service demands for the High Price Case that were consistent with the 1985 Base Case and an historical year--1967. The bridge model establishes this consistency. Because this model contains only prices and GNP as explanatory variables, government programs are assumed to be the same for any two scenarios being compared. For the 85B and 85HP cases, government programs enacted to date are assumed (no proposals in the National Energy Plan). To compare energy consumption in 1967 with a 1985 scenario, on the other hand, it is necessary to assume only those energy programs existing in 1967. The relevant 1985 case (85NG) is thus one which eliminates, primarily, the auto efficiency standards already mandated by the U.S. Congress.

Fuel prices (I-O sectors 1 to 12) were of course already established from the basic assumptions. Historical 1967 energy service demands and prices (I-O sectors 13-20) were then corrected to 1985 end-use efficiencies so that energy service demands in all cases would be directly proportional to fuel demands to each energy service. This allowed estimation of price elasticities with respect to the most relevant price facing decision makers --the average fuel price to each energy service.* Energy service prices for 1967, 85B and 85NG** were then calculated with the BNL 110-sector I-O model

*The elasticities may not be correct if changes in end-use efficiencies over time for a particular energy service are different with respect to fuel type.

**The 85B A-matrix and value-added coefficients were assumed for the 85NG case because of time limitations.

(A-matrix and value-added coefficients). Strictly speaking, these prices are average fuel prices per unit of energy service demand, after taking into account end-use equipment efficiency. Because of constant end-use efficiencies across all cases, however, they are proportional to average fuel prices per unit of delivered fuel for each energy service. They do account for changes in the fuel mix to each energy service.

The bridge model was set up for two comparisons--85NG vs 1967 and 85HP vs 85B. For the first, percentage change in energy service prices and GNP were known.* The problem was to find a set of price and GNP elasticities which results in 85NG energy service demands somewhat higher than in the 1985 Base Case. Actual differences chosen were judgemental because of the lack of adequate statistics. For the second comparison, the combined DRI-BNL I-O models had to be solved under the assumption of higher energy supply prices. The problem in this was to estimate the percentage change in energy service prices and GNP and find a set of elasticities and, thus, energy service demands consistent with fuel and electricity consumption in the DRI model. An iterative solution procedure was used and a set of elasticities eventually derived which appeared reasonable and feasible and which satisfied the two bridge-model comparisons. Because this procedure was rather complicated, energy service demands were broken down into only two categories--residential and all other. Over all, this still provides energy service demand estimates of greater confidence than one could obtain without the bridge model. The resultant elasticities can be used in certain other cases to eliminate running the combined DRI/BNL models. Most importantly, they represent an estimate of how the economy will respond to changes in energy prices alone, aside from other government programs that do not affect the prices of fuels and electricity.

In iteratively solving the DRI and BNL input-output models, the DRI LITM model was used as the demand model and the BNL Energy Input-Output Model** as the supply model for energy. *Prices* of fuels and electricity supplied were thus fed from a BNL solution to DRI and *quantities* of fuels and electricity demanded were fed from a DRI solution to BNL.

After aligning the BNL and DRI models for the 1985 Base Case, a High Price Case solution was obtained in the following manner. Prices of oil and gas in the DRI model were increased to the desired level and the model was re-solved. The drop in the level of two final demand components (PCE and investment) was then used to scale down the corresponding 110 sector level vectors in the BNL model. Changes in certain linear program constraints such as fuel/electricity mixes to energy services were judgementally changed on the basis of DRI fuel shifts as well as BESOM fuel prices. An initial estimate of new energy service prices and elasticities was made, and the energy product coefficients and final demands decreased on this basis. Coefficients in the crude sector were increased to reflect increased scarcity

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*The 85NG GNP was assumed to be the same as the Base Case GNP.

**This is actually a combination of the I-O model developed jointly with the University of Illinois and the Brookhaven Energy System Optimization Model (BESOM).

of oil and gas, and certain coefficients in the capital matrix were increased to reflect energy-saving capital investment. Adjustments to value-added coefficients were made to bring energy prices into alignment with the high price assumptions, and the BNL model was then solved, using the capital adjustment subprogram.

Iteration continued between the two models. The primary information fed to DRI after a BNL run was oil and gas prices (prespecified), coal price (exogenously changed on the basis of change in production), electricity price (from BESOM solution), prices and quantities of renewable resources (exogenously changed), and oil and gas imports (from BNL solution). The primary information used for a BNL run after a DRI run was aggregate fuel and electricity consumption, PCE demand for fuels and electricity, and aggregate GNP components. Bridge-model calculations and adjustment of assumed elasticities were, of course, required before making a BNL model run. Near the end of the iterative procedure, the balance of payments subprogram was used in a BNL run to estimate changes in exports and imports resulting from the change in energy imports. The solution GNP's for the two models are the same value, but the components (PCE, investment, net exports) differ somewhat between the two models. Capital investment, for example, is somewhat larger in the BNL model.

The results of the bridge model are summarized in the elasticities of demand listed in Table A-2. The real energy prices upon which they are based are listed in Table A-1, and energy service demands for the several cases are listed in Table A-3. These elasticities were also used to estimate demand under the assumption of constant energy prices from 1975 to 1985. GNP in this case was a judgemental decision, based on the difference in the aggregate cost of energy for 85HP vs 85B and 85B vs 85-75P and upon the corresponding GNP differences between the high price and base cases.

The BNL model solution is very informative because it depicts changes in energy use per unit of production and consumption activities over time. If one has reasonable estimates about the lifetime of energy-using capital stock, estimates can be made of the improved efficiency of both new and retrofitted stock that are consistent with the BNL/DRI model solutions.

As an example, the 1985 Base Case is compared with 1967 historical data to show the combined effects of better fuel efficiency and better ways of using end-use capital equipment over this time period. The following assumptions are made because of the lack of comprehensive evidence to the contrary:

1. No significant improvements in fuel use or methods for using capital equipment between 1967 and 1975;

2. 1976 capital stock still remaining in 1985 can be retrofitted and usage patterns changed such that the improvement in fuel consumption is half of that to be gained by purchasing new capital stock over that time period.

The further assumptions listed in Table A-4 are also made. The amount of new capital stock emplaced between 1976 and 1985 can be found from the growth in energy service demands over this time period and the old (pre-1976) stock still remaining in 1985. One can then calculate the average increase in efficiency associated with new capital stock emplaced between 1976 and 1985. Table A-5 shows the estimated increase in efficiency for each energy

Table A-2
Elasticities of Demand for Energy Services

Personal consumption demand

		PCE Elasticity	Price Elasticity
15.	Motive power	1.17*	-0.40
16.	Process heat	0.75	-0.20
17.	Water heat	0.65	-0.22
18.	Space heat	0.85	-0.25
19.	Air conditioning	1.00**	-0.12
20.	Electrical power	1.10	-0.15

All other demand

		GNP Elasticity	Price Elasticity
13.	Coke	0.37†	-0.22
14.	Petrochemicals	1.50	-0.35
15.	Motive power	1.38*	-0.40
16.	Process heat	1.05	-0.33
17.	Water heat	0.85	-0.28
18.	Space heat	1.00	-0.32
19.	Air conditioning	1.20	-0.24
20.	Electric power	1.32	-0.16

*These elasticities are derived from 1967-1973 fuel consumption for automobiles and trucks-buses respectively.

**This is for 1985 comparisons. A value of 2.30 was used to estimate 1985 demand from a 1967 base level.

†This elasticity is with respect to the real output of the iron and steel sector, not GNP.

Table A-3

Demand for Energy Services* (10^{15} Btu After End-use Efficiency)

	I-O Sector	1967	1985-75P**	1985-(NG)†	1985-B**	1985-HP**
13.	Coke					
	all	0.541	0.581	0.535	0.522	0.517
14.	Petrochemicals					
	all	3.118	6.646	5.943	5.820	4.733
15.	Motive power					
	res.	2.137	3.273	3.560	2.910	2.199
	other	1.453	2.223	2.554	1.988	1.516
16.	Process heat					
	res.	0.454	0.700	0.607	0.600	0.555
	other	8.482	14.403	11.402	11.332	10.177
17.	Water heat					
	res.	0.911	1.349	1.120	1.115	1.061
	other	0.626	0.966	0.785	0.763	0.723
18.	Space heat					
	res.	3.340	5.175	4.449	4.300	3.513
	other	2.581	4.147	3.314	3.310	2.598
19.	Air conditioning					
	res.	0.381	2.027	1.902	1.820	1.610
	other	0.637	1.166	1.001	0.975	0.802
20.	Electric power					
	res.	0.756	1.560	1.455	1.431	1.363
	other	2.553	5.588	5.230	5.134	4.927

*End-use efficiencies are the same for all 1985 estimates. All 1967 demands are adjusted to the same 1985 efficiencies. Energy service demand differences between cases are thus proportional to real demand differences for delivered fuels.

**Government policies and standards to date are assumed.

†No new government policies and programs subsequent to 1967 are assumed.

Table A-4
End-Use Capital Stock Assumptions

Energy service	Old 1976 stock remaining in 1985: Fraction remaining	Old 1976 stock remaining in 1985: Fraction retrofitted
	Residential consumers	
Motive power	0.10	0.20
Water heat	0.40	0.30
Space heat	0.74	0.40
Electric power	0.40	0.10
	Service consumers	
Motive power	0.10	0.50
Process heat	0.40	0.85
Water heat	0.10	0.85
Space heat	0.40	0.85
	Manufacturing consumers	
Motive power	0.10	0.50
Process heat	0.40	0.85
Water heat	0.10	0.85
Space heat	0.40	0.85
Electric power	0.40	0.85

Table A-5

Energy Conservation by End Users and Energy Service

Energy service	Decrease in fuel use per HH, 85B vs 67, %
Residential consumers	
Motive power	21
Water heat	10
Space heat	11
Electric power	12
Energy service	**Decrease in fuel use per unit of output, 85B vs 67, %**
Service consumers	
Motive power	53
Process heat	52
Water heat	46
Space heat	42
Manufacturing consumers	
Motive power	53
Process heat	45
Water heat	35
Space heat	26
Electric power	18

service in terms of fuel use per household (for residential consumers) or fuel use per unit of output (for manufacturing and service consumers). The greatest improvement is in motive power, and this reflects mandated vehicle efficiency standards as well as the impact of higher oil prices. Significant improvements also appear in process heat, water heat, and space heat demands, particularly for manufacturing and service consumers. Improvements are least in the use of electric power because of the smaller increase in the price of electricity over this time period.

APPENDIX B

ALLOCATION OF THE CONSERVATION BUDGET

A framework and methodology are presented in this appendix for allocating portions of the DOE Conservation budget according to broad policy objectives and allocation rules. This methodology goes beyond the issues addressed in the body of this study: economic feasibility and appropriateness of federal involvement for specific conservation projects, major concerns of DOE project managers.* As such, the framework assesses alternative end uses of energy and their relative importance in regard to some broad policy objective such as reduction in the consumption of our scarcest domestic resources, i.e., oil and gas. It should be especially useful in deciding in which areas new project proposals should be solicited: new versus retrofit capital equipment, commercial versus residential energy users, process heat versus space heat energy demands, and so forth. It should also be useful for the allocation of monies across major conservation program areas. Since selection of policy objectives and allocation rules is the responsibility of DOE, this appendix focuses on the use of economic and energy models for quantifying objectives, and it suggests certain categorizations of the end use of energy that are useful in this regard.

By its very nature, research and development activities are risky and uncertain. In many instances the specific end product is unknown at the time a project is initiated. Or, as new knowledge is gained or as relative prices change over time, the economic feasibility of a project under development may shift radically. One cannot, therefore, do a cost/benefit analysis of all projects, rank them, and pick those with the highest payoff.

The ultimate benefit of R&D investment is a change in the pattern of energy use by those demanding the end services of energy. It is both appropriate and necessary for the federal government to decide what kinds of change it wishes to encourage and what priorities it should set to allocate monies in a manner intended to achieve that change. This is the essence of an energy conservation policy.

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*It is implicitly assumed that expected benefits of *all* funded projects are sufficient to justify expenditures on them and that *all* are also within the appropriate jurisdiction of the federal government and DOE. Decisions on the justification of any individual project are thus separated from the broader policy decisions discussed in this appendix which deal with the overall allocation of the Conservation budget.

Once a list of relevant attributes is established, the next step is to break down current federal expenditures or some portion of them on those bases and to quantify the policy objective and allocation rule on the same bases. The present pattern of expenditure can then be compared with the desired allocation pattern. This provides a basis for changing current program funding levels, initiating new requests for proposals, and so forth.

Table B-1
Classifications for the End Uses of Energy

Attribute	Classification
Type of federal expenditure	1. R & D on a) equipment b) systems 2. Reduction of institutional constraints through: a) standards/regulations/incentives b) information transfer and behavioral change
Energy-using capital stock	1. Existing (implying retrofit) 2. New
Energy consumer	1. Residential 2. Commercial or service sectors 3. Industrial 4. Government 5. Energy supply sectors
Final energy service	1. Feedstocks 2. Motive power 3. Space conditioning 4. Process heat 5. Water heat 6. Electric power
Time frame	1. The present 2. Short term (to 1985) 3. Intermediate term (1985-2000) 4. Long term (beyond 2000)

"Allocation" implies classification of both federal expenditures and energy consumption activities on the basis of certain important attributes. These can include items which categorize the energy-using capital stock, its users, how it is used, and the energy services demanded. A partial listing and categorization of important attributes is presented in Table B-1.

A variety of *conservation policy objectives* either have been or could be adopted by DOE. These include, but are not limited to, the following:

- Reduce use of our scarcest domestic resources i.e., oil, gas;
- promote fuel switching to more abundant resources, i.e., coal, uranium, solar;
- reduce energy consumption across-the-board;
- improve efficiency of energy-using capital stock;
- promote behavioral changes in the way that capital stock is utilized;
- utilize that energy now wasted at the point of end use;
- reduce use according to more pessimistic assumptions about future energy supply.

It is evident that the objectives posed in this list are not mutally exclusive. It is very probable that current policy incorporates some combination of them. It may therefore be advantageous to adopt separate policy objectives for separate portions of the Conservation budget such as that devoted to R & D versus that devoted to institutional constraints or behavioral change. In any case, desired policy objectives must be explicitly recognized and stated if they are to be used to allocate Conservation monies.

In addition to identifying basic objectives, it is necessary to agree upon *allocation rules* for distributing the federal budget across the various end uses of energy. Allocation of federal monies *or* the number of federal projects can be made according to a number of rules such as the following:

- Current or future level of energy consumption (of specific fuels or all energy forms);
- expected energy use in new vs old capital stock at some future time;
- amount of energy conservation that is economically feasible, but not likely to be undertaken by consumers;
- technical expertise of energy consumers;
- number of energy consumers.

Selection of an appropriate allocation rule is dependent upon the perceived role of the federal government in energy conservation activities. Should it limit its activity to high capital, high risk programs, or support promising ideas originated by federal researchers who have the interest and dedication to pursue those ideas? Should it limit its activity in information transfer to residential or small business consumers with limited technical expertise, or should it identify foreign advancements and encourage their adoption in the U.S.? While resolution of these issues may not be simple, establishment of specific objectives and allocation rules is feasible, as demonstrated by the Environmental Protection Agency's recent approach to Zero Base Budgeting.

Let us now turn to specific examples. First, the current Conservation budget is classified with respect to several important attributes. Then, certain policies and allocation rules are quantified and classified with respect to the same attributes for comparison with budget figures. The policy objectives and allocation rules are arbitrarily picked for illustrative purposes only, and effort is directed at quantifying these objectives by the use of energy and economic models available at BNL.

1. Budget Classification

It is useful to classify the goal of each program in the conservation budget as follows:

1) RD & D on: a. equipment
b. systems

2) Reducation of institutional constraints through:
a. standards/regulations/incentives
b. information transfer and behavioral change.

Programs can also be cross-classified on the basis of the end-use of energy toward which the program is directed:

a. existing vs new energy-using capital stock
b. energy consumer, i.e., residential, industrial, etc.
c. final energy service, i.e., motive power, space heating, etc.

Such cross-classifications of the FY 78 budget are made for the Industry and the Buildings and Community Systems programs in Tables B-2 to B-4. Classification is shown for both FY 78 dollar expenditures and number of projects, although the tabulations are incomplete and probably inaccurate because of lack of knowledge about certain programs by BNL.

These cross-classifications are informative in their own right. Industrial conservation programs sponsored by DOE (Table B-2) are heavily weighted toward research and development as opposed to institutional constraints. Both the funding level and the number of projects are greater for new capital stock than for retrofitting old capital stock. Also, major emphasis is placed upon energy use for process heating with, evidently, no funding applied to water heating, despite the large use of hot water in many industrial processes. No projects are listed for space conditioning since this area is probably within the province of the Buildings and Community Systems program. Even so, systems type projects dealing with a manufacturer's joint demands for space conditioning, water heat, and process heat might appropriately be funded within the Industry conservation program. It is also surprising to see that programs dealing with new standards and regulations are not weighted more toward new capital stock and less toward equipment already in use.

The cross-classifications of the Buildings and Community Systems conservation programs (Tables B-3 and B-4) are likewise informative. Here there is an almost equal amount of monies directed to R & D and to institutional constraints. Programs of the latter type are weighted toward standards/regulations/incentives if one looks at dollar expenditures, but toward information transfer and behavioral change if one looks at number of projects. This points out the necessity to determine whether dollars or projects or some combination of the two measures are most useful for classification of the federal program and comparison with policy objectives.

Research and development spending on equipment *and* systems is heavily weighted toward new capital stock, even though part of the "system" - the building itself - is very long-lived. The lack of any program listings under manufacturing, agriculture, mining, and construction consumers is probably a mistake. A DOE program for office buildings would doubtless apply to all nonresidential consumers. There appears to be no program for

Table B-2
Classification of ERDA Conservation Budget (FY 1978)
for Industry*

Attributes of program:	Energy-using capital stock		Energy service						
Type of program	Existing	New	Petrochem	Electric Power	Process Heat	Water Heat	Space Heat	Air Cond.	Motive Power
R & D on:									
a) Equipment 49 (13.0)	21 (3.4)	49 (13.0)	4 (3.5)	9 (1.8)	38 (8.0)				9 (1.8)
b) Systems 6 (0.8)	5 (0.7)	6 (0.8)	5 (0.5)	5 (0.7)	4 (0.4)				5 (0.7)
Reduce institutional constraints through:									
a) Standards/regulations/ incentives 2 (0.3)	2 (0.3)	2 (0.3)			2 (0.3)				
b) Information transfer & behavioral change 8 (1.1)	7 (1.0)	8 (11.1)	5 (0.8)	5 (0.8)	8 (1.1)				5 (0.8)

*Figures without parentheses are number of FY 78 projects; figures inside parentheses are FY 78 funding levels in millions of dollars. This compilation does not include 30 projects ($4.8 million) because of classification difficulties. Classification under program attributes entails double counting when, for example, a program has impact on both existing and new capital stock.

Table B-3
Classification of ERDA Conservation Budget (FY 1978)
for Buildings & Community Systems*

Attributes of program:	Energy-using capital stock		Energy consumer				
Type of program	Existing	New	Res.	Comm. & Gov.	Mfg.	Trans.	Ag., Min., Const.
R & D on:							
a) Equipment 32 (13.4)	10 (3.0)	30 (13.1)	27 (12.0)	20 (7.8)			
b) Systems 17 (25.2)	7 (7.1)	11 (21.6)	10 (16.8)	12 (21.4)			
Reduce institutional constraints through:							
a) Standards/regulations/ incentives 9 (24.2)	6 (3.0)	9 (24.2)	9 (24.2)	8 (4.2)			
b) Information transfer & behavioral change 25 (11.6)	16 (7.0)	18 (10.2)	21 (8.9)	22 (8.7)			

*Figures without parentheses are number of FY 78 projects; figures inside parentheses are FY 78 funding levels in millions of dollars. This compilation does not include 41 projects accounting for 32.5 million dollars because of classification difficulties. A significant portion of these deleted items is the 18 urban waste projects accounting for 18.4 million dollars. Classification under program attributes entails double counting when, for example, a program has impact on both existing and new capital stock.

Table B-4
Classification of ERDA Conservation Budget (FY 1978) for Buildings & Community Systems*

Attributes of program:			Energy service (res., comm. & gov. consumers				
Type of program	Petrochem	Motive Power	Process Heat	Water Heat	Space Heat	Air Cond.	Electric Power
R & D on:							
a) Equipment 32 (13.4)				9 (5.1)	17 (6.5)	16 (6.1)	10 (4.1)
b) Systems 17 (25.2)				7 (5.6)	17 (25.2)	17 (25.2)	10 (7.4)
Reduce institutional constraints through:							
a) Standards/regulations/ incentives 9 (24.2)				6 (2.8)	9 (24.2)	9 (24.2)	8 (4.2)
b) Information transfer & behavioral change 25 (11.6)				13 (4.9)	21 (9.9)	23 (10.1)	18 (6.6)

*Figures without parentheses are number of FY 78 projects; figures inside parentheses are FY 78 funding levels in millions of dollars. This compilation does not include 41 projects accounting for 32.5 million dollars because of classification difficulties. A significant portion of these deleted items is the 18 urban waste projects accounting for 18.4 million dollars. Classification under program attributes entails double counting when, for example, a program has impact on both space heat and air conditioning.

buildings specific to manufacturing, construction, and agricultural consumers such as mobile work places or animal-raising shelters. There also appears to be no program directed toward process heat energy use, e.g., cooking, drying, washing, etc. Again, it should be emphasized that these statements are only exemplary. Budget classification should be undertaken by DOE personnel more familiar with their programs before valid conclusions can be reached.

2. Policy Objectives and Allocation Rules

Two illustrative objectives and allocation rules are chosen for the RD & D portion of the budget:

A. To reduce energy consumption across-the-board and allocate the budget across end uses in proportion to expected 1985 fuel consumption;

B. to accelerate the economy's adjustment to expected oil and gas scarcity in the mid-80's and to allocate the budget in proportion to the reduction in 1985 fuel consumption expected from such scarcity.

For the second objective we first ask what we expect patterns of energy consumption to look like in 1985, and then how they would change if liquid hydrocarbons do become much scarcer (and higher priced). The difference in the economy's long-run equilibrium adjustment to these two possible futures (measured in terms of fuel consumption) then forms the quantitative basis for allocating money or projects under (B) above.

The objectives posed above have been quantified with the assistance of several analytic tools: the DRI LITM model, and the BNL Energy Input/Output Model. These are described in Appendix A.

Long-run adjustment of the economy to two 1985 price forecasts (ERDA forecast F-2 and a higher oil/gas price forecast) was estimated with these combined models. Levels of energy use in ERDA forecast-2 form the quantitative basis for objective (A) above. The difference in petroleum consumption between the high priced oil/gas case and F-2 form the quantitative basis for objective (B) above.

Process models for specific consumers can also be of use in quantifying certain policy objectives. Suppose, for example, that DOE wished to allocate monies across end uses in proportion to that which is economically justified and feasible, but not expected without government action. The hypothesis behind this policy might be that energy consumers will not reduce fuel use as much as is feasible within their own economic criteria because of such factors as lack of technical knowledge of energy-using equipment, inadequate information about actual energy use and available options, energy use being determined by one who does not pay the fuel bill, etc. For such a policy, the difference between F-2 levels of consumption and what was shown to be feasible by process models under the same price assumptions could give an estimate of how much more conservation would be economically feasible. In addition, many technical studies have measured actual fuel consumption for specific uses of energy and have estimated the extent to which consumption could be reduced.

3. Comparison of Conservation Budget With Policy Objectives

The unit of measure for both policies is 10^{15} Btu of delivered fuel, with electricity converted to the equivalent Btu of refined oil necessary to generate the electricity. As some of the numbers listed are tentative, the statements which follow are exemplary only, and not final conclusions.

The 1978 Buildings and Community Systems budget for R & D activities is compared to the two quantified policies in Table B-5. The budget is presented in two ways: number of projects and dollar expenditures. Comparison is made on the basis of three attributes: final energy service, type of consumer, and capital stock (in this example it is buildings rather than energy-using equipment such as furnaces or air conditioners).

Current budget allocation for residential and commercial/government consumers is largest for space heat and air conditioning, with successively lower dollar and project amounts for electric power and water heat. It may be useful in this case to view space heat and air conditioning together as a demand for "space conditioning." This allocation is then similar to the desired allocation under Policy A for both residential and commercial/government consumers. The only exception is the lack of funding for process heat demands. Current allocation by energy service does not correspond to Policy B, however. If this policy were adopted, it would be desirable to direct almost all of the budget to space conditioning.

Dollar expenditures are directed about evenly to residential and commercial/government consumers. The number of projects, on the other hand, is weighted toward the residential sector as are the desired allocations for both Policy A and Policy B.

Current allocation on the basis of capital stock is larger for new buildings than for existing buildings and retrofit, corresponding to Policy A. Policy B would indicate an even split between the two. Overall, current allocation of R & D effort in Buildings and Community Systems more closely resembles Policy A than Policy B.

The 1978 Industry Conservation budget for R & D activities is compared to the two quantified policies in Table B-6. The budget is presented in terms of the number of projects and dollar expenditures, and comparison is made on the basis of one attribute - final energy service. Comparison on the basis of capital stock was infeasible within the time limits of this study because of the great variation in that stock among industrial processes and industries.

Both policies emphasize the great importance of the demands for process heat, and this is indeed the area where most of the current budget goes. If one is very concerned about oil and gas scarcity, the second most important area is petrochemicals, and this policy is supported by current allocation of monies. If one is more interested in energy conservation across-the-board, electric power demands are second in importance. Present allocation of projects is consistent with this policy. The lack of programs for other energy services is apparent. However, relevant R & D on motive power is probably the responsibility of the Transportation Conservation Division, and certain space conditioning programs of the Buildings and Community Systems Division would no doubt apply to industrial concerns.

Table B-5
Evaluation of 1978 R & D Budget for Buildings & Community Systems

	Current allocation		Desired allocation††	
	No. of projects	Expenditure*	Policy A**	Policy B†
1. By energy service for residential consumers				
Space heat	24	10.7	9.0	1.6
Air conditioning	23	10.7	1.4	0.2
Electric power	12	6.9	4.1	0.2
Water heat	11	3.2	2.4	0.2
Process heat	0	0	0.8	0.2
2. By energy service for commercial & government consumers				
Space heat	24	12.6	6.0	1.3
Air conditioning	21	12.2	0.5	0.1
Electric power	18	10.5	5.3	0.2
Water heat	9	2.6	1.4	0.2
Process heat	0	0	0.7	<0.1
3. By type of consumer				
Residential	37	28.8	17.7	2.4
Commercial & government	32	29.2	13.9	1.9
4. By capital stock				
Existing buildings	17	10.1	9.3	1.2
New buildings	41	34.7	11.0	1.1

*Millions of dollars.

**Reduce energy consumption across-the-board.

†Reduce energy consumption in anticipation of scarcer oil and gas.

††Unit of measure is 10^{15} delivered fuel Btu, with electricity converted to equivalent Btu of refined oil necessary to generate that electricity.

Table B-6
Evaluation of 1978 R & D Budget for Industry Conservation

	Current allocation		Desired allocation††	
	No. of projects	Expenditure*	Policy A**	Policy B†
1. By energy service for manufacturing consumers				
Space heat	-	-	0.7	0.2
Air conditioning	-	-	0.2	<0.1
Electric power	14	2.5	9.3	0.3
Water heat	-	-	0.3	<0.1
Process heat	42	8.4	17.5	0.9
Petrochemicals	9	4.0	4.0	0.7
Motive power	-	-	0.2	<0.1
2. By energy-using capital stock				
Existing (retrofit)	26	4.1		
New	55	13.8		

*Millions of dollars.

**Reduce energy consumption across-the-board.

†Reduce energy consumption in anticipation of scarcer oil and gas.

††Unit of measure is 10^{15} delivered fuel Btu, with electricity converted to equivalent Btu of refined oil necessary to generate that electricity.

This comparison for industrial consumers might be more informative if carried out at a greater level of detail. The demand for process heat could be disaggregated by temperature range or type of process, and industrial consumers could be subdivided into categories such as extractive industries, basic metals, etc.

The basic analytical approach to budget allocation as presented in this appendix appears to be very useful. As a next step, the Conservation Divisions in DOE should experiment with the methodology by picking several alternative policy objectives and allocation rules and by categorizing the entire Conservation budget according to the attributes suggested here or others. Work should then be continued at BNL or elsewhere on quantification of additional policy objectives to permit a more comprehensive evaluation of the DOE Conservation budget on an on-going basis.