**ECONOMY-WIDE IMPACTS OF INTERFUEL SUBSTITUTION:
SUBSTITUTION OF ELECTRICITY FOR IMPORTED OIL**

RAYMOND G. TESSMER, JR., AND JOAN LUKACHINSKI

June 1976

Prepared for the
OFFICE OF THE ASSISTANT ADMINISTRATOR FOR PLANNING AND ANALYSIS
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Abstract

An Energy Input-Output Model is applied to analysis of the long run effects (to 1985) of higher oil prices in the U. S. economy. Two questions are examined. First, what are the effects of sustained, higher international oil prices? Second, what are the effects of substituting domestic coal--produced electricity for high-priced foreign oil. Variables examined include capital investment, personal consumption expenditures, exports and imports, labor force, and energy production.

Executive Summary

A new analytic tool -- the Brookhaven/University of Illinois Combined Energy Optimization/Input-Output Model -- has been applied to an analysis of the long run effects (to 1985) of higher oil prices in the U.S. economy. Case I with \$5.35/Bbl. oil (in 1967 dollars) is compared to Case II with \$10.70/Bbl. oil and no constraint on oil imports. Case III with \$10.70/Bbl. oil and sharply curtailed oil imports is then compared with Case II. An earlier Brookhaven study examined the same question with the more limited Brookhaven Energy System Optimization Model as an analytic tool. With the richer content of the combined model, the following 1985 economy-wide effects have been identified:

- Capital Investment
 - Case II vs. Case I - 1.7% more (\$202.4 billion for Case II)
 - Case III vs. Case II - 3.7% more (\$209.9 billion for Case III)
- Personal Consumption
 - Case II vs. Case I - 1.5% less
 - Case III vs. Case II - 0.8% less
- Exports
 - Case II vs. Case I - 7.5% more
 - Case III vs. Case II - 7.0% less
- Labor Force in Energy Sectors
 - Case II vs. Case I - 10.4% more
 - Case III vs. Case II - 11.0% more .

Most of the increase in capital investment provides greater capacity for the production of coal and electricity as domestic electric energy is substituted for imported oil. Coal production is 31% larger and electricity production is 16% larger in Case II than in Case I. Case III shows 30% greater coal output and 19% greater electricity output than Case II. In Case II there is also greater investment in exporting industries to pay for the more costly oil imports. Increases in investment of this order would most likely have major impact on capital markets (pp. 19-23).

The additional investment occurs at the expense of personal consumption expenditures (standard of living). While this impact seems small, it is on the order of one year of per capita income growth based on recent growth trends (pp. 19-23).

Finally, the study shows a marked reallocation of labor to the energy producing areas. Both labor and output are lower in consumer oriented industries and in food and food products and medical and educational services (pp. 34-36).

An additional contribution of the combined model is the new estimates of total energy demand based upon a consistent treatment of economy-wide economic growth. Preliminary findings are that prior energy demand projections seem to be too large (pp. 24-27).

The study results in a set of recommendations directed to improving energy analysis tools. Perhaps the most important is:

"The difference in energy product demands predicted by the energy I-O model and those specified in "Sourcebook for Energy Assessment" (commonly used energy demand projections) should be reconciled and definitional differences identified and recorded." (p. 37).

Although this is primarily a report on a combined model application, a further methodological development that is not reported on elsewhere is incorporated in Appendix B. This is a technique for estimating capital investment requirements. It will be used in conjunction with the combined model until superseded by the use of a full capital coefficient matrix.

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I. SUMMARY OF FINDINGS

Short-run impacts of reduced availability of Arab oil during the embargo of 1973-1974 and of the subsequent large price increases have been experienced by the entire U.S. economy. The long run effects of higher prices and policies aimed at decreased dependence on imports are not clear. In this report two major policy questions are evaluated in terms of their long-run impact on the structure of the nation's economy:

- 1) If the higher oil price initiated by the Organization of Petroleum Exporting Countries persists over the next ten years, how will the structure of the economy change?
- 2) Given the higher price of oil, what will be the further effect on the economy of U.S. policies designed to reduce oil imports below that level resulting from the price increase alone?

In answer to the first question, this study finds that a doubling of oil price to \$10.70/barrel* will result in an increase of \$3.4 billion, or 1.7% in 1985 annual capital equipment expenditures over the capital expenditures with \$5.35/bbl oil. This capital will be emplaced in the coal and coal steam electric generation sectors of the economy as

*All data is presented in constant 1967 dollars.

electricity is substituted for direct combustion of oil products, assuming limitations on domestic capacity for crude oil and nuclear electricity production. On an average annual basis, capital equipment requirements between 1967 and 1985 will increase from a 3.2% to a 3.3% rate of growth.

The production of consumer goods and services will be \$13.8 billion or 1.5% smaller as resources are reallocated to the increased production of capital goods and goods for export. This represents a substantial change in the rate of growth of the standard of living for Americans: On an average annual basis, this means an annual growth rate of 3.7% instead of 3.8% as a result of higher priced oil. Under the assumption of 100% recycle of petrodollars, one can also expect the demand for U.S. export goods to increase by 7.5%.

1) Doubled Oil Price Results

	absolute change, billions of dollars	change in mean annual growth rate, 1967-1985
Capital Investment	+ \$3.4	from 3.2% to 3.3%
Consumer Goods & Services	-\$13.8	from 3.8% to 3.7%
Exports	+ \$7.5	from 5.8% to 6.2%

Non-energy sectors which will experience the greatest percentage increase in output as a direct result of OPEC's high oil price policy are water transportation and iron and ferroalloys ore mining. Non-energy sector increases in

employment will be greatest in new construction, other agricultural products, and general industrial equipment.

Reductions in employment will be greatest in food and kindred products, wholesale and retail trade, and medical and educational services.

In answer to the second question this study finds that a 42% reduction in oil imports will increase 1985 capital equipment expenditures by an additional \$7.5 billion, or 3.7%! Such an increase in the demand for capital is large enough to affect the cost of capital within the capital market. Increase in capital requirements will again be greatest in the coal and coal steam electric generation sectors. Employment in the energy sectors as a whole will increase 11.0% to 2.3 million man-years.

With a decrease in petrodollar expenditures to foreigners of \$15 billion, demand for U.S. exports will be as much as \$7.5 billion less. Production of consumer goods and services could be as much as \$7.5 billion lower, or slightly under 1% of personal consumption expenditures, because of the greater production of capital goods. (Considering the combined impact of higher oil prices and restricted oil imports, reduction in personal

consumption expenditures could be as great as \$21.3 billion, or 2.3%!)

2) Reduced Oil Imports Results

	Absolute change, billions of dollars	change in mean annual growth rate, 1967-1985
Capital Investment	+ \$7.5	from 3.3% to 3.5%
Consumer Goods & Services	- \$7.5	from 3.7% to 3.6%
Exports	- \$7.5	from 6.2% to 5.8%

Non-energy sectors which will experience the greatest percentage increase in output as a direct result of restricted oil imports include most construction and capital goods sectors. The largest percentage decreases will appear in the water transportation and pipeline transportation sectors.

The greatest increase in non-energy employment will occur in new construction and capital goods sectors. The greatest decrease will occur in wholesale and retail trade and in medical and educational services.

One additional finding comes from this application of Brookhaven's energy input-output model. The composition of energy demands for 1985 as forecast by the I-O are somewhat different from the forecasts presented in "Sourcebook for Energy Assessment" (1), a standard reference document. The I-O

calculates energy demands in the framework of a realistic constraint placed by Gross National Product on 1985 productive capacity of the country. The Sourcebook projects demands on the basis of judgemental growth rates applied to each demand category. If further study indicates that the I-O coefficients are not in error, the I-O technique can now be used to provide high confidence energy demand projections.

II. METHODOLOGY AND ASSUMPTIONS

The central question addressed by this report is, What will be the economy-wide impacts of higher oil prices and reduced oil imports over the long run? Within the energy sector, probable impacts have been analyzed in the report, "Interfuel Substitution Study - The Role of Electrification," or, as it is referred to here, the Electrification Study. (2) Long-run adjustments that can be expected include development and production of synthetic fuels, an increase in the use of coal, and increased substitution of electricity and electrical end-use devices for direct combustion of fuels (i.e. substitution of heat pumps for oil-fired furnaces). Such changes were estimated with the assistance of a linear programming (LP) optimization model of the nation's energy system, which is described in (10).

Important as these changes are, there are effects outside the energy sector that can not be investigated with the optimization model alone. What, for instance, might be the effect of higher priced oil imports on the country's international balance of payments? Or what would be the effect of higher capital spending in the energy sector on production of consumer goods and services?

In order to analyze economy-wide effects of changes in

energy prices and technology, a new analytical tool has been developed - a Combined Energy Optimization/Input-Output Model of the U.S. economy, the I-O. This model, which is a combination of the linear program energy optimization model with a standard input-output model, is employed in this analysis of increased substitution of electricity for imported oil. Two cases from the Electrification Study are analyzed along with a case with even more drastic reduction in oil imports. Comparison of Case II with Case I and of Case III with Case II are of special interest. The first comparison looks at the question, "What happens if the oil cartel is able to maintain their higher price for oil over the next ten years?" The second comparison looks at the question, "Given that higher oil prices do prevail, what are the effects of policies which will cut oil imports drastically by 1985?"

Discussion of results concentrates on those findings from the I-O model that were not determinable with the I.P model alone. A detailed discussion of the nation's energy system configuration is not presented as this has already been done in the previous study.

A. Description of Combined Energy Optimization/Input-Output Model

This specialized input-output model of the national

economy has been developed in collaboration with the Center for Advanced Computation of the University of Illinois and is described in detail in (6). A significant feature is that the output of the energy sectors is not measured in dollars but in BTU's of raw coal, crude oil and gas, refined petroleum products, pipeline gas, and generated electricity. The output of these sectors, termed energy supply/conversion sectors, is not distributed directly to other sectors of the economy. Aside from distribution of fuels among these sectors,* their output is distributed to eight dummy energy product sectors defining nonsubstitutable end-use demands for energy--coke, petrochemical feedstocks, motive power, process heat, water heat, space heat, air conditioning, and electric power (7).

Energy input to non-energy sectors is respecified in terms of these functional energy products rather than in terms of generated electricity and specific fuels such as coal or natural gas. By specifying input requirements in terms of energy products such as process heat, substitution among fuel supplies is permitted, and an invariant production function for non-energy sectors suffices. Technological change associated with fuel substitution is localized in the

*All crude oil and gas output goes to either the refined petroleum products sector or to the pipeline gas sector, and a portion of the coal output goes to the electric generation/distribution sector, for example.

production functions of energy supply/conversion sectors.

The revised input-output coefficient of production matrix is depicted in Figure 1. It is based on the Bureau of Economic Analysis (BEA) input-output table for 1967 with 78 regular producing sectors.(8) Outputs of the energy supply and energy product sectors are measured in physical units, British Thermal Units (Btu), and outputs of the non-energy sectors are measured in dollars. Production coefficients in the A_{SS} , A_{SP} , and A_{PS} submatrices have units of Btu/Btu, in the A_{PI} submatrix Btu/\$, in the A_{IS} submatrix \$/Btu, and the A_{II} submatrix \$/\$. A_{PP} and A_{IP} coefficients are zero because energy product sectors are dummy, non-productive sectors. The A_{SI} coefficients are zero because sectoral energy use is described in terms of final energy products via the A_{PI} and A_{PS} coefficients.

The BEA input-output table for 1967 contains five energy supply/conversion sectors: coal, crude petroleum and gas, refined petroleum products, natural gas utilities, and electric utilities. In this model the electric sector is disaggregated on the basis of fuel used--fossil fuel, nuclear, and hydroelectric. In addition, input-output coefficients for six new energy technologies, as developed by the MITRE Corporation, McLean, Virginia, have been incorporated. Their

COEFFICIENT OF PRODUCTION MATRIX			FINAL DEMAND	TOTAL OUTPUT
	ENERGY SUPPLY SECTORS	ENERGY PRODUCT SECTORS		
ENERGY SUPPLY SECTORS, S (Btu)	A_{SS}	A_{SP}	Y_S	X_S
ENERGY PRODUCT SECTORS, P (Btu)	A_{PS}	0	Y_P	X_P
NON ENERGY SECTORS, I (\$)	A_{IS}	0	Y_I	X_I

Figure 1. Energy input-output model.

derivation is described in (4). These technologies are the solvent refined coal process for low sulphur, ashless coal production, mining and retorting of shale oil, the high temperature gas cooled reactor, high Btu coal gasification, low Btu coal gasification with the combined low Btu coal gas and steam cycle electric generation plant, and the light water reactor. Data used to develop input-output coefficients of production were, for the most part, taken from detailed engineering cost studies of these new technologies.

The model is specified in such a manner that fuel substitution effects in the energy supply/conversion sectors can be reflected by coefficient changes within only the A_{SS} and A_{SP} submatrices. These coefficients are, in turn, estimated from solution of the energy optimization model, the LP.

Figure 2 depicts the solution sequence for the combined model pictorially. The interface between the models consists of two sets of equations: one calculating demand constraints for the linear programming model from the total outputs determined by the I-O, and the other calculating input-output coefficients from the solution to the energy optimization model. They are described in (9) for the 110 sector model used in this analysis.

Policy variables within the combined model include energy supply, capacity, environmental and other energy model constraints; the input-output Y vector of final demand; and certain A matrix coefficients, particularly energy product coefficients which can be changed to reflect energy conservation by producing sectors. The Y vector of final demand, representing Gross National Product, is actually an aggregation of eight components: personal consumption expenditures, gross private fixed capital formation, net inventory change, exports, imports, federal government defense, federal government non-defense, and state/local government. Policies affecting the detailed composition as well as aggregate level of GNP can thus be analyzed.

Figure 2. Solution sequence.

Combination of the LP and the I-O models reduces the a priori judgments that must be made before running either model. With the input-output model one no longer must specify A_{SS} and A_{SP} coefficients, those which describe fuel flows and conversion into end-use energy products. These become determinable from an optimization model solution. With the optimization model one no longer must specify total demands for energy products. Instead, only those portions which comprise final demand in an input-output sense, i.e., that which is included in compilation of GNP, must be predetermined. Interindustry (sectoral) input demands for energy products are obtained through solution of the I-O.

At the present time this two-level model is solved by iteration. The solution sequence is as follows:

1. Develop a projected final demand vector for the I-O representing GNP for the planning year being analyzed. Insert estimated costs, capacities, resource availability, and other constraints for this planning year into the energy optimization model.
2. Run the I-O model to determine the Basic Energy Demands, or total outputs of the eight energy product sectors, associated with the GNP projection. A_{SS} and A_{SP} coefficients can start out equal to zero, or approximate values can be inserted to reduce running time to convergence.

3. Disaggregate Basic Energy Demands for motive and electric power to obtain (along with the other basic--energy demands) demand equation constraints for the optimization model.

4. Run the optimization model with disaggregated energy product demands to determine energy supply-demand configuration, the set of z_j energy flows.

5. Convert energy optimization model output to A_{SS} and A_{SP} coefficients and insert these into I-O model.

6. Perform iterative runs, testing for convergence of Basic Energy Demands after each iteration.

B. Assumptions.

Three cases are analyzed in this report. Case I corresponding to the Base Case of the Electrification Study (2); Case II corresponding to Case II of the Electrification Study (doubled oil price); and Case III which is the same as Case II except that oil imports are half the level of Case I.

Optimization model parameters and prices used in this study for Cases I and II correspond respectively with those used in the Electrification Study Base Case and Case II. An oil price of \$5.35/barrel is assumed in Case I and of \$10.70 for Cases II and III (in 1967 dollars).*

*These are equivalent to \$6.17/barrel and \$12.34/barrel in 1970 dollars, all prices in the optimization model being expressed in constant 1970 dollars.

Supply constraints correspond exactly in Cases I and II except for several new energy technologies which are not specified in the I-O model. As shown in Table A-1, Appendix A, coal combined-cycle capacity is substituted for oil combined-cycle, and additional pipeline-quality coal gas is substituted for hydrogen from coal. Solar electric and methanol from coal capacities are set equal to zero since these two did not enter into Base Case or Case II solutions in the Electrification Study. In Case I of this study, imported oil is constrained to the solution value in the Electrification Study, 21.75×10^{15} BTU, (10.6 million barrels/day), in order to achieve correspondence between the two analyses. In Case II, domestic oil is constrained to the solution value for Case I, 20.59×10^{15} BTU (10 million barrels/day), permitting decreased oil usage to reduce oil imports. In Case III imported oil is constrained at half the level of the other cases, 10.88×10^{15} BTU (5.3 million barrels/day). Domestic oil supply is increased over the first two cases in order to get a feasible LP solution. Because the potential for substituting electricity for oil is limited within a 1985 time framework, some minimum quantity of oil must be available if there are to be no serious disruptions or constraints in the national energy system.

Optimization model demand constraints are not prespecified

in this study as they were in the Electrification Study. They come directly from the I-O solution vector of total energy product sector outputs. These demands directly reflect overall economic activity. This, then, is the major difference in how the LP model is set up in the two studies.

The basic assumption of the input-output model is long-term economic equilibrium. Sectoral growth rates for the planning year being analyzed are presumed to be equilibrium rates with no constraints placed on output of non-energy sectors. Concurrently it is assumed that resources of production are perfectly mobile over the long run and that price expectations for any scenario or case persist long enough for full reallocation of factors of production to occur.

Derivation of the 1985 estimated GNP and coefficients of production which are used in this analysis is presented in (3). The assumptions for labor force, manpower requirements per unit of output, and capital requirements per unit of output which lie behind the GNP estimate do not change for the three cases analyzed. This means that a constant real GNP is assumed. The structure of the 1985 GNP purchases, however, is not held constant. It is this shift to production of export and capital goods and away from

consumer goods and services resulting from lower oil imports that is analyzed. Other less likely economic adjustments can be postulated and analyzed. For example, one could analyze the effect of greater labor force participation or underemployment if there is reason to believe these might result from higher oil prices or lower imports.

For simplicity, specific price elasticities for each final energy product are not assumed; thus, use of energy products by each sector per unit of output does not change as oil price and relative energy product prices shift although the mix of fuels supplying those products may shift.

Under these assumptions of long-run equilibrium adjustment, the input-output model provides a picture of alternative production and consumption patterns in the economy of 1985. Detailed results are presented in the following sections.

III. RESULTS

A. Gross National Product

The value of 1985 Gross National Product (GNP) assumed in this analysis is \$1439 billion (in 1967 dollars),* or a growth rate of 3.4% per annum from 1967 to 1985. The basis for this estimate is presented in (3). This estimate of aggregate real GNP was used for all three cases in order to standardize on single values for the labor force, labor productivity, and capital productivity.

Although real GNP in the aggregate is the same, individual components** in the disaggregate vary among the three cases. Several factors account for this shift in the production of final goods and services. First, higher payment to foreigners for more expensive oil means that more export goods must be produced and/or fewer goods imported in order to maintain balance of payments equilibrium. Second, substitution of domestic for foreign energy supplies means that more capital goods must be produced to support higher levels of domestic production, under the assumption of fixed capital/output ratios. Finally, increased output of export and capital goods in turn shifts production away from goods and services that are consumed by individuals and/or government.

*This is equivalent to \$1220 billion in 1958 dollars.

**GNP purchases are divided into eight components: personal consumption expenditures, gross private fixed capital formation, inventory change, federal government defense expenditures, federal government non-defense expenditures, state and local government expenditures, exports, and competitive imports.

Table 1 shows shifts in the GNP components as oil imports are reduced, under the assumptions described in Appendix C. The driving force, of course, is the decrease in crude oil and refined oil imports. Expressed in real terms, competitive imports are 4.7% less for Case II and, for Case III, 12.9% less than for Case II.

The immediate impact on GNP is that more capital goods must be produced to provide additional domestic productive capacity in coal mining, coal-fired electric generating plants, shale oil, pumped storage plants, and certain other industries. In the aggregate, capital investment must be greater by \$3.4 billion, or 1.7%, in Case II over Case I and by another \$7.5 billion, or 3.7%, in Case III over Case II to support necessary domestic energy production.

Because total dollar payments for imports are the same in Case I and Case III (doubled oil price, but half the quantity), it is assumed that balance of payments effects in the aggregate are negligible. Exports are therefore assumed to be the same for these two cases. In Case II, on the other hand, total dollar payments for imports increase because oil doubles in price while oil imports fall only 14%. As described in Appendix C, the increase in dollars held by foreigners

Table 1
Components of 1985 GNP in Real Terms
(Billions of 1967 Dollars)

	<u>Case I</u>	<u>Case II</u>	<u>Case III</u>
Personal Consumption Expenditures	930.0	916.2	908.7
Capital Investment	199.0	202.4	209.9
Exports	99.6	107.1	99.6
Competitive Imports	-61.2	-58.3	-50.8
Government, Inventory Change	152.5	152.5	152.5
Excluded Purchases *	<u>119.2</u>	<u>119.2</u>	<u>119.2</u>
Total:	1439.1	1439.1	1439.1

*Wages to employees not covered by sectors in model, non-competitive imports, and "U.S. outside" transactions.

generates a 7.5% increase in the demand for exports through a drop in the value of the dollar relative to foreign currencies.

Finally, the increase in net exports and capital goods production draws resources away from the production of other consumption goods and services. Assuming that the full effect takes place in personal consumption expenditures in lieu of government purchases, inventory change, and excluded purchases, the following significant effects take place. In Case II personal consumption expenditures drop by 1.5% and in Case III by another 0.8% over Case I. In addition to a change in the standard of living, these necessary changes in composition of GNP have significant effects on the composition of domestic production and employment, which are described in detail in the following sections of this report.

Table 2 summarizes the shift in relative GNP shares for the three cases. Mean annual rates of growth from 1967 to 1985 are shown for four of the eight GNP components. Most significant is: (1) the increase in capital investment from an annual growth rate of 3.2% in Case I to 3.3% in Case II and to 3.5% in Case III; and (2) the decrease in PCE from 3.8% annual growth in Case I to 3.7% in Case II and 3.6% in Case III.

TABLE 2
COMPARISON OF MEAN ANNUAL RATES OF GROWTH
FOR SELECTED GNP COMPONENTS

B. Demand for Energy

Within an input-output model framework, demand for energy can be partitioned into two components - inter-industry demand by producing sectors of the economy, and final demand by consumers and government as counted in Gross National Product. To use the I-O model only that portion of total demand included in GNP must be prespecified, about 30%. The other 70% depends on the GNP bill of other goods and services prespecified and the industrial processes used to produce them. Techniques for estimating a future GNP and its components are highly developed, and considerable confidence can be placed in them.

In the form used for this study, with energy demand specified in physical units (BTU), the approximate proportion of each total energy demand prespecified is shown below in Table 3.

Table 3. Exogenously Specified Energy Demands

<u>Energy Product, i</u>	<u>Percent Prespecified*</u>
coke	0
chemical feedstocks	2
process heat	4
electric power	25
space heat	47
water heat	59
motive power	59
air conditioning	67

*Figures are presented for the Case I solution. The proportion of each demand that is determined within the model is found by subtracting the amount prespecified in the aggregate vector of final demand, Y_i , from total output of an energy product sector, X_i .

Significantly, virtually all of the demand for coke,
chemical feedstocks, and process heat is endogenously determined
by the model. And three-fourths of the demand for electric power
is endogenously determined. This is in sharp contrast with the
optimization model when it is used without the I-O. Then
the entire demand for energy must be estimated and prespecified
for the economy.

Table 4 lists total demands as determined by the three
runs of the combined model and compares them with earlier es-
timates from the Sourcebook* (1) and the Electrification Study (2).
Demand estimates differ significantly in the latter two studies,
those in the Sourcebook being more recent. Comparing Sourcebook
estimates with the combined model solutions, correspondence in
the demand for coke, motive power, air conditioning and electric
power is fairly close. Differences for the other energy products
are greater because of variation in definitions and assumptions
among the studies and because the earlier studies had no over-
all demand constraint based on productive resources of the
economy.

The much larger demand for space heat in the combined
model solution results from two factors. First, residential
space heat demand is assumed to grow at the same rate as GNP

*The 1985 Reference Energy System in the Sourcebook is used
for comparison.

Table 4

1985 Total Energy Demands, 10^{15} BTU

	Sourcebook		Electrification Study Base Case	Combined I-O/LP Model		
	1985	RES		Case I	Case II	Case III
Coke	1.95*		1.62**	2.04	2.08	2.08
Chemical Feedstocks	7.90		8.01	5.97	5.98	5.97
Motive Power	4.98		6.05	4.56	4.53	4.50
Process Heat	11.30		13.89	13.23	13.26	13.26
Water Heat	2.41		1.77	2.07	2.05	2.04
Space Heat	10.00***		9.50	15.08	14.97	14.90
Air Conditioning	2.78		1.96	2.49	2.47	2.42
Electric Power	7.09		8.98	6.31	6.31	6.30
Total:	46.46		51.8	51.4	51.7	51.5

* This is equivalent to 2.81×10^{15} Btu of cleaned coal in the RES going to blast furnaces.

** This is equivalent to 2.34×10^{15} Btu of cleaned coal in the Electrification Study going to blast furnaces.

*** Space heat demand in the Sourcebook is multiplied by 1.58 to achieve comparability with the definition of space heat demand used in the other studies.

between 1967 and 1985 in the combined model-an unrealistically high rate. This biases total space heat demand upward. Second, the combined model includes industrial sector demands for space heat which are not included in Sourcebook and Electrification Study demands.

There is clearly a need to develop techniques for projecting changes in I-O energy product coefficients and GNP components of energy demand over time. The need is greatest for those demands which are expected to grow at rates significantly different from GNP-space heat, air conditioning, water heat and motive power. Development of appropriate techniques has been initiated, and they will be used in future applications of the combined model.

C. Capital Investment

The total level of investment needed to support domestic production in Case I is \$199.0 billion. For Case II, doubled oil price, capital investment is 1.7% larger, \$202.4 billion. Comparing Case III with Case II, restricted oil imports, capital requirements are 3.7% greater, totaling \$209.9 billion.

Capital requirements can be partitioned into those for energy sectors and those for non-energy sectors. Energy sector requirements increase over the three cases from \$47.8 to \$51.5 to \$60.1 billion. Non-energy sector requirements, on the other hand, show less than one percent variation over the three cases.

If in fact the higher oil price initiated by OPEC in late 1973 persists through 1985, investment in domestic energy facilities will be significantly greater over this period. Policies designed to reduce oil imports beyond that which would occur as a direct result of their higher price will further increase domestic energy investment. The increase in capital expenditures in the energy sectors under either of the two policies analyzed is large enough to affect the cost of capital within the capital market and to divert some of the country's resources from the production of personal consumption goods and services.

Which energy sectors, then, will experience the greatest growth in capacity? Table 5 indicates the Mean Annual Growth Rates from 1967 to 1985 for the energy supply sectors under

Table 5
Mean Growth Rates for
Energy Supply Sectors

Sector	Mean Annual Growth 1967-1985, %		
	Case I	Case II	Case III
1 Coal	-0.3	1.2	2.7
2 Crude Oil and Gas	0.5	0.5	0.9
6 Refined Oil Products	1.1	0.9	0.8
7 Pipeline Gas	1.3	1.3	1.3
9 Fossil Electric	-0.9	1.1	2.7
10 LWR Electric	32.6	32.6	32.6
12 Hydroelectric	5.7	6.3	6.3

Case I, Case II and Case III. The most significant increases appear in the Coal and Fossil Electric sectors.* The coal sector, which had a negative growth rate of -0.3% for Case I has Case II and Case III annual growth rates of 1.2% and 2.7% respectively. Similarly, the growth rate for Fossil Electric changed from -0.9% in Case I to a positive growth rate of 1.1% for Case II and 2.7% in Case III. Annual growth rates for other energy supply sectors such as Pipeline Gas and LWR Electric remain constant over the three cases. The only energy supply sector to show a decline in mean annual growth as compared with Case I growth was the Refined Oil Products sector. The remaining two energy supply sectors, Crude Oil and Gas and Hydroelectric had relatively small increases in annual growth rates for Case II and Case III.

Thus, if OPEC's policy of maintaining oil at the post embargo price continues, or if the U.S. carries out its policy to further reduce oil imports, capital investment in energy will primarily be larger in the Coal and Coal steam electric generating sectors, under the assumption that 1985 nuclear generating capacity cannot be increased.

* All of the increase in the fossil electric sector is for coal-fired plants.

D. Composition of Output in the Non-Energy Sectors

This section describes the major changes in composition of output for the two policies analyzed.

For Case II versus Case I, doubled oil price, the sectors with the largest increases in total output over Case I levels are water transportation with a 5% increase and iron and ferroalloys ores mining with 4%. All other non-energy sectors had increases or decreases in output of 0-3%. Table 6 shows changes in output between Case II and Case I for selected sectors.

Comparison of Case III with Case II levels of output, restricted oil imports, shows greater degrees of change. The most significant increases in output are in new construction and capital goods sectors. Residential construction output in Case III increases 3.6% over the Case II level. New construction for non-residential buildings and public utilities both increase 2.6%. Outputs of most capital goods sectors such as construction, mining and oil field machinery and equipment, materials handling equipment, special industrial machinery equipment and heating, plumbing and fabricated structural metal products increase by at least 2%. The most significant decreases in output occur in the water transportation and pipeline transportation sectors. Table 7 shows changes in output between Case III and Case II for selected non-energy sectors.

TABLE 6
SELECTED CHANGES IN OUTPUT, %
CASE II VS. CASE I

TABLE 7
SELECTED CHANGES IN OUTPUT, %
CASE III VS. CASE II

E. Employment Distribution

As the composition of total output changes for each of the three cases, there is also a change in the distribution of labor among the sectors. Using the solution vector of total output along with a "labor coefficient" vector which gives man-years per dollar of output for each sector, it is possible to calculate the associated employment distributions for each case.

Case II represents the situation in which the oil cartel maintains doubled oil prices while the U.S. continues pre-oil cartel import policy. The resulting total 1985 employment in the domestic energy supply sectors increases by 191,000, or 10%, over the Case I level to approximately 2.03 million man-years. Sectors having net decreases in employment of greater than 10,000 man-years include: food and kindred products (30,000), wholesale and retail trade (229,000), medical and educational services (163,000), and apparel (36,000). These decreases reflect the smaller proportion of GNP going to personal consumption expenditures in Case II. Increases of greater than 10,000 man-years occur in the following sectors: New Construction (65,000), Coal (43,000), Hydroelectric (22,000), Fossil Electric (132,000), and General Industrial Equipment (13,000). All capital equipment supply sectors have increased levels of employ-

ment for Case II, in response to increased total investment in 1985 under Case II. The large increase in employment for the aggregated new construction sectors reflects the need for additional industrial plant capacity and public utility construction for increased domestic coal use.

Comparison between Case II and Case III employment levels indicates the effects of the specific oil policy to cut oil imports in half. For Case III total employment in the energy supply sectors rises an additional 224,000 man-years from the Case II level to a total of 2.24 million. All capital equipment supply sectors have increased employment levels in accordance with the higher level of capital investment required for Case III outputs. The energy supply sectors which show the greatest net increases in employment for Case III are Coal, having a 54,000 man-year increase and Fossil Electric, increasing by 150,000 from Case II to Case III. This is the result of substitution of domestic coal and electricity production for previously used foreign oil imports. Non-energy sectors which show major changes in employment levels for Case III include New Construction, increasing by 145,000 man-years, wholesale and retail trade with a 132,000 man-years decrease, and medical and educational

services having a 79,000 decrease in man-years. For Case III, there is clearly an even greater reduction in expenditures, and therefore employment, in the personal consumption areas in order to compensate for the large amount of construction and capital formation necessary for the 4.1% increase in investment required for Case III. The Refined Oil Products sector has a decrease of 2,000 man-years indicating the direct employment effect of the reduction of oil imports.

IV. RECOMMENDATIONS

This analysis presents the first outputs from the 110 sector energy input-output model. Certain problems were, of course, discovered in specifying the model and in making analytical runs. The following recommendations are made in order to overcome problems which remain and to provide increased confidence in its use.

1. The difference in energy product demands predicted by the energy I-O model and those specified in the Sourcebook (1), commonly used energy demand projections, should be reconciled and definitional differences identified and recorded.
2. The energy I-O model should be validated by inserting 1967 parameters and prices in the LP and comparing the combined model solution with historical 1967 I-O data.
3. Techniques should be developed for estimating 1985 energy product coefficients (A_{PS} and A_{PI} submatrices) as a function of technological change and relative energy price changes. Estimated 1985 coefficients as well as 1967 historical coefficients are available for use in all other parts of the A-matrix.
4. Imputed prices for energy supplies and products in the I-O should be calculated from the LP solution. This will permit adjustment of the entire Y vector in terms of dollars, and not a mixture of dollars and BTU's.

5. A more recent set of total sectoral outputs than 1967 (preferably 1974) should be developed with which to more accurately estimate sectoral growth rates to 1985.

6. Econometric estimation procedures should be developed to estimate that portion of energy product demands which are included in GNP.

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Appendix A

Combined Model Input Data and Output

TABLE A-1

LP Supply Constraints, * 10^{15} BTU

Category	Electrification	Combined I-O/LP Model		
	Study Base Case	Case I	Case II	Case III
Fuels:				
Coal, Underground	15.30	15.30	15.30	15.30
Coal, Stripmined	18.70	18.70	18.70	18.70
Domestic Oil	= 23.60	23.60	= 20.59	23.60
Imported Oil	28.00	= 21.75	21.75	= 10.88
Oil Shale	0.20	0.20	0.20	0.20
Natural Gas	28.39	28.39	28.39	28.39
Electricity:				
Coal Steam	Open	Open	Open	Open
Coal Steam Comb. Cycle	0.00	1.63	1.63	1.63
Oil Steam	= 2.90	= 2.90	= 2.90	= 2.90
Oil Steam Comb. Cycle	1.60	0.00	0.00	0.00
Gas Turbine	1.40	1.40	1.40	1.40
Gas Steam	= 3.45	= 3.45	= 3.45	= 3.45
Total Energy Systems	0.10	0.10	0.10	0.10
LWR	12.67	12.67	12.67	12.67
HTGR	0.53	0.53	0.53	0.53
Hydroelectric	4.32	4.32	4.32	4.32
Geothermal	0.50	0.50	0.50	0.50
Solar Electric	0.03	0.00	0.00	0.00
Pumped Storage	0.30	0.30	0.30	0.30
Solvent Ref. Coal/Steam	0.00	0.00	0.00	0.00
Synthetic and Other:				
Syngas from Oil	0.00	0.00	0.00	0.00
Methane from Coal	2.12	2.32	2.32	2.32
H ₂ from Electrolysis	0.00	0.00	0.00	0.00
H ₂ from Coal	0.20	0.00	0.00	0.00
Methanol from Coal	0.20	0.00	0.00	0.00
Solar Direct Thermal	0.34	0.34	0.34	0.34

*"Equality" constraints are indicated by an = sign. All others are "less than or equal" constraints.

TABLE A-2

LP Solutions, 10^{15} BTU

Category	Electrification	Combined I-O/LP Model		
	Study Base Case	Case I	Case II	Case III
Fuels:				
Coal, Underground	8.50	6.45	10.62	15.30
Coal, Stripmined	10.40	5.10	5.15	6.10
Domestic Oil	23.60	20.59	20.59	23.60
Imported Oil	21.75	21.75	18.72	10.88
Oil Shale	0.00	0.00	0.20	0.20
Natural Gas	28.39	28.39	28.39	28.39
Electricity:				
Coal Steam	8.60	1.08	5.20	10.83
Coal Steam Comb. Cycle	0.00	0.00	0.00	1.63
Oil Steam	2.90	2.90	2.90	2.90
Oil Steam Comb. Cycle	0.00	0.00	0.00	0.00
Gas Turbine	0.00	1.16	0.16	0.17
Gas Steam	3.45	3.45	3.45	3.45
Total Energy Systems	0.10	0.10	0.10	0.00
LWR	12.67	12.67	12.67	12.67
HTGR	0.53	0.53	0.53	0.53
Hydroelectric	4.32	4.32	4.32	4.32
Geothermal	0.50	0.50	0.50	0.50
Solar Electric	0.00	0.00	0.00	0.00
Pumped Storage	0.30	0.00	0.30	0.30
Solvent Ref. Coal/Steam	0.00	0.00	0.00	0.00
Synthetic and Other:				
Syngas from Oil	0.00	0.00	0.00	0.00
Methane from Coal	2.12	2.32	2.32	2.32
H ₂ from Electrolysis	0.00	0.00	0.00	0.00
H ₂ from Coal	0.20	0.00	0.00	0.00
Methanol from Coal	0.00	0.00	0.00	0.00
Solar Direct Thermal	0.34	0.34	0.34	0.34

TABLE A-3

Adjusted Components of
1985 Gross National Product *

<u>Component</u>	<u>Case I</u>	<u>Case II</u>	<u>Case III</u>
Personal consumption expenditures			
energy products, 10^{15} BTU	12.6	12.4	12.3
non-energy sectors, 10^9 \$	885.9	872.3	866.1
Capital investment			
non-energy sectors, 10^9 \$	199.0	202.4	209.9
Federal government, defense			
energy products, 10^{15} BTU	0.4	0.4	0.4
non-energy sectors, 10^9 \$	33.5	33.5	33.5
Federal government, non-defense			
energy products, 10^{15} BTU	0.2	0.2	0.2
non-energy sectors, 10^9 \$	19.1	19.1	19.1
State and local government			
energy products, 10^{15} BTU	1.7	1.7	1.7
non-energy sectors, 10^9 \$	79.0	79.0	79.0
Inventory change			
energy supplies, 10^{15} BTU	0.2	0.2	0.2
non-energy sectors, 10^9 \$	14.3	14.3	14.3
Exports			
energy supplies, 10^{15} BTU	3.4	3.7	3.4
non-energy sectors, 10^9 \$	97.8	105.1	97.8
Competitive imports			
energy supplies, 10^{15} BTU	-26.6	-23.8	-16.3
non-energy sectors, 10^9 \$	-54.9	-54.9	-54.9

* Expressed in real terms (1967 constant dollars and physical Btu's). GNP purchases of \$119.2 billion excluded from the final demand vector used with the combined model are not shown in this table.

Table A-4
Capital/Output Ratios
For Input-Output Model

		Capital Output Ratio	
<u>Sector</u>			
1	Coal	.252	\$/10 ⁶ BTU
2	Crude oil & gas	.557	
3	Shale oil	1.97	
4	Methane from coal	1.15	
5	Solvent refined coal	1.25	
6	Refined oil products	.974	
7	Pipeline gas	1.945	
8	Coal combined cycle electric	21.84	
9	Other fossil electric	26.27	
10	LWR electric	31.97	
11	HTGR electric	44.84	
12	Hydroelectric	70.77	
13	Ore reduction feedstocks	0	
14	Chemical feedstocks	0	
15	Motive power	0	
16	Process heat	0	
17	Water heat	0	
18	Space heat	0	
19	Air conditioning	0	
20	Electric power	0	
21	Livestock and livestock products	2.172631	\$/
22	Other agricultural products	1.252832	
23	Forestry and fishery products	.935497	
24	Agricultural, forestry and fishery services	.708594	
25	Iron and ferroalloys ores mining	1.507280	
26	Nonferrous metal ores mining	1.517025	
27	Stone and clay mining and quarrying	1.363933	
28	Chemicals and fertilizer mineral mining	1.003235	
29	New construction, residential buildings	.136571	
30	New construction, nonresidential buildings	.113074	
31	New construction, public utilities	.357925	
32	New construction, highways	.573761	
33	New construction, all other	.227873	
34	Maintenance and repair construction, residential	.090571	
35	Maintenance and repair construction, all other	.26433	
36	Ordnance and accessories	.257883	
37	Food and kindred products	.473557	
38	Tobacco manufactures	.173325	
39	Broad and narrow fabrics, yarn and thread mills	.809689	
40	Misc. textile goods and floor covering	.488396	
41	Apparel	.200399	
42	Misc. fabricated textile products	.278651	
43	Lumber and wood products, except containers	.563031	
44	Wooden containers	.482703	
45	Household furniture	.335799	
46	Other furniture and fixtures	.396303	
47	Paper and allied products except containers and boxes	.942681	
48	Paperboard containers and boxes	.471882	
49	Printing and publishing	.646143	
50	Chemicals and selected chemical products	1.151676	
51	Plastics and synthetic materials	1.459702	
52	Drugs, cleaning and toilet preparations	.465975	
53	Paints and allied products	.431879	
54	Paving mixtures and blocks	.909833	
55	Asphalt felts and coatings	.909833	

Table A-4 (cont'd)

<u>Sector</u>		<u>Capital</u> <u>Output</u> <u>Ratio</u>	
56	Rubber and miscellaneous plastics products	.537163	\$/\$
57	Leather tanning and industrial leather products	.239616	
58	Footwear and other leather products	.167655	
59	Glass and glass products	.711399	
60	Stone and clay products	.866195	
61	Primary iron and steel manufacturing	1.326454	
62	Primary nonferrous metals manufacturing	.438728	
63	Metal containers	.422197	
64	Heating, plumbing and fabricated structural metal products	.473663	
65	Screw machine prod., bolts, nuts, etc. & metal stampings	.449835	
66	Other fabricated metal products	.491376	
67	Engines and turbines	.412413	
68	Farm machinery	.332401	
69	Construction, mining, oil field machinery, equipment	.343139	
70	Materials handling machinery and equipment	.352319	
71	Metalworking machinery and equipment	.574835	
72	Special industry machinery and equipment	.560392	
73	General industrial machinery and equipment	.497869	
74	Machine shop products	.611867	
75	Office, computing and accounting machines	.797522	
76	Service industry machines	.340867	
77	Elec. trans. & dist. eq. & elec. industry apparatus	.4504	
78	Household appliances	.414493	
79	Electric lighting and wiring equipment	.230721	
80	Radio, television and communications equipment	.271688	
81	Electronic components and accessories	.371999	
82	Miscellaneous elec. machinery, equipment & supplies	.310085	
83	Motor vehicles and equipment	.284464	
84	Aircraft and parts	.249017	
85	Other transportation equipment	.383887	
86	Professional, scientific & controlling inst. & supp.	.301494	
87	Optical, ophthalmic, & photographic equip. & supp.	.542486	
88	Miscellaneous manufacturing	.417585	
89	Railroads and related services	4.102074	
90	Local, suburban & interurban highway pass. trans.	.429891	
91	Motor freight transportation and warehousing	.31522	
92	Water transportation	2.360189	
93	Air transportation	1.129331	
94	Pipe line transportation	6.97954	
95	Transportation services	.520187	
96	Communications except radio & television broadcasting	4.227327	
97	Radio and TV broadcasting	.473309	
98	Water and sanitary services	1.494666	
99	Wholesale and retail trade	1.063951	
100	Finance and insurance	.275388	
101	Real estate & rental	.040004	
102	Hotels & lodging; pers. & repair serv., except auto repair	1.224099	
103	Business services	.388553	
104	Automobile repair & services	2.981520	
105	Amusements	.873775	
106	Medical, educ. services & nonprofit inst.	1.291188	
107	Federal government enterprises	0	
108	State and local government enterprises	0	
109	Business travel, entertainment & gifts	0	
110	Office supplies	0	

Table A-5
I-O Solutions: Total Output by Sector
(domestic production)

Sector		Case I	Case II	Case III	
1	Coal	13.99	18.35	23.79	10 ¹⁵ BTU
2	Crude oil & gas	43.99	43.98	47.01	
3	Shale oil	0.00	.20	.20	
4	Methane from coal	1.63	1.63	1.63	
5	Solvent refined coal	0.00	0.00	0.00	
6	Refined oil products	28.08	27.08	26.75	
7	Pipeline gas	23.17	23.18	23.17	
8	Coal combined cycle electric	0.00	0.00	.55	
9	Other fossil electric	2.85	4.06	5.43	
10	LWR electric	4.18	4.18	4.18	
11	HTGR electric	.20	.20	.20	
12	Hydroelectric	2.05	2.25	2.25	
13	Ore reduction feedstocks	2.04	2.08	2.08	
14	Chemical feedstocks	5.97	5.98	5.97	
15	Motive power	4.56	4.53	4.50	
16	Process heat	13.23	13.26	13.26	
17	Water heat	2.07	2.05	2.04	
18	Space heat	15.08	14.97	14.90	
19	Air conditioning	2.49	2.47	2.42	
20	Electric power	6.31	6.31	6.30	10 ⁹ \$
21	Livestock and livestock products	46.97	46.54	46.08	
22	Other agricultural products	42.11	42.23	41.47	
23	Forestry and fishery products	2.99	2.99	2.98	
24	Agricultural, forestry and fishery services	2.72	2.72	2.68	
25	Iron and ferroalloys ores mining	1.65	1.71	1.69	
26	Nonferrous metal ores mining	3.96	4.03	4.02	
27	Stone and clay mining and quarrying	3.71	3.76	3.78	
28	Chemicals and fertilizer mineral mining	2.47	2.51	2.49	
29	New construction, residential buildings	46.42	47.17	48.85	
30	New construction, nonresidential buildings	37.53	38.00	39.05	
31	New construction, public utilities	25.17	25.47	26.14	
32	New construction, highways	6.90	6.90	6.90	
33	New construction, all other	8.50	8.55	8.64	
34	Maintenance and repair construction, residential	24.88	24.61	24.47	
35	Maintenance and repair construction, all other	23.44	23.63	23.95	
36	Ordnance and accessories	8.21	8.27	8.21	
37	Food and kindred products	138.76	137.20	135.95	
38	Tobacco manufactures	9.72	9.66	9.52	
39	Broad and narrow fabrics, yarn and thread mills	24.59	24.41	24.18	
40	Misc. textile goods and floor covering	9.51	9.48	9.43	
41	Apparel	40.44	39.90	39.57	
42	Misc. fabricated textile products	9.13	9.05	8.99	
43	Lumber and wood products, except containers	21.85	22.12	22.22	
44	Wooden containers	.57	.57	.58	
45	Household furniture	8.41	8.32	8.31	
46	Other furniture and fixtures	4.33	4.37	4.46	
47	Paper and allied products except containers and boxes	29.88	30.02	29.66	
48	Paperboard containers and boxes	11.25	11.23	11.16	
49	Printing and publishing	36.93	36.77	36.58	
50	Chemicals and selected chemical products	59.33	59.93	59.81	
51	Plastics and synthetic materials	30.62	30.83	30.50	
52	Drugs, cleaning and toilet preparations	32.92	32.65	32.34	
53	Paints and allied products	6.26	6.27	6.27	
54	Paving mixtures and blocks	1.25	1.25	1.25	
55	Asphalt felts and coatings	1.14	1.14	1.14	

Table A-5 (cont'd)

	<u>Sector</u>	<u>Case I</u>	<u>Case II</u>	<u>Case III</u>	
56	Rubber and miscellaneous plastics products	42.70	42.80	42.68	10 ⁹ \$
57	Leather tanning and industrial leather products	.30	.30	.30	
58	Footwear and other leather products	3.40	3.37	3.29	
59	Glass and glass products	6.42	6.44	6.39	
60	Stone and clay products	17.33	17.53	17.80	
61	Primary iron and steel manufacturing	39.26	39.85	39.91	
62	Primary nonferrous metals manufacturing	42.04	42.68	42.71	
63	Metal containers	6.51	6.47	6.42	
64	Heating, plumbing and fabricated structural metal products	24.34	24.63	25.05	
65	Screw machine prod., bolts, nuts, etc. & metal stampings	10.88	11.01	10.96	
66	Other fabricated metal products	23.61	23.84	23.87	
67	Engines and turbines	10.59	10.81	10.78	
68	Farm machinery	5.29	5.41	5.52	
69	Construction, mining, oil field machinery, equipment	10.77	11.13	11.16	
70	Materials handling machinery and equipment	5.34	5.44	5.53	
71	Metalworking machinery and equipment	12.42	12.65	12.72	
72	Special industry machinery and equipment	7.85	8.07	8.08	
73	General industrial machinery and equipment	15.55	15.88	15.98	
74	Machine shop products	6.67	6.75	6.74	
75	Office, computing and accounting machines	21.83	22.45	22.45	
76	Service industry machines	17.79	18.02	18.17	
77	Elec. trans. & dist. eq. & elec. industry apparatus	22.57	22.97	23.20	
78	Household appliances	11.98	11.90	11.84	
79	Electric lighting and wiring equipment	10.06	10.16	10.22	
80	Radio, television and communications equipment	35.59	35.81	35.83	
81	Electronic components and accessories	22.80	23.18	22.99	
82	Miscellaneous elec. machinery, equipment & supplies	7.14	7.19	7.17	
83	Motor vehicles and equipment	97.64	97.98	97.78	
84	Aircraft and parts	27.80	28.34	28.12	
85	Other transportation equipment	19.13	19.19	19.28	
86	Professional, scientific & controlling inst. & supp.	11.85	12.01	11.99	
87	Optical, ophthalmic, & photographic equip. & supp.	14.85	15.03	14.92	
88	Miscellaneous manufacturing	16.62	16.55	16.42	
89	Railroads and related services	14.55	14.74	14.85	
90	Local, suburban & interurban highway pass. trans.	4.35	4.31	4.30	
91	Motor freight transportation and warehousing	33.15	33.27	33.15	
92	Water transportation	5.35	5.64	5.33	
93	Air transportation	30.93	31.06	30.75	
94	Pipe line transportation	1.67	1.65	1.63	
95	Transportation services	1.22	1.25	1.22	
96	Communications except radio & television broadcasting	56.53	56.25	56.07	
97	Radio and TV broadcasting	3.74	3.74	3.73	
98	Water and sanitary services	5.49	5.46	5.44	
99	Wholesale and retail trade	315.80	313.50	312.18	
100	Finance and insurance	96.31	95.38	94.91	
101	Real estate & rental	203.99	201.73	200.65	
102	Hotels & lodging; pers. & repair serv., except auto repair	30.77	30.47	30.20	
103	Business services	119.12	119.02	118.79	
104	Automobile repair & services	24.05	23.85	23.75	
105	Amusements	14.37	14.28	14.12	
106	Medical, educ. services & nonprofit inst.	107.25	105.79	105.08	
107	Federal government enterprises	16.31	16.26	16.21	
108	State and local government enterprises	11.58	11.53	11.48	
109	Business travel, entertainment & gifts	19.07	19.08	19.08	
110	Office supplies	3.60	3.60	3.60	

Table A-6

Alignment of BNL 110 with Other Classification Systems

June 20, 1975

BNL 110	Sector	BNL 101	BEA	Battelle	A. Carter	BLS
1	Coal	1	7	7	7	8
2	Crude oil & gas	2	8	8	8	9
3	Shale oil	3	-	-	-	-
4	Methane from coal	3	-	-	-	-
5	Solvent refined coal	4	31.01	part 31	part 41	part 42
6	Refined oil products	5	68.02	68.2	93	102
7	Pipeline gas	-	-	-	-	-
8	Coal combined cycle electric	6	68.02	-	-	-
9	Other fossil electric	7	68.02	-	-	-
10	LWR electric	-	-	68.1	92	101
11	HTGR electric	-	-	-	-	-
12	Hydroelectric	8	68.02	-	-	-
13	Ore reduction feedstocks	9	-	-	-	-
14	Chemical feedstocks	10	-	-	-	-
15	Motive power	11	-	-	-	-
16	Process heat	12	-	-	-	-
17	Water heat	13	-	-	-	-
18	Space heat	14	-	-	-	-
19	Air conditioning	15	-	-	-	-
20	Electric power	16	-	-	-	-
21	Livestock and livestock products	17	1	1	1	1
22	Other agricultural products	18	2	2	2	2
23	Forestry and fishery products	19	3	3	3	3
24	Agricultural, forestry and fishery services	20	4	4	4	4
25	Iron and ferroalloys ores mining	21	5	5	5	5
26	Nonferrous metal ores mining	22	6	6	6	6-7
27	Stone and clay mining and quarrying	23	9	9	9	10
28	Chemicals and fertilizer mineral mining	24	10	10	10	11
29	New construction, residential buildings	11.21	11.1	11	12	12
30	New construction, nonresidential buildings	11.22	11.2	12	13	13
31	New construction, public utilities	25	11.33	11.3	13	14
32	New construction, highways	11.34	11.4	14	15	15
33	New construction, all other	11.35	11.5	15	16	16
34	Maintenance and repair construction, residential	12.51	12.1	16	17	17
35	Maintenance and repair construction, all other	12.52	12.2	17	18	18
36	Ordnance and accessories	27	13	13	18-19	19
37	Food and kindred products	28	14	14	19	20
38	Tobacco manufactures	29	15	15	20	21
39	Broad and narrow fabrics, yarn and thread mills	30	16	16	21	22
40	Misc. textile goods and floor coverings	31	17	17	22	23
41	Apparel	32	18	18	23	24-25
42	Misc. fabricated textile products	33	19	19	24	26
43	Lumber and wood products, except containers	34	20	20	25	27, p28
44	Wooden containers	35	21	21	26	part 28
45	Household furniture	36	22	22	27	29
46	Other furniture and fixtures	37	23	23	28	30
47	Paper and allied products except containers and boxes	38	24	24.1 24.2 24.3	29 30 31	31
48	Paperboard containers and boxes	39	25	25	32	32
49	Printing and publishing	40	26	26	33	33-34
50	Chemicals and selected chemical products	41	27	27.1 27.2 27.3	34 35 36	35-36
51	Plastics and synthetic materials	42	28	28.1 28.2	37 38	37
52	Drugs, cleaning and toilet preparations	43	29	29	39	39-40
53	Paints and allied products	44	30	30	40	41
54	Paving mixtures and blocks	45	31.02	part 31	part 41	part 42
55	Asphalt felts and coatings	46	31.03	part 31	part 41	part 42
56	Rubber and miscellaneous plastics products	47	32	32.1 32.2 32.3	42 43 44	43-44
57	Leather tanning and industrial leather products	48	33	33	45	45
58	Footwear and other leather products	49	34	34	46	46
59	Glass and glass products	50	35	35	47	47
60	Stone and clay products	51	36	36	48	47-48

BNL 110	Sector	BNL 101	BEA	Battelle	A. Carter	BLS
61	Primary iron and steel manufacturing	52	37	37	49	49-50
62	Primary nonferrous metals manufacturing	53	38	38.1 38.2 39.3	50 51 52	51-57
63	Metal containers	54	39	39	53	58
64	Heating, plumbing and fabricated structural metal products	55	40	40	54	59-60
65	Screw machine products, bolts, nuts, etc. & metal stampings	56	41	41	55	61
66	Other fabricated metal products	57	42	42	56	62
67	Engines and turbines	58	43	43	57	63
68	Farm machinery	59	44	44	58	64
69	Construction, mining, oil field machinery, equipment	60	45	45	59	65
70	Materials handling machinery and equipment	61	46	46	60	66
71	Metalworking machinery and equipment	62	47	47	61	67
72	Special industry machinery and equipment	63	48	48	62	68
73	General industrial machinery and equipment	64	49	49	63	69
74	Machine shop products	65	50	50	64	70
75	Office, computing and accounting machines	66	51	51	65	71-72
76	Service industry machines	67	52	52	66	73
77	Elec. trans. & dist. eq. & elec. industry apparatus	68	53	53.1 53.2	67 68	74 75
78	Household appliances	69	54	54	69	76
79	Electric lighting and wiring equipment	70	55	55	70	77
80	Radio, television and communications equipment	71	56	56	71	78-80
81	Electronic components and accessories	72	57	57.1 57.2 57.3	72 73 74	81
82	Miscellaneous elec. machinery, equipment & supplies	73	58	58	75	82
83	Motor vehicles and equipment	74	59	59	76	83
84	Aircraft and parts	75	60	60	77	84
85	Other transportation equipment	76	61	61	78	85-87
86	Professional, scientific & controlling inst. & supp.	77	62	62	79	88-89
87	Optical, ophthalmic, & photographic equip. & supp.	78	63	63	81	90-91
88	Miscellaneous manufacturing	79	64	64	82	92
89	Railroads and related services	80	65.01	65.1	83	93
90	Local, suburban & interurban highway pass. trans.	81	65.02	65.2	84	94
91	Motor freight transportation and warehousing	82	65.03	65.3	85	95
92	Water transportation	83	65.04	65.4	86	96
93	Air transportation	84	65.05	65.5	87	97
94	Pipe line transportation	85	65.06	65.6	88	98
95	Transportation services	86	65.07	65.7	89	99
96	Communications except radio & television broadcasting	87	66	66	90	100
97	Radio and TV broadcasting	88	67	67	91	101
98	Water and sanitary services	89	68.03	68.3	94	103
99	Wholesale and retail trade	90	69	69	95	104-105
100	Finance and insurance	91	70	70	96	106-107
101	Real estate & rental	92	71	71	97	108-109
102	Hotels & lodging; pers. & repair serv., except auto repair	93	72	72	98	110-111
103	Business services	94	73	73	99	112-114
104	Automobile repair & services	95	75	75	101	115
105	Amusements	96	76	76	102	116-117
106	Medical, educ. services & nonprofit inst.	97	77	77	103	118-121
107	Federal government enterprises	98	78	-	104	122-124
108	State and local government enterprises	99	79	-	105	125
109	Business travel, entertainment & gifts	100	81	-	107	128
110	Office supplies	101	82	-	108	129
-	Research & Development	-	74*	-	100	-
-	Gross imports	-	80	-	106	126-127
-	Scrap, used and second hand goods	-	83	-	109	130
-	Government industry	-	84	-	-	131
-	Rest of world industry	-	85	-	-	132
-	Households	-	86	-	-	133
-	Inventory valuation adjustment	-	87	-	-	134

*Eliminated as a separate sector by BEA in the 1963 and 1967 studies.

Appendix B. Estimation of Capital Investment Requirements.

The 1985 GNP estimate used as a basis for model runs (3) contains estimates of how much capital equipment has to be supplied by those sectors which produce capital goods. These figures are contained in the GNP component entitled Gross Private Fixed Capital Formation, GPFCF. Using a solution vector of total outputs from a model run and what are called "capital/output ratios" and a "capital replacement vector," one can estimate how much capital equipment is required in order to support the indicated growth in output from some historical year.

Capital investment needs by energy sectors are generally large, and these requirements will increase significantly as domestic energy supplies are substituted for foreign energy supplies. In order to capture the economic impact of this change as oil imports were reduced, capital requirements were estimated and compared with the GNP estimate of capital equipment supplied. The GNP component, GPFCF, was then adjusted to obtain consistency between the level of investment required and the amount supplied.* A compensating adjustment was made in personal consumption expenditures in order to maintain a constant real GNP, and the modified GNP vector used to obtain

* All GPFCF components of final demand for each sector were adjusted by the same proportional difference.

a new combined model solution.*

Following is a description of the use of capital/output ratios and a capital replacement vector in estimating investment requirements for the 1985 base case run.

An annual growth rate in output $g(i)$ is determined for each sector, by comparing levels of output for 1967 with those given by the solution in the X_{85} vector, and solving the following formula for each $g(i)$: $X_{85}(i) = (1 + g(i))^{18} \cdot X_{67}(i)$. Once the average growth rate over this 18 year period, 1967-1985, is determined, it is possible to calculate the amount of investment needed during 1984-1985, I_{84-85} , to support this level of growth. Let K_t represent the capital stock in year t ; let C be the capital/output ratio, $C = \frac{K_t}{X_t}$ ** ; and δ the capital replacement rate. Then the endogenously determined level of gross investment for each sector from 1984 to 1985 is determined by:

$$I_{84-85} = K_{85} - K_{84} + \delta K_{84}$$

$$\begin{aligned} I_{84-85} &= C \cdot X_{85} - C \cdot X_{84} - \delta \cdot C \cdot X_{84} \\ &= C \cdot X_{85} - C \cdot (1-\delta) \cdot X_{84} \end{aligned}$$

*This was actually an iterative procedure requiring one or two additional capital requirement comparisons, GNP adjustments, and subsequent combined model runs. This iterative procedure is continued until the level of capital equipment supplied, as contained in the Y vector of final demand, is "equal" at some specified level of accuracy to the estimated capital equipment required.

**Capital/output ratios used for this study are tabulated in Appendix A.

$$= C \cdot X_{85} - C \cdot (1-\delta) \cdot \frac{X_{85}}{(1+g)}$$

$$I_{84-85} = C \cdot X_{85} \cdot \left[1 - \frac{1-\delta}{1+g} \right] \text{ for each sector, } i.$$

Then a comparison is made between total investment requirements, $\sum_i I_{84-85}$, and capital supplied, total GPFCF in the Y final demand vector. When the total capital investment given in the final demand vector is lower than that necessary to support the X_{85} vector, the GPFCF component of final demand is increased to equal $\sum_i I_{84-85}$ and the PCE component of final demand is adjusted downward by the same amount. This is one method of maintaining a constant "real" GNP and other adjustment mechanisms could be assumed.

The combined model is run a second time using the new Y vector. The new solution after this second run is checked to determine if the new level of capital equipment supplied is sufficient to support investment requirements consistent with the new solution vector of total outputs. This iterative procedure is followed until there is satisfactory agreement between the exogenous investment vector in final demand and those requirements calculated with capital coefficients.

The table below illustrates the converging solution of the Case I run as capital investment supplied becomes consistent with capital investment required.

	$\sum_i Y(2,i)$, or GPFCF (capital investment supplied)	$\sum_i I_{84-85}$ (capital investment required)	Difference	% Difference
Run 1	211.76798	198.62091	-13.14707	-6.2%
Run 2	198.62091	199.03736	.41645	.2%
Run 3	199.03736	199.02400	-.01336	-.007%

Appendix C. GNP Standardization Techniques*

Aggregate real GNP was assumed to be constant over all three cases analyzed. The reason for this was to standardize on the estimates of the labor force, labor productivity and capital productivity used for the forecast of 1985 GNP in (3). Since the economic basis for the input-output model is long-term dynamic equilibrium, resources of production can be assumed to be perfectly mobile and short-term business cycle fluctuations can be ignored. These conditions are consistent with asking the question, "How will the composition of goods and services produced by the economy shift over the long-run as the price of oil increases and policies are introduced to decrease oil imports?", which is the central topic addressed by this report.

Case I

For Case I only one adjustment in the composition of GNP was required. Gross private fixed capital formation (GPFCF), which represents capital goods supplied by the economy in 1985, was reduced** to the amount of capital goods required, as estimated by capital coefficients from Dattelle (5) and Mitre (4). Estimation of "required" capital is described in Appendix B. Personal consumption expenditures were "increased"*** by the amount GPFCF was reduced in order to maintain the same real GNP of \$1439 billion.

*The techniques described in this section were only applied to GNP purchases "included" in the combined model final demand vector which total \$1319.9 billion. "Excluded" purchases (wages to employees not covered by sectors in model, non-competitive imports, and U.S. outside transactions) total \$119.2 billion, and they are held constant for all three cases.

**Each entry in the GPFCF vector was decreased in the same proportion.

***Each entry in the PCE vector was increased in the same proportion.

Case II

In Case II it is presumed that the price of oil remains at twice the level of that in Case I over the next ten years. With domestic oil supply held at the Case I level, oil imports are 14% less and domestic coal production is 31% greater. Payment to foreigners for oil increases by \$15 billion, affecting the country's international balance of payments.

Foreigners can do three things with the additional dollars they get from us. They can directly buy more goods and services from us; they can hoard the dollars or buy U.S. financial assets (e.g. stocks and bonds) and real assets (e.g. land, buildings, factories), all of which would equal transfers in U.S. assets; and they can spend the dollars to obtain other currencies. If they do the latter, the value of the dollar will decrease relative to other currencies, and this dollar devaluation, in turn, will lead to more U.S. exports and less U.S. imports.

For this analysis only one situation is analyzed - 100% recycle of the additional U.S. foreign payments, with 50% of the dollars used for asset transfer and 50% used to purchase more U.S. exports. No adjustment in the components of GNP has to be made for the asset transfer. Total exports, however, have to be increased by \$7.5 billion.*

* Each entry in the export vector was increased in the same proportion. A vector of export good elasticities is also available for use when the change in composition of exports is important.

Although imports in monetary terms are larger for Case II, they are less in real terms (less oil is being imported).

No change has yet been made in domestic production. But less imports in real terms means less goods available for consumption. In order to standardize on a single level of domestic production capacity, other GNP purchases must decrease by the amount that imports have dropped in real terms. For Case II it is assumed that the entire adjustment is made in PCE purchases. Thus, individual consumers receive the direct effect versus federal, state, or local governments.

One more adjustment in GNP relative shares is required. Increased use of domestic fuels means that more capital goods must be produced (more coal mines have to be opened and more coal steam electric plants constructed, for example). Capital coefficients are used to estimate the new level and composition of required capital goods, and GPFCE increased accordingly. In accordance with the procedure described in Appendix B, PCE purchases are reduced in order to maintain the same real GNP.

In summation, composition of GNP purchases in Case II differs from that in Case I in the following ways:

- 1) Imports are greater in monetary terms, but less in real terms;

- 2) Exports are greater because of recycled foreign dollar payments;
- 3) GPFCF is greater because domestic production of energy must be substituted for oil imports;
- 4) PCE is less and reflects three things: the drop in imported goods available for domestic consumption, the shift to production of more export goods, and the shift to production of more capital goods for the energy sector.

Price elasticities are ignored in these shifts.* These adjustments result in maintaining labor force participation, manpower requirements per unit of output, and capital requirements per unit of output consistent for all cases.

Case III

In Case III it is presumed that the price of oil remains at twice the level of that in Case I over the next ten years. Also, policies are introduced to limit oil imports to half the Case I level. Payment to foreigners for imported oil is thus the same in Case III as in Case I, and there is no aggregate change in the country's balance of payments.

As in Case II, imports in real terms are less. Lower imports mean that fewer goods are available for domestic consumption. In order to standardize on a single level of domestic

* Elasticities can be incorporated in the analysis. For the most part they are either unknown or would be rough estimates. The error introduced by ignoring them is of a second order effect in most sectors.

productive capacity, it is assumed that the entire adjustment is made in PCE purchases as opposed to a drop in government purchases. This drop in terms of 1967 prices totals \$10.4 billion from Case I.

As in Case II, upward adjustment is needed in GPFCF at the expense of PCE purchases in order to substitute domestic fuel production for the drop in imported oil. The procedure described in Appendix B is also used here.

In summation, composition of GNP purchases in Case III differs from that in Case I in the following ways:

- 1) Imports are the same in monetary terms, but less in real terms;
- 2) GPFCF is greater because domestic production of energy must be substituted for oil imports;
- 3) PCE is less and reflects two things: the drop in imported goods available for domestic consumption, and the shift to production of more capital goods for the energy sector.

The breakdown on GNP for each of the three cases is presented in Table A-3, Appendix A. All entries are in real terms with energy purchases expressed in physical units (BTU) and non-energy purchases expressed in constant 1967 dollars.