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ANALYSIS OF PAST AND EXPECTED FUTURE TRENDS IN U.S. ENERGY CONSUMPTION, 1947-2000

DAVID J. BEHLING, JR.

February 1977

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

In the first part of this paper, energy consumption trends to the year 2000 are estimated for 110 different industrial sectors and for household and government final demand sectors, and these trends are compared with historical 1947 to 1967 trends. For most sectors, energy consumption is expected to increase much less rapidly in the 1967-1985 period than it did in the 1947-1967 period as a result of the recent large energy price increases. Between 1985 and 2000, the rate of growth of energy consumption continues to moderate for most purchasing sectors primarily because of a slackening in output growth rates rather than because of any further decrease in per unit of output energy requirements. These future trends are estimated under the assumption that post 1976 energy price increases will be moderate.

In the second part of the paper, alternative strategies for further reducing future energy consumption are considered, and a data base is presented for use in analyzing the effects of implementing the alternative strategies.

Introduction

Part I of this report presents estimates of energy consumption by consuming sector and by utilization process to the year 2000 and compares time trends in these estimates with historical post World War II trends. First estimates are presented for a broad grouping of energy consuming sectors. Then estimates are presented for more detailed energy consumption activities occurring within the industrial sectors. All aggregate energy estimates presented in this report are consistent with preliminary ERDA estimates for "Surprise Free" Forecast (SF-2) to be presented in the forthcoming ERDA 77-1 Energy Plan.

Part II of this report defines different policy strategies for reducing energy consumption within industry and presents detailed data for use in implementing these strategies. Part II concludes with a discussion of interrelationships which exist between strategies and considers methods for estimating optimum strategy combinations.

Part I

U.S. Energy Consumption by Economic Sector and by Process, 1967-2000

I. Methodology

The following methodology was used to generate estimates of energy consumption by sector and by utilization activity for 1985, 1990 and 2000. First ERDA, in consultation with Brookhaven National Laboratory (BNL), exogenously specified the prices of crude oil, crude gas, coal, shale oil and uranium to the year 2000, along with capital costs for all energy conversion and end use devices. Then Data Resources Incorporated (DRI), using an econometrically specified 10-sector general equilibrium model,[1] estimated aggregate energy demand amounts to the year 2000, given the ERDA specified energy price trends and given an assumed aggregate average GNP growth rate of 3.8%/year between now and 1985, and of 3.1%/year between 1985 and 2000. Then BNL, using a 110-sector input-output (I/O) model,[2] solved for energy service levels for the years 1985, 1990, and 2000, given the DRI specified 10-sector aggregate economic and energy estimates for those years. Finally, the BNL BESOM model[3] was used to estimate the mix and level of fuels and energy conversion activities required to meet the energy service demands.

Throughout this estimation process, many inter-model feedback mechanisms were utilized to ensure consistency of estimates between the various models employed. Time did not permit the full employment of all the feedback mechanisms between the I/O model and the DRI model. The results reported here are from the Brookhaven combined I/O, BESOM model.

In general, the BNL results track closely with corresponding DRI results for the 1985-2000 period, but less closely for the 1967-1985 period. One addi-

tional constraint was imposed on the BNL estimation procedure. For 1985, the allocation of fuels to consuming sectors in the combined BESOM-IO model was constrained to match estimates obtained by FEA using the PIES model.[4]

II. Assumptions

The results presented in this report are predicated on the following assumptions:

Energy Prices - ERDA specified the following trends for the prices of primary energy fuels:

Forecasted Average Annual Rate of Real Price Increase (%/Year)

	1967-1975	1975-1985	1985-1990	1990-2000
Domestic Crude Oil	7.3	4.7	1.0	2.0
Imported Crude Oil	13.7	-.1	1.0	2.0
Shale Oil	--	--	--	0.5
Natural Gas	8.1	16.2	0.5	1.0
Nuclear Fuel	--	4.2	1.5	1.0
Strip Mined Coal	14.2	-2.9	0.5	0.5
Underground Coal			1.0	1.0

Degree of Energy Price Regulation - All prices for primary energy supplies are assumed to be equilibrium market clearing prices except for natural gas, which is assumed to be regulated approximately 20% below its equilibrium level to the year 2000. In allocating the scarce natural gas supplies, it is assumed that residential users will be favored at the expense of industrial users. For electricity, it is assumed that regulatory imposed price ceilings will continue to reflect historical capital costs rather than the much larger replacement capital costs.

Economic Activity - GNP is assumed to grow at 3.8%/year between 1976 and 1985, and 3.1%/year between 1985 and 2000. The DRI Long Term Interindustry Model (LTIM) was used to estimate the growth rates of GNP spending components listed below. The growth rate for investment is negative for the 1967 to 1975 period and large for the 1975-1985 period due to the abnormally low amount of investment in 1975, a year of sharp recession.

Forecasted Average Annual Rate of Growth in Real Purchases
(in %/year in constant 1972 $)

	1967-1975	1975-1985	1985-2000
Consumption	3.3%/yr	4.0%/yr	3.1%/yr
Investment	-0.8%/yr	6.7%/yr	3.0%/yr
Government	0.5%/yr	2.8%/yr	3.4%/yr
Total GNP	2.3%/yr	4.1%/yr	3.1%/yr

Energy Supply - Total primary energy consumption is assumed to increase from 70.9 quads (10^{15} BTU) in 1975 to 98.4 quads in 1985 and to 140.9 quads in 2000. The 1985 estimate is that of FEA's for their $13/barrel oil reference case, while the 2000 estimate is a preliminary ERDA SF-2 estimate. These estimates yield the following average annual growth rates for total primary energy consumption:

1967-1975	1975-1985	1985-2000
3.0%/year	3.3%/year	2.4%/year

III. Fuel Use by Consuming Sector, 1947-1967

Total fuel use for four non-energy interindustry sectors and for the household and final demand sector are listed in Table 1 for the years 1947, 1967, 1985 and 2000. The sectors are defined in Appendix C. The fuel use for each sector is measured in terms of the total quads (10^{15} BTU) of coal, oil, natural gas,

Table 1

Gross Fuel Use by Sector, 1947-2000

Purchasing Sector	1947 (10^{15} BTU)	1967 (10^{15} BTU)	1985 (10^{15} BTU)	2000 (10^{15} BTU)
Agriculture, Mining, and Construction	1.41	2.70	4.01	6.81
Manufacturing	9.94	16.71	29.70	54.72
Transportation	5.61	3.23	4.26	5.99
Services	3.47	7.57	11.14	17.12
Household and Government	9.03	22.51	34.91	43.90
Other	1.07	3.20	14.33	12.36
Total Consumption	30.53	55.92	98.35	140.90

Note: Total energy purchases for each purchasing sector are equal to the total quads of coal, oil, natural gas, direct solar and direct geothermal purchased plus three times the quads of electricity.

Sources: 1947: "An Input/Output Analysis of Energy Use Change from 1947 to 1958 and 1958 to 1963," W.A. Reardon, Pacific Northwest Laboratories, Battelle, June 1972, pp. III 3 and III 7.

1967: Bullard III, C.W., and R.L. Knecht, End Uses of Energy in the U.S. Economy 1967, CAC Document No. 145, Section 1.0-2.0, p. 33.

1985, 2000: Forecast 2 BNL Combined IO/LP Runs of 3/22/77 based on ERDA reference energy systems dated 1/5/77.

direct solar and direct geothermal consumed in that year plus three times the quads of electricity consumed. Consumption of energy by the "other" sectors refers to the amount of energy consumed in refining coal, oil, and gas, plus the amount consumed in delivering refined fossil fuels and electricity to the non-energy purchasing sectors, plus any excess (or deficit) amount of primary energy processed by electric utilities at a BTU input to BTU output efficiency of less than (greater than) .33.

The purchasing sectors are defined in terms of conventional interindustry and national income account sector definitions. These differ from the energy sector classifications employed by Bureau of the Mines in that the transportation sector purchases listed in Table 1 include only those amounts of energy purchased by the for-hire transportation sector. Purchases of fuel and electricity for all "own" transportation activities are included in the totals for the purchasing sectors in which the "own" transportation activity occurs.

Total outputs of each of the interindustry sectors (in constant 1958 $) are shown in Table 2, along with total household and government purchases. Estimates of energy consumption per unit of output or expenditure are listed in Table 3. Over all years, for-hire transportation remains the most energy intensive activity and manufacturing the second most intensive. Between 1947 and 1967, the service sector replaced the primary agricultural, mining, and construction sector as the least fuel intensive sector.

Average annual growth rates for each of the gross energy input, gross output, and energy per unit of output estimates are listed in Table 4. First let us consider the growth rates of constant dollar outputs for the 1947 to 1967 period. These are listed in column (1), line C of Table 4. Between 1947 and 1967, there was a wide dispersion in output growth rates; manufacturing output grew the most

Table 2

Total Output by Aggregate Interindustry Sector and Total Household and Government Purchases, 1947, 1967, 1985, 2000

(in 10^9 1958 dollars)

Interindustry Sector	1947	1967	1985	2000
Agriculture, Mining and Construction	89.92	150.37	278.93	447.64
Manufacturing	246.31	541.57	1034.43	1661.41
Transportation	34.19	52.05	101.25	155.84
Services	214.92	437.06	844.41	1354.35
Household and Government	247.20	570.30	1039.87	1658.51

Source: "An Input/Output Analysis of Energy Use Changes from 1947 to 1958 and 1958 to 1963," Battelle, Pacific Northwest Laboratories, W.A. Reardon, June 1972, Pages A1-A5.

BNL IO/LP Combined Model Runs 5/8/75, 3/22/77.

BLS 1958-1967 Deflators.

Table 3

Energy Input Requirements Per Unit of Output
for Aggregate Non-Energy Sectors

Interindustry Sector	1947 [10^3 BTU/(1958 $)]	1967 [10^3 BTU/(1958 $)]	1985 [10^3 BTU/(1958 $)]	2000 [10^3 BTU/(1958 $)]
Agriculture, Mining, and Construction	15.70	17.98	14.38	15.21
Manufacturing	40.34	30.85	28.71	32.94
Transportation	163.96	61.97	42.07	38.44
Services	16.14	17.33	13.19	12.64
Household and Government	36.38	39.47	33.57	26.47

Sources: 1947: "An Input/Output Analysis of Energy Use Changes from 1947 to 1958 and 1958 to 1963," W.A. Reardon, Pacific Northwest Laboratories, Battelle, June 1972.

1967: 1967 BNL Combined IO/LP Verification Run of 5/8/75.

1985, 2000: Forecast 2 BNL Combined IO/LP Runs of 3/22/77.

Table 4

Growth Rates For: Total Primary Fuel Usage, Energy Input Per Unit of Output, and Total Output, by Interindustry Sector and by Household and Government, for 1947-67; 1967-85; 1985-2000

(%/year)

Interindustry Sector	1947-1967	1967-1985	1985-2000
Agriculture, Mining and Construction			
A. Total Gross Fuel Use	3.3	2.2	3.6
B. Energy Input Per Unit of Output	0.7	-1.2	0.4
C. Total Output	2.6	3.4	3.2
Manufacturing			
A. Total Gross Fuel Use	2.6	3.2	4.2
B. Energy Input Per Unit of Output	-1.4	-0.4	0.9
C. Total Output	4.0	3.6	3.3
Transportation			
A. Total Gross Fuel Use	-2.7	1.6	2.3
B. Energy Input Per Unit of Output	-4.8	-2.1	-0.6
C. Total Output	2.1	3.7	2.9
Services			
A. Total Gross Fuel Use	4.0	2.2	2.9
B. Energy Input Per Unit of Output	0.4	-1.5	-.3
C. Total Output	3.6	3.7	3.2
Household and Government			
A. Gross Fuel Use	4.7	2.5	1.5
B. Energy Per Unit of Total Purchases	.4	-.9	-1.6
C. Total Purchases of All Goods & Services	4.3	3.4	3.1

Source: Tables 1, 2, and 3.

rapidly at 4%/year, followed closely by services, at 3.6%/year, while the outputs of agriculture, mining, and construction; and of services grew less rapidly at rates of 2.6%/year and 2.1%/year respectively. It should be noted that these growth rates reflect average annual rates of change in the physical amounts of output produced. When measured in terms of actual "current" dollar transactions, the output of the service industry grew most rapidly, as the price of services increased sharply relative to the prices of other outputs.

Growth rates in energy per unit of output for the 1947-1967 period are listed in lines B of Column (1) in Table 4. If energy "conservation" is defined as reducing direct primary energy input per unit of output, the greatest amount of conservation occurred in the for-hire transportation sector. In the early part of the 1947-1967 period, large amounts of conservation resulted from the substitution of diesel for coal burning locomotives, while over the entire period, increases in the load and capacity factors of trucks, ships, pipelines, trains, and airplanes were also important explanatory factors.

Energy per unit of output requirements also declined in manufacturing over the 1947 to 1967 period due to increases in processing efficiencies and because the composition of manufacturing output shifted towards a greater percentage of fabricated products. Much of this shift is reflected in greater amounts of "miniturization." That is, over time, fewer and fewer pounds of materials are being incorporated in each product. For example, consider the weight of such products as computers and radios over time. During this 1947-1967 period, per unit energy requirements increased in the services sector, as more operations became electrified, while per unit of output energy requirements also increased in the agriculture, non-energy mining, and construction sector as more agricultural operations

became mechanized, and as more energy was required to mine and process increasingly lower grade mineral deposits.

Growth rates in total fuel purchases, shown in line A of Table 4, are the sum of the two growth rates in total output and in energy per unit of output, both of which have already been considered. Growth rates for direct household and government energy consumption, for energy consumption per unit of total purchases, and for total household and government purchases are also listed in Table 4. In the 1947-1967 period, energy purchases grew more rapidly than total expenditures on all goods and services. Rapid increases in private automobile ownership rates and travel were most responsible.

IV. Fuel Usage by Consuming Sector: Estimates for the 1967-1985 and the 1985-2000 Periods.

Total Sectoral Outputs - Now let us consider the projected SF-2 sectoral output growth rates and the energy per unit of output growth rates, and compare these rates with historical 1947-1967 rates. Growth rates in outputs from Table 4 are repeated below:

	1947-1967	1967-1985	1985-2000
Agriculture, et al.	2.6%/yr	3.5%/yr	3.2%/yr
Manufacturing	4.0 "	3.7 "	3.2 "
Transportation	2.1 "	3.8 "	2.9 "
Services	3.6 "	3.7 "	3.2 "
Household & Government	4.3 "	3.4 "	3.2 "

In both the 1967 to 1985 and the 1985 to 2000 periods, the economy is expected to achieve "balanced growth" in terms of the broad sectoral classifica-

tion used. That is, there is little dispersion in the sectoral output growth rates during each period.

The only exception is the low 3.4%/year growth rate for aggregate household and government purchases for the 1967-1985 period. This results from the slow growth of real government purchases. The growth rate of constant dollar military expenditures has already sharply declined since 1967, while growth rates for state and local expenditures for roads and education are both expected to slacken.

Since households and government are the second most energy intensive sector, this shift away from government spending (in constant $) will tend to lower aggregate energy consumption. Effects from this shift will be more than offset by the increase in the 1967-85 growth rate of for-hire transportation output, however, as for-hire transportation is the most energy intensive sector.

Energy Per Unit of Output - Average annual growth rates in energy per unit of output from Table 4 are repeated below:

	1947-1967	1967-1985	1985-2000
Agriculture, et al.	+.7%/yr	-1.2%/yr	+.4%/yr
Manufacturing	-1.4%/yr	-.4%/yr	+.9%/yr
Transportation	-4.8%/yr	-2.1%/yr	-.6%/yr
Services	+.4%/yr	-1.5%/yr	-.3%/yr
Household & Government	+.4%/yr	-.9%/yr	-1.6%/yr

In the 1967-1985 period, declines in per unit energy requirements are expected for all sectors, the largest declines occurring in the transportation sector, the smallest in the manufacturing and in the household and government sectors. In the 1985-2000 period relative to the 1967-1985 period, energy con-

sumption per unit of output is expected to accelerate, with the major exception of per unit consumption for households and governments.

First let us consider the quickening in energy conservation expected (on a per unit of output basis) for the 1967 to 1985 period. The most important explanatory factor is the assumed rapid increase in energy prices (see Section II for price assumptions). Other factors are direct regulations, moral suation and so on. However, for two sectors, per unit energy requirements are expected to decrease less than they did from 1947 to 1967. Changes in the product-mix of the for-hire transportation sector toward more airplane travel will limit per unit energy declines in this sector. Within the manufacturing sector it is estimated that the product-mix will shift toward more energy intensive products. The relative output share of these products will tend to increase, despite large energy price increases, for two reasons. First, more petrochemicals and heavy machinery products will be exported to pay for oil imports; second, capital goods production for public utility construction will also increase.

In the 1985-2000 period, the growth rates in per unit energy purchases will all be smaller than those in the 1967-1985 period, with the exception of the growth rate of per unit household and government energy consumption. The reason for this deceleration in conservation within the inter-industry sectors is that energy prices in this period are assumed to increase less rapidly than in the 1967-1985 period. The increasing conservation effect estimated for households and government in the 1985-2000 period results from several factors, including expected saturation in automobile travel and in the ownership of air conditioning units, and expected improvements in housing insulation.

Total Energy Consumption - Growth rates in total energy consumption are listed below. They are simply the sum of the two growth rates already considered.

	1947-1967	1967-1985	1985-2000
Agriculture, et al.	3.3%/yr	2.2%/yr	3.6%/yr
Manufacturing	2.6%/yr	3.2%/yr	4.2%/yr
Transportation	-2.7%/yr	1.6%/yr	2.3%/yr
Services	4.0%/yr	2.2%/yr	2.9%/yr
Households and Government	4.7%/yr	2.5%/yr	1.5%/yr

For all periods considered, the dispersion in these sectoral rates is considerable. "Unbalanced growth" is estimated for all periods with respect to sectoral energy purchases.

Time did not permit analysis of detailed 110-order growth rates in output, and in energy inputs. This material is presented in Appendix C.

V. Importance of Agricultural, Mining, Construction and Manufacturing Energy Consumption

The energy consumption of the agriculture et al. sector plus that of the manufacturing sector as a percent of total energy consumption by all sectors is expected to change over time as follows (from Table 1):

1947	37.2%
1967	34.7%
1985	34.3%
2000	43.7%

The estimated 1985 to 2000 trend toward greater concentration of energy consumption within industry partially reflects greater than average expected improvements in the efficiency of non-manufacturing uses of energy. In particular, ERDA estimates that in this time period transportation end use efficiencies will significantly increase and that space heating requirements will decline via im-

proved insulation. Much smaller efficiency improvements are expected in manufacturing-oriented activities such as process heat, feedstock, and direct electric drive activities.

It should also be mentioned that this trend toward greater concentration of energy consumption within industry over time has also been forecasted by econometricians. They estimate that a greater degree of non-energy for energy substitution exists outside of manufacturing sector.[5]

VI. Energy Consumption by Type of End Use Activity, 1967-1985 and 1985-2000

Total Energy Consumption - Estimated amounts of energy consumption for eight different types of energy service activities are listed in Table 5 for 1967, 1985, and 2000. These estimates include the amount of energy (in quads) flowing into energy end use devices, plus the additional amount used in intra-energy sector processing and transportation activities. Thus the estimates in Table 5 sum to the annual amount of total primary energy consumption. Corresponding average annual growth rates of these service fuel requirements for the 1967-1985 and the 1985-2000 periods are listed in Table 6, while percentage breakdowns for each of the three years are listed in Table 7.

Over the 1967-1985 period, energy requirements for air conditioning grow most rapidly, at an average annual rate of 7.7%/year. They then sharply taper off in 1985-2000 period to an average rate of 2.7%/year. Motive power requirements likewise increase rapidly (5.9%/year) then taper off (1.6%/year). Total energy requirements for the following industry-oriented activities accelerate in the 1985-2000 period: ore-reduction feedstocks, chemical feedstocks, and process heat.

Table 5

Total Primary Fuel Usage by Energy Service Activity
For 1967, 1985, 2000

(10^{15} BTU)

Activity Name	1967	1985	2000
Ore Reduction Feedstocks	2.00	2.24	3.97
Chemical Feedstocks	3.52	6.23	11.75
Motive Power	7.41	20.70	26.48
Process Heat	13.73	20.81	31.51
Water Heat	2.70	4.68	6.38
Space Heat	15.01	17.50	18.86
Air Conditioning	.83	3.18	4.76
Electric Power	10.72	23.01	37.19
Total Primary Fuel Usage	55.92	98.35	140.90

Source: Tables 1, 8 and 9.

Table 6

Growth Rates in Total Fuel Use By
Energy Service Activity
For 1967-1985 and 1985-2000

(%/Year)

Activity Name	1967-1985	1985-2000
Ore Reduction Feedstocks	0.6	3.9
Chemical Feedstocks	3.2	4.3
Motive Power	5.9	1.6
Process Heat	2.3	2.8
Water Heat	3.1	2.1
Space Heat	0.8	0.5
Air Conditioning	7.7	2.7
Electric Power	4.3	3.2
Total Consumption	3.2	2.4

Source: Table 5

Table 7

Percent of Total Primary Fuel Usage By
Energy Service Activity
For 1967, 1985, 2000

(%)

Activity Name	1967	1985	2000
Ore Reduction Feedstocks	3.6	2.3	2.8
Chemical Feedstocks	6.3	6.3	8.3
Motive Power	13.2	21.0	18.8
Process Heat	24.6	21.2	22.4
Water Heat	4.8	4.8	4.5
Space Heat	26.8	17.8	13.4
Air Conditioning	1.5	3.2	3.4
Electric Power	19.2	23.4	26.4
Total %	100.0	100.0	100.0

Source: Table 5

Changes in energy requirements over time can be viewed as the sum of changes over time in the demand for the services of end use activities (where services are measured in terms of the BTU's flowing out of an "end use device") and changes over time in the energy requirements required per unit of end use service. Estimated amounts of primary fuel inputs required per unit of energy service output are listed in Table 8 for 1967, 1985, and 2000. The 1985 and 2000 values were estimated using the ERDA estimated SF-2 values of supply, conversion, and end use efficiencies. The mix of fuels used for each activity was estimated by BESOM.

Over the 1967-1985 period, aggregate input per unit of output requirements decline for four service activities, increase for three and stay the same for one. Input requirements for electric power decrease the most. This decline reflects ERDA anticipated efficiency improvements for most types of electric generating capacities and shifts in the mix of capacities. On the other hand, it is estimated that fuel requirements per unit of motive power output will increase sharply over the 1967-1985 period despite large increases in individual end use efficiencies. The decline in aggregate efficiency results from a change in the mix of transportation activities toward greater use of automobiles and airplanes, and lesser use of railroads. (Electrified mass transit is included in electric power). The decline in the aggregate efficiency for water heat results from an estimated shift toward the use of more electric water heaters, which, in turn, have lower aggregate efficiencies than gas or oil water heaters when primary resource to electricity efficiency losses are taken into account. Over the 1985-2000 period, all input per unit of output requirements stay constant or decrease, except for water heat.

Table 8

Average Primary Fuel Inputs Per Unit of Energy Utilization Activity

Activity	1967 BTU/BTU	1985 BTU/BTU	2000 BTU/BTU	1967-1985 Growth Rate %/yr	1985-2000 Growth Rate %/yr
Ore Reduction Feedstocks	4.33	4.30	4.30	-0.04	0.0
Chemical Feedstocks	1.10	1.10	1.10	0.0	0.0
Motive Power	2.62	3.98	3.22	+2.4	-1.4
Process Heat	1.74	1.77	1.71	+0.1	-0.2
Water Heat	1.98	2.56	2.70	+1.4	+0.4
Space Heat	2.37	2.30	2.02	-0.2	-0.9
Air Conditioning	1.10	1.15	1.07	-0.2	-0.5
Electric Power	3.79	3.45	3.22	-0.5	-0.4

Sources: 1967: 1967 BNL Combined IO-LP Verification Run of 5/8/75.

1985, 2000: Forecast 2 ERDA Reference Energy Systems of 1/5/77.

Energy Services - End use service (or "demand") amounts are listed in Table 9 for 1967, 1985, and 2000. These were estimated by the BNL IO model, by multiplying sectoral input per unit of output (or "product") coefficients by total output values. For each year, these demands thus reflect the estimated level and structure economic activity. These demands are also listed in Appendix B for 110 different sectors.

Summary - Comparison of Growth Rates for Energy Services, Energy Consumption and GNP - These growth rates are as follows:

	1947-1967	1967-1985	1985-2000
Primary Energy Consumption (BTU's)	3.1%/yr	3.2%/yr	2.4%/yr
Energy Services (BTU's)	Not Estimated	2.9%/yr	3.0%/yr
Real GNP (constant $)	4.0%/yr	3.3%/yr	3.1%/yr
Real Energy Consumption (constant $)	6.0%/yr	2.4%/yr	2.6%/yr

The growth of primary energy consumption (in BTU's) is expected to almost parallel that of real GNP in the 1967-1985 period, and then to decrease sharply in the 1985-2000 period to 77% of the GNP growth rate. However, the growth rate of energy services (in BTU's) tends to accelerate slightly in the 1985-2000 period relative to 1967-1985 period.

It should be pointed out that these comparisons are extremely dependent on the units of measurement chosen. For example, when energy consumption is measured in terms of 1972 dollars worth of sales of energy to non-energy sectors (excluding exports), energy consumption grows at an average annual rate of 6.0%/yr from 1947 to 1967; 2.4%/yr from 1967 to 1985; and 2.6%/year from 1985 to 2000. These estimates were obtained from DRI model results and from

Table 9

Services Obtained from Energy Utilization Activities

Activity	1967 10^{15} BTU	1985 10^{15} BTU	2000 10^{15} BTU	1967-2000 Growth Rate %/year	1985-2000 Growth Rate %/year
Ore Reduction Feedstocks	0.45	0.52	0.92	0.8	3.9
Chemical Feedstocks	3.13	5.66	10.66	3.3	4.3
Motive Power	2.76	5.20	8.21	3.6	3.1
Process Heat	7.70	11.76	18.40	2.4	3.0
Water Heat	1.33	1.83	2.36	1.8	1.7
Space Heat	6.19	7.61	9.32	1.2	1.4
Air Conditioning	0.74	2.77	4.44	7.6	3.2
Electric Power	2.98	6.67	11.53	4.6	3.7
Total	25.28	42.02	65.84	2.9	3.0

Sources: 1967: 1967 Combined IO/LP verification run of 5/8/75.

1985, 2000: Forecast 2 BNL Combined IO/LP runs of 3/22/77.

Jack Faucett historical data. Much of the slow down in the growth rate of constant dollar energy consumption is due to the expected slow down in the rate of electrification.

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Part II

Designing Strategies to Reduce Energy Consumption Within Industry

I. Introduction

In Part I it was estimated that the share of total energy consumption which will occur within the goods producing portion of the U.S. economy ("industry") will increase sharply between 1985 and 2000. In this part of the report, different policy strategies for reducing industrial energy consumption will be considered. Next inter-relationships existing between the policy strategies will be described. Finally some methodological issues will be raised concerning the nature of "optimum" combinations of policy strategies.

Before considering potential policy strategies, it is helpful to identify those types of energy using activities which occur primarily in industry. In Table 10, estimates are given of the percentage of total energy service consumption which occurs within industry for eight different energy service activities for the years 1967, 1985 and 2000. Industrial energy consumption growth rates are listed in Table 11. By 2000, it is estimated that industry will account for 100% of the direct consumption of coke, 88% that of petrochemicals; 85% that of process heat; and 49% that of direct electric power consumption, and for only 15% or less of the other energy service amounts. Policies devoted toward reducing industrial energy consumption should thus concentrate primarily on reducing the consumption of feedstocks, process heat, and direct electric power and/or on reducing energy input requirements for unit levels of these activities.

Table 10

Percent of Total Energy Service Activity Occurring Within Selected Interindustry Sectors

(%)

Activity Name	Agriculture, Mining, and Construction			Manufacturing		
	1967	1985	2000	1967	1985	2000
Ore Reduction Feedstocks	--	--	--	100.0	100.0	100.0
Chemical Feedstocks	29.7	22.8	22.1	44.1	57.4	66.4
Motive Power	6.6	4.3	5.2	0.7	0.5	0.5
Process Heat	3.9	4.6	4.9	67.8	72.7	79.6
Water Heat	2.6	2.3	2.8	1.0	1.0	1.5
Space Heat	3.0	2.5	2.8	5.9	7.1	8.7
Air Conditioning	--	--	--	18.2	9.0	9.1
Electric Power	2.2	2.6	2.7	36.8	42.9	46.1

Source: Adjusted BNL I/O-LP runs 3/22/77.

Table 11

Growth Rates in Amounts of Energy Services Occurring Within Selected Interindustry Sectors

(%/year)

Activity Name	Agriculture, Mining, and Construction		Manufacturing	
	1967-1985	1985-2000	1967-1985	1985-2000
Ore Reduction Feedstocks	-	-	0.8	3.9
Chemical Feedstocks	1.9	4.1	4.9	5.3
Motive Power	1.1	4.4	1.5	4.0
Process Heat	3.3	3.5	2.8	3.6
Water Heat	1.0	3.0	2.1	4.4
Space Heat	0.2	2.0	2.2	2.7
Air Conditioning	-	-	3.5	3.3
Electric Power	4.2	4.1	4.2	4.2
Growth Rates of Total Output	3.5	3.1	3.7	3.2
Growth Rates of BTU Fuel Usage	2.2	3.5	3.2	4.1

Source: Adjusted BNL I/O-LP runs 3/22/77

II. Policy Strategies for Reducing Industrial Energy Consumption

Four strategies for reducing industrial energy consumption can be identified; "final demand switching;" "materials switching;" "energy service reduction;" and "energy efficiency improvement." Any of a number of policy tools can be used to implement these strategies -- taxes, subsidies, government R&D, and direct regulations are a few of the more important ones. In this paper, attention is focused on the choice of strategies rather than the choice of tools used to implement a strategy.

"Final Demand Switching" - By use of policy tools, final demand purchases can be switched towards purchase of those goods and services which require, directly and indirectly, small amounts of feedstocks, process heat, and electric power. Estimates of these "direct plus indirect" final demand service requirements are contained in Tables A-1 through A-8 in Appendix A for the years 1967, 1985 and 2000. The tables are arranged by type of energy service, one table for each type of energy service. Thus, looking at column (1), line 1 of Table A-1, it is estimated that sales of all motor vehicles to final demand (which equals all motor vehicle purchases of households, plus all business purchases on capital account, plus all government purchases, plus all net exports) required, directly and indirectly, .095 quads of coke feedstock consumption in 1967, 17.6% of all the coke consumption in that year. In these Appendix A tables, flow estimates of direct plus indirect service requirements for final demand purchases are listed in the first three columns, while coefficient estimates of direct plus indirect service requirements per 1967 dollars worth of delivery to final demand are listed in the second three columns. These are often referred to as "inverse" coefficients.

Each table lists direct plus indirect requirements for the 20 largest service using sectors, ranked in order of importance of total use as of 1985. Estimates of inverse coefficients and of inverse matrix flows for all 110 BNL sectors are available on request.

As would be expected, sectors whose outputs embody a high percentage of materials tend to predominate in the "top 20" sectors in the tables for coke, petrochemicals, process heat, and electric power. These are primarily the construction, machinery, and consumer durable sectors. On the other hand, only a few consumer service oriented sectors make the top 20 in these tables. Thus any switching of final demand purchases toward the output of such sectors as education and radio and TV will lower industrial energy consumption.

Materials Switching - Another strategy to reduce industrial energy consumption is to encourage energy-saving "materials" or "inputs" switching within industry itself. This can be illustrated with respect to the automobile sector (BNL sector #83). In order to meet FEA mandated fuel efficiency requirements, automobiles will become lighter over time. In estimating SF-2 energy demands, it was assumed that the automobile industry will switch toward the use of more aluminum and plastics, and less steel and glass. Estimates of the direct input requirements of plastics, aluminum, and iron and steel into the motor vehicle industry shown in Table 12 for 1967, 1985 and 2000. The impact of this switch in direct input requirements over time, on the movement in direct plus indirect energy service requirements over time, can be found in Tables A-1 through A-8. For example, in Table A-1, it is shown that the direct plus indirect coke requirement per unit of auto sales to final demand decreases from 3432 BTU's/67$ in 1967 to 1112 BTU's/67$ in 2000, while in Table A-4 it is shown that corresponding process heat requirements decrease from 15,410 BTU's/67$ in 1967 to

Table 12

Selected Input Requirements Per Unit of Output of the Automobile Industry for 1967, 1985 and 2000

($ 1967/1967 $)

Input Category	Direct Requirements		
	1967	1985	2000
Rubber & Misc. Plastics Products	.0209	.0220	.0241
Primary Iron & Steel Mfg.	.0720	.0508	.0381
Primary Non-ferrous Metals Mfg.	.0156	.0193	.0233

Source: Derived from data provided by: Robert U. Ayres, Adele Shapanka and Stedman Noble, Internation Research and Technology Corporation publication: IRT-362-R, "The Use of Explicit Technological Forecasts in Long Range Input-Output Models," December 1974, pp. 3-4.

11,908 BTU's/67$ in 2000. On the other hand, in Tables A-2 and A-8 it is shown that the direct plus indirect requirements of automobile final demand sales for petrochemicals and for direct electricity increase slightly. Overall the switch toward lighter materials leads to less total industrial energy consumption.

Energy Service Reductions - Another strategy for reducing industrial energy consumption is to use policy tools to reduce direct energy service input requirements. An example of this strategy is encouraging the introduction of centrifuge rather than gaseous diffusion techniques for enriching uranium within the chemical sector (BNL sector #50). This process change would tend to reduce direct electric power requirements for uranium enrichment.

The actual energy service (or "product") coefficients for 1967, 1985 and 2000 which were used to estimate SF-2 energy service activity levels (or "basic energy demands") are listed in the last three columns in Tables B-1 through B-8 in Appendix B. Actual IO-LP model solution values of energy service flows by industry are listed in the first three columns of these tables.

Now, let us consider the direct electric power input per unit of output requirements listed in the last three columns of Table B-8. For most manufacturing sectors, it was estimated that these requirements would increase at an average annual rate of from 1.0%/yr to 1.5%/yr between 1967 and 2000, and that they would increase by smaller rates within service sectors. However, within the chemicals sector (#50), it was estimated that the introduction of the centrifuge enrichment process over time would limit per unit electric power increases over time to an average rate of 0.5%/yr. (Increases in the amount of electric-intensive enrichment activities as a percent of all chemical activities will still require an increase in per unit electric power requirements in this industry.)

Improving Energy "Efficiencies" - A fourth strategy for reducing industrial energy consumption is to encourage the introduction of more energy efficient conversion and end use devices within industry. For example, BTU losses associated with the decentralized industrial generation of electricity may be limited by simultaneously producing process heat with the electricity via cogeneration. The potential for introducing such efficiency improving technologies within industry is being considered by the Technology Assessment Group of BNL under Morris Beller. Preliminary results for several technologies are available upon request.

If successful, implementation of these technologies will lower fuel requirements for given energy service requirements. That is, the rate of efficiency improvements estimated in Table 9 in Part I will accelerate (or deteriorate less rapidly).

As a guide to identifying sectors in which such efficiency improving technologies might be particularly effective and/or quantitatively important, the distribution of total energy service requirements across the 20 largest energy service using sectors is presented in the first 3 columns of Tables B1 through B8. For example, in column 2 of Table B-4, estimated 1985 process heat requirements are estimated for the 20 largest process heat using sectors. In total, these sectors account for 72% of all process heat requirements in 1985.

One of the major determinants of how rapidly efficiency improving techniques can be implemented in a particular sector will be the expected growth rate of that sector. Barring retrofiting possibilities, the faster the growth rate of the sector, the greater the potential for new technology introduction. Expected average annual growth rates of sector outputs between 1967 and 1985, and between 1985 and 2000 are listed in Appendix C, Table C-3, for all 110 BNL

sectors. Unfortunately, little information is available as to the age structure of existing capital stocks within most industries.

III. Analysis of Inter-Relationships Existing Between the Alternative Strategies for Reducing Industrial Energy Consumption

The four strategies just discussed were presented as if they were independent of one another. They are not. Again, I will use examples from the ERDA SF-2 energy forecast to illustrate my point.

First consider the expected materials switching within the automobile industry. As explained, on balance, this switching will reduce direct plus indirect energy requirements for producing automobiles. However, this substitution will also increase the average automobile end use efficiency to an estimated 20.9 miles per gallon in 1985, and to 26.0 miles per gallon in 2000, relative to the current 13.0 mile per gallon efficiency average. Thus the system-wide energy conservation effect will exceed that obtained from either materials switching or from end use efficiency improvement alone.

As another example, consider the expected declines in the aggregate electricity heat rate over time. In this case, this conversion efficiency improvement will also require significant "final demand switching." That is, over the 1990 to 2000 period, ERDA projects a large scale introduction of solar electric, coal combined cycle, and LMFBR generating capacities. While these technologies are more "energy efficient," large increases in public utility construction expenditures will also be required, since these technologies are particularly capital intensity. The direct plus indirect energy requirements associated with public utility construction purchases are estimated in Tables A-1 through A-8. For example, coal feedstock requirements for public utility construction increase at an average annual rate of 4.3%/yr between 1967 and 2000, from .03 quads to .12

quads. Likewise, process heat requirements for public utility construction increase from .20 quads to .99 quads. Thus, in this case, the system-wide energy conservation effect will be less than the direct efficiency conservation effect.

IV. Developing Methodologies for Estimating System-Wide Effects

Since the four strategies considered are not independent, policy makers should not concentrate on achieving goals defined in terms of just one strategy -- e.g., just increasing supply, conversion, and end use efficiencies to target values. Instead they should pursue that mix of strategies which will achieve target goals, which, in turn, are defined in terms of the entire energy/economic system -- e.g., obtaining minimum energy consumption growth rates for specified GNP growth rates and specified environmental damages.

In order to estimate such an optimum mix of strategies, it thus becomes necessary to estimate the various inter-relationships involved between tools, strategies, targets and goals. Various frames can be used. For ERDA 77-1, a combined ERDA/DRI/BNL framework was used-ERDA maintaining prime responsibility for estimating energy prices, costs and efficiencies and maximum availability amounts for new technologies; DRI for estimating aggregate GNP and aggregate energy demand; and BNL for estimating the detailed composition of GNP, detailed energy service demands, and the mix of energy conversion and supply activities.

As part of this framework, BNL employed a static, time phased, fixed coefficient IO model for disaggregation of aggregate GNP and energy demand estimates. This model could be expanded so as to permit choice between alternative industrial sector input mixes, some of which would incorporate energy efficiency increasing technologies such as co-generation. This expansion would permit estimation of system-wide effects associated with efficiency increasing technologies. This expanded model could also be used, as well, within the over-all ERDA/DRI/BNL framework to estimate optimum strategy combinations.

Footnotes

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List of Appendix Tables

Appendix A

Direct plus Indirect Energy Service Requirements for Aggregate Final Demands and Per Unit of Final Demand

TABLE A-1

ENERGY PRODUCT SECTOR = 13: Ore Reduction Feedstocks

Sec. #	Sector Name	Direct & Indirect Flows 10^{15} BTU			$(I-A)^{-1}$ Coefficients 10^{6} BTU/67 $		
		1967	1985	2000	1967	1985	2000
83	Motor Vehicles and Equipment	.094904	.091795	.090877	.003432	.001757	.001112
31	New Construction, Public Utilities	.028932	.060128	.117307	.002650	.001543	.001931
30	New Construction, Nonresidential Buildings	.041667	.045847	.111460	.001550	.000778	.001234
29	New Construction, residential Buildings	.024971	.028490	.089482	.000946	.000661	.001258
85	Other Transportation Equipment	.024580	.023387	.045034	.003912	.001926	.002298
37	Food and Kindred Products	.027859	.022004	.041362	.000439	.000215	.000252
101	Real Estate & Rental	.009731	.014055	.028218	.000131	.000095	.000119
69	Construction, Mining, Oil Field Machinery, Equipment	.019362	.012554	.021834	.004810	.002188	.002560
64	Heating, Plumbing and Fabricated Structural Metal Products	.010140	.012207	.024673	.006466	.002744	.004115
99	Wholesale and Retail Trade	.013335	.011932	.023169	.000110	.000052	.000063
78	Household Appliances	.010895	.011923	.018886	.002762	.001345	.001344
35	Maintenance and Repair Construction, all other	.005518	.011253	.011727	.001000	.000546	.000680
80	Radio, Television and Communications Equipment	.009117	.010449	.018597	.000705	.000482	.000556
72	Special Industry Machingery and Equipment	.011902	.010393	.018065	.003076	.001491	.001771
84	Aircraft and Parts	.019021	.009983	.017541	.001301	.000587	.000652
68	Farm Machinery	.016898	.009740	.022237	.004706	.002024	.002344
77	Elec. Trans. & Dist. Eq. & Elec. Industry Apparatus	.008214	.008710	.014834	.001932	.001174	.001366
76	Service Industry Machines	.007922	.008338	.015748	.002798	.001474	.001715
33	New Construction, all other	.013993	.008317	.009782	.001910	.001007	.000811
88	Miscellaneous Manufacturing	.005688	.008092	.014350	.001131	.000791	.000919
0	Other	.130527	.095293	.159620	0.000000	0.000000	0.000000

TABLE A-2

ENERGY PRODUCT SECTOR = 14: Chemical Feedstocks

Sec. #	Sector Name	Direct & Indirect Flows 10^{15} BTU			$(I-A)^{-1}$ Coefficients 10^{6} BTU/67 $		
		1967	1985	2000	1967	1985	2000
30	New Construction, Nonresidential Buildings	.356785	.536757	1.009819	.013269	.009109	.011182
101	Real Estate and Rental	.124095	.473138	.825249	.001667	.003207	.003488
37	Food and Kindred Products	.173459	.354896	.687047	.002732	.003467	.004187
50	Chemicals and Selected Chemical Products	.177057	.311896	.549357	.048555	.047517	.048101
29	New Construction, Residential Buildings	.333256	.294895	.599060	.012630	.006839	.008419
31	New Construction, Public Utilities	.140339	.285923	.516577	.012853	.007337	.008504
35	Maintenance and Repair Construction, all other	.081579	.262091	.236764	.014783	.012718	.013720
99	Wholesale and Retail Trade	.118310	.260522	.479369	.000979	.001137	.001298
32	New Construction, Highways	.179885	.231127	.425444	.021489	.035746	.040448
41	Apparel	.086951	.214185	.521350	.005175	.008079	.012472
52	Drugs, Cleaning and Toilet Preparations	.062843	.162023	.297003	.007364	.007125	.008047
83	Motor Vehicles and Equipment	.057580	.144068	.312400	.002083	.002757	.003823
55	Rubber and Miscellaneous Plastics Products	.034462	.142311	.352485	.011112	.019177	.030684
22	Other Agricultural Products	.042296	.122026	.243616	.006193	.007384	.007667
105	Medical, Educ. Services & Nonprofit Inst.	.057277	.109216	.201604	.001250	.001125	.001297
51	Plastics and Synthetic Materials	.027598	.066939	.236087	.044003	.045909	.076612
33	New Construction, all other	.093396	.066655	.111623	.012749	.008068	.009257
88	Miscellaneous Manufacturing	.017773	.057018	.128228	.003533	.005571	.008210
80	Radio, Television and Communications Equipment	.018473	.054663	.117162	.001428	.002521	.003500
102	Hotel and Lodging; Pers. & Repair Serv., except Auto Repair	.030801	.052811	.098458	.001905	.001945	.002236
0	Other	.416749	.704154	1.725051	0.000000	0.000000	0.000000

TABLE A-3

ENERGY PRODUCT SECTOR = 15: Motive Power

Sec. #	Sector Name	Direct & Indirect Flows 10^{15} BTU			$(I-A)^{-1}$ Coefficients 10^{6} BTU/67 $		
		1967	1985	2000	1967	1985	2000
93	Air Transportation	.117306	.197822	.285160	.029439	.023433	.027130
99	Wholesale and Retail Trade	.108321	.171674	.320133	.000896	.000749	.000867
37	Food and Kindred Products	.120622	.150415	.279786	.001900	.001469	.001705
92	Water Transportation	.077863	.085592	.147750	.031717	.020017	.023174
22	Other Agricultural Products	.037336	.068663	.152849	.005467	.004155	.004810
106	Medical, Educ. Services & Nonprofit Inst.	.030075	.059626	.110043	.000656	.000614	.000708
89	Railroads and Related Services	.036784	.057019	.109899	.009594	.006937	.008030
30	New Construction, Nonresidential Buildings	.029482	.049878	.090438	.001096	.000846	.001001
101	Real Estate and Rental	.026421	.048755	.090601	.000355	.000330	.000383
91	Motor Freight Transportation and Warehousing	.032622	.044338	.079467	.005703	.004017	.004650
29	New Construction, Residential Buildings	.031282	.036765	.070173	.001186	.000853	.000986
31	New Construction, Public Utilities	.012218	.034425	.062710	.001119	.000883	.001032
83	Motor Vehicles and Equipment	.018915	.032221	.056548	.000684	.000617	.000692
100	Finance and Insurance	.015100	.027726	.0513336	.000585	.000555	.000642
90	Local, Urban and Interurban Highway Pass. Trans.	.024727	.024093	.052725	.007782	.005756	.006595
41	Apparel	.013605	.018912	.034593	.000810	.000713	.000828
102	Hotels & Lodging; Pers. & Repair Serv., except Auto Repair	.012171	.018549	.034881	.000753	.000683	.000792
52	Drugs, Cleaning and Toilet Preparations	.006320	.017059	.031649	.000741	.000750	.000857
35	Maintenance and Repair Construction, all other	.004449	.014700	.014318	.000806	.000713	.000830
107	Federal Government Enterprises	.003849	.014045	.026584	.002091	.002997	.003468
0	Other	.132126	.202580	.378453	0.000000	0.000000	0.000000

TABLE A-4

ENERGY PRODUCT SECTOR = 16: Process Heat

Sec. #	Sector Name	Direct & Indirect Flows 10^{15} BTU			$(I-A)^{-1}$ Coefficients 10^{6} BTU/67 $		
		1967	1985	2000	1967	1985	2000
37	Food and Kindred Products	.955551	1.392379	2.275141	.015051	.013603	.013864
30	New Construction, Nonresidential Buildings	.460543	.763235	1.313370	.017128	.012952	.014543
83	Motor Vehicles and Equipment	.426076	.658221	.972936	.015410	.012597	.011908
99	Wholesale and Retail Trade	.408413	.607353	.988556	.003379	.002651	.002677
29	New Construction, Residential Buildings	.400632	.605077	1.129611	.015184	.014033	.015875
31	New Construction, Public Utilities	.202593	.596812	.988535	.018554	.015314	.016274
50	Chemicals and Selected Chemical Products	.273498	.430460	.757661	.075003	.065580	.066340
101	Real Estate and Rental	.159016	.385699	.630225	.002136	.002614	.002664
41	Apparel	.208900	.374997	.606404	.012432	.014145	.014507
52	Drugs, Cleaning and Toilet Preparations	.164835	.369171	.581055	.019314	.016234	.015743
56	Rubber and Miscellaneous Plastics Products	.079649	.243610	.386780	.025682	.032827	.033670
106	Medical, Educ. Services & NonProfit Inst.	.153138	.221713	.360196	.003342	.002284	.002318
35	Maintenance and Repair Construction, all other	.061814	.183210	.158060	.011201	.008890	.009159
47	Paper and Allied Products except Containers and Boxes	.083141	.163358	.211089	.066369	.057345	.058006
22	Other Agricultural Products	.071971	.162285	.313849	.010539	.009820	.009877
80	Radio, Television and Communications Equipment	.083641	.157830	.253950	.006464	.007279	.007587
85	Other Transportation	.098007	.153329	.259094	.015599	.012628	.013222
102	Hotels & Lodging; Pers. & Repair Serv., except auto repair	.109234	.141432	.226804	.006757	.005209	.005150
78	Household Appliances	.066580	.138591	.228300	.016881	.015629	.016249
88	Miscellaneous Manufacturing	.067346	.136726	.214719	.013386	.013359	.013747
0	Other	1.869780	2.292850	3.768060	0.000000	0.000000	0.000000

TABLE A-5

ENERGY PRODUCT SECTOR = 17: Water Heat

Sec. #	Sector Name	Direct & Indirect Flows 10^{15} BTU			$(I-A)^{-1}$ Coefficients 10^{6} BTU/67 $		
		1967	1985	2000	1967	1985	2000
99	Wholesale and Retail Trade	.166326	.208282	.320051	.001376	.000909	.000867
102	Hotels & Lodging; Pers. & Repair Serv., except Auto Repair	.092454	.102460	.158373	.005719	.003774	.003596
106	Medical, Educ. Services & Nonprofit Inst.	.051311	.070899	.108238	.001120	.000730	.000696
37	Food and Kindred Products	.025254	.028905	.045162	.000398	.000282	.000275
101	Real Estate and Rental	.011325	.017711	.027267	.000152	.000120	.000115
30	New Construction, Nonresidential Buildings	.010991	.017046	.025659	.000409	.000289	.000284
100	Finance and Insurance	.012141	.014702	.022477	.000471	.000295	.000281
29	New Construction, Residential Buildings	.011861	.012335	.019816	.000450	.000286	.000278
31	New Construction, Public Utilities	.004129	.009555	.014572	.000378	.000245	.000240
83	Motor Vehicles and Equipment	.004833	.007089	.010976	.000175	.000136	.000134
22	Other Agricultural Products	.003828	.006801	.012514	.000561	.000412	.000394
41	Apparel	.004053	.005022	.008278	.000241	.000189	.000198
96	Communications except Radio & Television Broadcasting	.003255	.004304	.006652	.000323	.000175	.000167
103	Business Services	.004037	.004093	.006507	.000435	.000259	.000249
104	Automobile Repair and Services	.003152	.003662	.005610	.000380	.000286	.000274
52	Drugs, Cleaning and Toilet Preparations	.002145	.003534	.005605	.000251	.000155	.000152
105	Amusements	.003684	.003358	.005274	.000608	.000368	.000352
35	Maintenance and Repair Construction, all other	.001336	.003136	.002553	.000242	.000152	.000148
80	Radio, Television and Communications Equipment	.002344	.002975	.004733	.000181	.000137	.000141
21	Livestock and Livestock Products	.001258	.002127	.003380	.000699	.000491	.000470
0	Other	.035176	.036639	.0061332	0.000000	0.000000	0.000000

TABLE A-6

ENERGY PRODUCT SECTOR = 18: Space Heat

Sec. #	Sector Name	Direct & Indirect Flows 10^{15} BTU			$(I-A)^{-1}$ Coefficients 10^{6} BTU/67 $		
		1967	1985	2000	1967	1985	2000
99	Wholesale and Retail Trade	.652476	.784770	1.056162	.005399	.003425	.002860
106	Medical, Educ. Services & Nonprofit Inst.	.317443	.421356	.562752	.006928	.004340	.003621
37	Food and Kindred Products	.260507	.292495	.401448	.004103	.002858	.002446
102	Hotels & Lodging; Pers. & Repair Serv., except Auto Repair	.256746	.272662	.369096	.015883	.010043	.008380
101	Real Estate and Rental	.160207	.214063	.288268	.002152	.001451	.001218
100	Finance and Insurance	.087542	.104850	.140293	.003393	.002101	.001755
83	Motor Vehicles and Equipment	.057186	.085742	.117752	.002068	.001641	.001441
30	New Construction, Nonresidential Buildings	.050268	.080785	.112565	.001870	.001371	.001246
104	Automobile Repair & Services	.071976	.073663	.098399	.008687	.005750	.004802
29	New Construction, Residential Buildings	.053606	.064215	.093366	.002032	.001489	.001312
31	New Construction, Public Utilities	.018839	.051648	.073212	.001725	.001325	.001205
41	Apparel	.040554	.051226	.072377	.002414	.001932	.001731
96	Communications except Radio & Television Broadcasting	.033145	.050797	.068608	.003285	.002068	.001727
108	State and Local Government Enterprises	.034552	.046543	.062350	.028025	.017973	.014964
98	Water and Sanitary Services	.056747	.044316	.059022	.029891	.018560	.015451
103	Business Services	.037101	.040066	.055787	.003994	.002535	.002131
80	Radio, Television and Communications Equipment	.028679	.039158	.054622	.002216	.001806	.001632
52	Drugs, Cleaning and Toilet Preparations	.019754	.035100	.049009	.002315	.001543	.001328
22	Other Agricultural Products	.012980	.028295	.045916	.001901	.001712	.001445
84	Aircraft and Pars	.032575	.027638	.039694	.002228	.001625	.001476
0	Other	.358947	.481149	.673090	0.000000	0.000000	0.000000

TABLE A-7

ENERGY PRODUCT SECTOR = 19: Air Conditioning

Sec. #	Sector Name	Direct & Indirect Flows 10^{15} BTU			$(I-A)^{-1}$ Coefficients 10^{6} BTU/67 $		
		1967	1985	2000	1967	1985	2000
99	Wholesale and Retail Trade	.100407	.194895	.344592	.000831	.000851	.000933
106	Medical, Educ. Services & Nonprofit Inst.	.042477	.091463	.160670	.000927	.000942	.001034
37	Food and Kindred Products	.018839	.036176	.062479	.000297	.000353	.000381
102	Hotels & Lodging; Pers. & Repair Serv., except Auto Repair	.019374	.033314	.058972	.001198	.001227	.001339
100	Finance and Insurance	.016886	.032625	.057291	.000655	.000654	.000717
41	Apparel	.017516	.028824	.045893	.001042	.001087	.001098
101	Real Estate and Rental	.010722	.027284	.047522	.000144	.000185	.000201
80	Radio, Television and Communications Equipment	.013355	.022241	.034616	.001032	.001026	.001034
83	Motor Vehicles and Equipment	.010037	.021867	.034896	.000363	.000418	.000439
30	New Construction, Nonresidential Buildings	.006754	.019069	.033198	.000251	.000324	.000368
52	Drugs, Cleaning and Toilet Preparations	.007147	.017862	.029239	.000837	.000785	.000792
29	New Construction, Residential Buildings	.006926	.013882	.025790	.000262	.000322	.000362
84	Aircraft and Parts	.012740	.013163	.021234	.000871	.000774	.000789
31	New Construction, Public Utilities	.002542	.010564	.018039	.000233	.000271	.000297
56	Rubber and Miscellaneous Plastics Products	.003052	.010375	.016231	.000984	.001398	.001413
96	Communications except Radio & Television Broadcasting	.003976	.010027	.017712	.000394	.000408	.000446
38	Tobacco Manufacturers	.008211	.009177	.014622	.001360	.001206	.001208
103	Business Services	.005316	.009113	.016430	.000572	.000577	.000628
75	Office, Computing and Accounting Machines	.003341	.007889	.013523	.000692	.000638	.000645
105	Amusements	.005005	.007608	.013700	.000826	.000834	.000913
0	Other	.060775	.116897	.197396	0.000000	0.000000	0.000000

TABLE A-8

ENERGY PRODUCT SECTOR = 20: Electric Power

Sec. #	Sector Name	Direct & Indirect Flows 10^{15} BTU			$(I-A)^{-1}$ Coefficients 10^{6} BTU/67 $		
		1967	1985	2000	1967	1985	2000
99	Retail and Wholesale Trade	.255405	.505220	.939374	.002113	.002205	.002544
106	Medical, Educ. Services & Nonprofit Inst.	.184859	.400166	.738226	.003362	.003893	.004522
37	Food and Kindred Products	.213484	.398487	.742140	.003362	.003893	.004522
83	Motor Vehicles and Equipment	.137299	.294519	.496226	.004966	.005636	.006073
30	New Construction, Nonresidential Buildings	.092797	.223049	.435309	.003451	.003785	.004820
31	New Construction, Public Utilities	.051663	.204146	.379505	.004731	.005238	.006248
101	Real Estate and Rental	.060826	.163479	.304751	.000817	.001108	.001288
29	New Construction, Residential Buildings	.080896	.159869	.341751	.003066	.003708	.004803
41	Apparel	.075914	.149184	.271591	.004518	.005627	.006497
90	Local, Urban and Interurban Highway Pass. Trans.	.010497	.138508	.203735	.003304	.033089	.025486
50	Chemicals and Selected Chemical Products	.067060	.129556	.259196	.018390	.019738	.022695
52	Drugs, Cleaning and Toilet Preparations	.037225	.104348	.189088	.004362	.004589	.005123
80	Radio, Television and Communications Equipment	.042206	.092839	.165082	.003262	.004281	.004932
100	Finance and Insurance	.040090	.076350	.140528	.001554	.001530	.001758
84	Aircraft and Parts	.059145	.072944	.131811	.004045	.004231	.004900
56	Rubber and Miscellaneous Plastics Products	.020580	.070771	.126582	.006636	.009537	.011019
85	Other Transportation Equipment	.031963	.065986	.124740	.005087	.005434	.006366
102	Hotels & Lodging; Pers. & Repair Serv., except Auto Repair	.035496	.065806	.122946	.002196	.002424	.002791
22	Other Agricultural Products	.020557	.059245	.130885	.003010	.003585	.004119
78	Household Appliances	.021529	.055992	.104160	.005459	.006314	.007413
0	Other	.531501	.986333	1.751185	0.000000	0.000000	0.000000

Appendix B

Direct Energy Service Input Requirements: Distribution of Total Requirements by Industry and Input Per Unit of Output Requirements

TABLE B-1

ENERGY PRODUCT SECTOR = 13: Ore Reduction Feedstock

Sec. #	Sector Name	Energy Flows 10^{15} BTU			Energy Product Coefficients 10^{6} BTU/67 $		
		1967	1985	2000	1967	1985	2000
61	Primary Iron and Steel Manufacturing	.535669	.512516	.910500	.017797	.012680	.014789
62	Primary Nonferrous Metals Manufacturing	.002011	.003399	.006575	.000108	.000074	.000086
83	Motor Vehicles and Equipment	.000918	.001336	.002135	.000021	.000016	.000017
64	Heating, Plumbing and Fabricated Structural Metal Products	.000339	.000645	.001015	.000027	.000021	.000022
68	Farm Machinery	.000487	.000484	.000946	.000107	.000083	.000085
66	Other Fabricated Metal Products	.000246	.000376	.000602	.000020	.000016	.000016
60	Stone and Clay Products	.000250	.000356	.000587	.000023	.000018	.000018
37	Food and Kindred Products	.000291	.000353	.000578	.000003	.000003	.000003
73	General Industrial Machinery and Equipment	.000131	.000209	.000327	.000017	.000013	.000014
67	Engines and Turbines	.000078	.000186	.000297	.000021	.000016	.000016
69	Construction, Mining, Oil Field Machinery, Equipment	.000096	.000117	.000180	.000016	.000013	.000013
79	Electric Lighting and Wiring Equipment	.000051	.000107	.000170	.000013	.000010	.000010
58	Footwear and other Leather Products	0.000000	.000056	.000084	0.000000	.000016	.000016
72	Special Industry Machinery and Equipment	.000033	.000048	.000074	.000006	.000005	.000005
74	Machine Shop Products	.000030	.000037	.000060	.000007	.000006	.000006
57	Leather Tanning and Industrial Leather Products	0.000000	.000005	.000007	0.000000	.000016	.000016
36	Ordnance and Accessories	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
54	Paving Mixtures and Blocks	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
32	New Construction, Highways	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
31	New Construction, Public Utilities	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
0	Other	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000

TABLE B-2

ENERGY PRODUCT SECTOR = 14: Chemical Feedstocks

Sec. #	Sector Name	Energy Flows 10^{15} BTU			Energy Product Coefficients 10^{6} BTU/67 $		
		1967	1985	2000	1967	1985	2000
50	Chemicals and Selected Chemical Products	.779992	1.770634	3.307605	.034759	.032667	.032124
51	Plastics and Synthetic Materials	.193714	.644458	2.472092	.023420	.022010	.050417
54	Paving Mixtures and Blocks	.197816	.483953	.688714	.332943	.312902	.307702
30	New Construction, Nonresidential Buildings	.251941	.366807	.640394	.009370	.006225	.007088
55	Asphalt Felts and Coatings	.177407	.303472	.530718	.305076	.286714	.281949
32	New Construction, Highways	.078436	.208368	.385912	.009370	.032226	.036690
35	Maintenance and Repair Construction, all other	.125739	.191317	.234942	.007340	.005642	.006423
31	New Construction, Public Utilities	.102311	.190540	.338153	.009370	.004889	.005566
29	New Construction, Residential Buildings	.247227	.173233	.325482	.009370	.004018	.004574
34	Maintenance and Repair Construction, residential	.045982	.108592	.336501	.007340	.007596	.008648
33	New Construction, all other	.068645	.040880	.067929	.009370	.004948	.005633
53	Paints and Allied Products	.021006	.039582	.066477	.007208	.006774	.006662
22	Other Agricultural Products	.006622	.009530	.018677	.000235	.000199	.000227
93	Air Transportation	.002240	.007276	.012275	.000281	.000238	.000271
99	Wholesale and Retail Trade	.004323	.007005	.012851	.000027	.000023	.000026
47	Paper and Allied Products except Containers and Boxes	.003323	.005779	.008918	.000217	.000204	.000201
91	Motor Freight Transportation and Warehousing	.000858	.001391	.002474	.000047	.000040	.000045
89	Railroads and Related Services	.001105	.001289	.002332	.000087	.000074	.000084
92	Water Transportation	.001218	.001224	.002054	.000256	.000217	.000247
106	Medical, Educ. Services & Nonprofit Inst.	.00579	.001066	.001943	.000012	.000010	.000011
0	Other	.003582	.005580	.010049	0.000000	0.000000	0.000000

TABLE B-3

ENERGY PRODUCT SECTOR = 15: Motive Power

Sec. #	Sector Name	Energy Flows 10^{15} BTU			Energy Product Coefficients 10^{6} BTU/67 $		
		1967	1985	2000	1967	1985	2000
93	Air Transportation	.221759	.607478	1.042236	.027851	.019867	.023002
22	Other Agricultural Products	.130323	.158189	.315254	.004633	.003305	.003826
99	Wholesale and Retail Trade	.085071	.116276	.216912	.000525	.000374	.000434
91	Motor Freight Transportation and Warehousing	.084903	.116152	.210076	.004635	.003307	.003828
89	Railroads and Related Services	.109397	.107601	.197983	.008613	.006144	.007114
92	Water Transportation	.120584	.102186	.174361	.025374	.018100	.020957
90	Local, Urban and Interurban Highway Pass. Trans.	.033660	.028392	.060596	.006148	.005335	.006177
106	Medical, Educ. Services & Nonprofit Inst.	.011387	.017691	.032790	.000235	.000167	.000194
21	Livestock and Livestock Products	.010182	.011449	.021507	.000335	.000239	.000276
23	Forestry and Fishery Products	.005782	.009866	.016411	.004140	.002953	.003419
31	New Construction, Public Utilities	.003822	.009731	.017561	.000350	.000250	.000289
103	Business Services	.005931	.009226	.017049	.000105	.000075	.000087
30	New Construction, Nonresidential Buildings	.009411	.008827	.015671	.000350	.000150	.000173
100	Finance and Insurance	.005839	.008466	.015601	.000123	.000088	.000101
35	Maintenance and Repair Construction, all other	.004111	.007257	.009063	.000240	.000214	.000248
102	Hotels & Lodging; Pers. & Repair Serv., except Auto Repair	.005987	.006245	.011706	.000288	.000205	.000238
32	New Construction, Highways	.002930	.005304	.009990	.000350	.000820	.000950
33	New Construction, all other	.002564	.004184	.007071	.000350	.000506	.000586
29	New Construction, Residential	.009235	.003998	.007640	.000350	.000093	.000107
94	Pipe Line Transportation	.004951	.003762	.005769	.004111	.002932	.003395
0	Other	.031797	.041097	.077164	0.000000	0.000000	0.000000

TABLE E-4

ENERGY PRODUCT SECTOR = 16: Process Heat

Sec. #	Sector Number	Energy Flows 10^{15} BTU			Energy Product Coefficients 10^{6} BTU/67 $		
		1967	1985	2000	1967	1985	2000
50	Chemicals and Selected Chemical Products	1.068739	2.178379	4.217138	.047627	.040190	.040957
47	Paper and Allied Products except Containers and Boxes	.673967	1.052391	1.683048	.044023	.037148	.037858
60	Stone and Clay Products	.605611	.942489	1.549409	.055965	.047226	.048128
61	Primary Iron and Steel Manufacturing	.813933	.769450	1.209518	.027042	.019036	.019645
37	Food and Kindred Products	.488917	.647700	1.059591	.005563	.004694	.004784
51	Plastics and Synthetic Materials	.215898	.644912	1.100636	.026102	.022026	.022447
62	Primary Nonferrous Manufacturing	.276723	.587013	1.105267	.014791	.012806	.014538
56	Rubber and Miscellaneous Plastic Products	.082358	.217375	.371591	.006064	.005117	.005215
59	Glass and Glass Products	.136653	.197873	.278500	.037175	.031370	.031970
83	Motor Vehicles and Equipment	.089792	.142721	.227472	.002083	.001758	.001791
28	Chemicals and Fertilizer Mineral Mining	.066517	.139996	.256779	.071668	.060477	.061633
43	Lumber and Wood Products	.087363	.137522	.190783	.007307	.006166	.006284
99	Wholesale and Retail Trade	.079453	.123710	.204139	.000490	.000398	.000408
39	Broad and Narrow Fabrics, Yarn and Thread Mills	.090743	.119868	.190734	.005878	.004960	.005055
52	Drugs, Cleaning and Toilet Preparations	.042897	.094586	.156386	.003448	.002909	.002965
27	Stone and Clay Mining, Quarrying	.056078	.094455	.147125	.025106	.021186	.021591
66	Other Fabricated Metal Products	.056025	.093585	.149309	.004603	.003884	.003959
54	Paving Mixtures and Blocks	.037595	.082583	.121796	.063276	.053395	.054416
64	Heating Plumbing and Fabricated Structural Metal Products	.036227	.075248	.118054	.002911	.002456	.002503
26	Nonferrous Metal Ores Mining	.025001	.067635	.116834	.019855	.016755	.017075
0	Other	.573659	.867853	1.408052	0.000000	0.000000	0.000000

TABLE B-5

ENERGY PRODUCT SECTOR = 17: Water Heat

Sec. #	Sector Name	Energy Flows 10^{15} BTU			Energy Product Coefficients 10^{6} BTU/67 $		
		1967	1985	2000	1967	1985	2000
99	Wholesale and Retail Trade	.201676	.260414	.399557	.001245	.000839	.000799
102	Hotels & Lodging; Pers & Repair Serv., except Auto Repair	.112591	.110951	.171069	.005412	.003647	.003473
106	Medical, Educ. Services & Nonprofit Inst.	.046897	.068831	.104930	.000967	.000652	.000620
103	Business Services	.012833	.018858	.028662	.000228	.000153	.000146
100	Finance and Insurance	.012633	.017304	.026227	.000265	.000179	.000170
22	Other Agricultural Products	.009394	.010772	.017656	.000334	.000225	.000214
21	Livestock and Livestock Products	.008142	.008649	.013363	.000268	.000180	.000172
30	New Construction, Nonresidential Buildings	.004571	.007544	.011017	.000170	.000128	.000122
96	Communications except Radio & Television Broadcasting	.003871	.007316	.011186	.000200	.000135	.000129
107	Federal Government Enterprises	.003768	.005805	.008830	.000527	.000355	.000338
31	New Construction, Public Utilities	.001856	.004202	.006238	.000170	.000108	.000103
29	New Construction, Residential	.004485	.004068	.006393	.000170	.000094	.000090
105	Amusements	.003444	.003445	.005367	.000357	.000241	.000229
101	Real Estate and Rental	.002785	.003303	.005037	.000025	.000017	.000016
104	Automobile Repair & Services	.002403	.002637	.004011	.000163	.000110	.000105
108	State and Local Government Enterprises	.001463	.001846	.002808	.000232	.000156	.000149
35	Maintenance and Repair Construction, all other	.001370	.001600	.001643	.000080	.000047	.000045
37	Food and Kindred Products	.001165	.001526	.002922	.000013	.000011	.000013
41	Apparel	.000960	.001424	.002680	.000043	.000036	.000042
34	Maintenance and Repair Construction, residential	.000501	.001060	.002747	.000080	.000074	.000071
0	Other	.017558	.022961	.040990	0.000000	0.000000	0.000000

TABLE B-6

ENERGY PRODUCT SECTOR = 18: Space Heat

Sec. #	Sector Name	Energy Flows 10^{15} BTU			Energy Product Coefficients 10^{6} BTU/67 $		
		1967	1985	2000	1967	1985	2000
99	Wholesale and Retail Trade	.0689604	.853991	1.144628	.004256	.002750	.002288
106	Medical, Educ. Services & Nonprofit Inst.	.276167	.388743	.517686	.005694	.003680	.003061
102	Hotels & Lodging; Pers. & Repair Serv., except Auto Repair	.293854	.277716	.374060	.014124	.009129	.007594
108	State and Local Government Enterprises	.169691	.205347	.272920	.026930	.017406	.014479
103	Business Services	.133418	.188022	.249641	.002367	.001530	.001273
21	Livestock and Livestock Products	.176300	.179604	.242417	.005796	.003746	.003116
101	Real Estate and Rental	.123658	.140639	.187346	.001092	.000706	.000587
104	Automobile Repair and Services	.103778	.109218	.145102	.007037	.004548	.003784
100	Finance and Insurance	.080630	.105927	.140251	.001694	.001095	.000911
96	Communications except Radio & Television Broadcasting	.050119	.090848	.121349	.002594	.001677	.001395
107	Federal Government Enterprises	.037879	.055967	.074370	.005301	.003426	.002850
37	Food and Kindred Products	.034948	.042737	.063416	.000398	.000310	.000286
98	Water and Sanitary Services	.041990	.042316	.055926	.011784	.007616	.006336
49	Printing and Publishing	.021621	.028052	.041555	.000979	.000763	.000705
56	Rubber and Miscellaneous Plastics Products	.010082	.024565	.038089	.000742	.000578	.000535
83	Motor Vehicles and Equipment	.015871	.023287	.033665	.000368	.000287	.000265
62	Primary Nonferrous Metals Manufacturing	.007654	.023172	.045579	.000409	.000506	.000599
89	Railroads and Related Services	.023844	.021249	.028091	.001877	.001213	.001009
80	Radio, Television and Communications Equipment	.012957	.020121	.028942	.000783	.000610	.000564
41	Apparel	.014405	.019943	.029076	.000640	.000499	.000461
0	Other	.314101	.433245	.621646	0.000000	0.000000	0.000000

TABLE B-7

ENERGY PRODUCT SECTOR = 19; Air Conditioning

Sec. #	Sector Name	Energy Flows 10^{15} BTU			Energy Product Coefficients 10^{6} BTU/67 $		
		1967	1985	2000	1967	1985	2000
99	Wholesale and Retail Trade	.113292	.223511	.395392	.000699	.000720	.000790
106	Medical, Educ. Services & Nonprcfit Inst.	.038018	.085256	.149851	.000784	.000807	.000886
51	Plastics and Synthetic Materials	.022880	.068356	.113440	.002766	.002335	.002314
103	Business Services	.019803	.044462	.077914	.000351	.000362	.000397
100	Finance and Insurance	.019493	.040799	.071296	.000410	.000422	.000463
102	Hotels & Lodging; Pers. & Repair Serv., except Auto Repair	.019987	.030094	.053497	.000961	.000989	.001086
50	Chemicals and Selected Chemical Products	.011234	.022902	.043114	.000501	.000423	.000419
39	Broad and Narrow Fabrics, Yarn and Thread Mills	.015892	.020997	.032488	.001029	.000869	.000861
96	Communications Radio & Television Broadcasting	.005973	.017248	.030408	.000309	.000318	.000350
81	Electronic Components and Accessories	.007398	.016472	.027219	.000928	.000783	.000776
80	Radio, Television and Communications Equipment	.009316	.015675	.024171	.000563	.000475	.000471
107	Federal Government Enterprises	.005814	.013687	.024003	.000814	.000838	.000920
52	Drugs, Cleaning and Toilet Preparations	.005480	.012085	.019430	.000440	.000372	.000368
84	Aircraft and Parts	.011234	.011401	.017871	.000515	.000435	.000431
105	Amusements	.005314	.008122	.014590	.000551	.000567	.000623
101	Real Estate and Rental	.004298	.007788	.013692	.000038	.000039	.000043
38	Tobacco Manufacturers	.007398	.007643	.012048	.000935	.000789	.000782
37	Food and Kindred Products	.005343	.007079	.011261	.000061	.000051	.000051
47	Paper and Allied Products, except Containers and Boxes	.004110	.006419	.009983	.000268	.000227	.000225
104	Automobile Repair & Services	.003709	.006218	.010903	.000251	.000259	.000284
0	Other	.036704	.065182	.105128	0.000000	0.000000	0.000000

TABLE B-8

ENERGY PRODUCT SECTOR = 20: Electric Power

Sec. #	Sector Name	Energy Flows 10^{15} BTU			Energy Product Coefficients 10^{6} BTU/67 $		
		1967	1985	2000	1967	1985	2000
50	Chemicals and Selected Chemical Products	.280792	.694288	1.470264	.012513	.012809	.014279
62	Primary Nonferrous Metals Manufacturing	.195675	.469716	.868514	.010459	.010247	.011424
99	Wholesale and Retail Trade	.230771	.453457	.814497	.001424	.001460	.001628
106	Medical, Educ. Services & Nonprofit Inst.	.157734	.352300	.628731	.003252	.003335	.003718
61	Primary Iron and Steel Manufacturing	.176613	.291912	.495672	.005868	.007222	.008051
90	Local, Urban and Interurban Highway Pass. Trans.	.011180	.162853	.216697	.002042	.030601	.022089
47	Paper and Allied Products, except Containers and Boxes	.079558	.150700	.263635	.005197	.005320	.005930
37	Food and Kindred Products	.091000	.146243	.261706	.001035	.001060	.001182
56	Rubber and Miscellaneous Plastics Products	.034367	.110035	.205759	.002531	.002590	.002888
60	Stone and Clay Products	.050093	.094569	.170063	.004629	.004739	.005283
51	Plastics and Synthetic Materials	.024816	.089924	.167875	.003000	.003071	.003424
39	Broad and Narrow Fabrics, Yarn and Thread Mills	.052636	.084347	.146811	.003410	.003490	.003891
83	Motor Vehicles and Equipment	.043886	.082691	.144168	.000995	.001018	.001135
100	Finance and Insurance	.034632	.072193	.128096	.000728	.000746	.000832
108	State and Local Government Enterprises	.025000	.048002	.085498	.003968	.004069	.004536
43	Lumber and Wood Products	.024373	.046541	.070627	.002038	.002087	.002326
26	Nonferrous Metal Ores Mining	.013104	.043006	.081264	.010407	.010654	.011877
96	Communications except Radio & Television Broadcasting	.014371	.041332	.073986	.000744	.000763	.000850
101	Real Estate and Rental	.022855	.041244	.073628	.000202	.000207	.000231
77	Elec. Trans. & Dist. Eq. & Elec. Industry Apparatus	.016627	.039705	.071479	.001717	.001758	.001960
0	Other	.453592	.832471	1.466758	0.000000	0.000000	0.000000

Appendix C

BNL and DRI Sector Definitions

and

Energy, Output, and Energy per Unit of Output by BNL Sector Definitions

Table C-1

BNL and DRI Sector Classification Definitions

DRI Sector	BNL 110 Sector
Coal	1. Coal
Crude oil and gas	2. Crude oil and gas
	3. Shale oil
	4. Synthetic oil from coal
Refined oil	5. Refined Oil Products
Gas Utilities (Refined Gas)	6. Pipeline gas
	7. Methane from coal
Electricity	8. Coal combined cycle electric
	9. Other fossil electric
	10. LWR electric
	11. HTGR electric
	12. Hydroelectric

Table C-1 (Cont'd)

Sectorial Classification Definitions

DRI Sector	BNL 110 Sector	
Agriculture, Mining, & Construction	21	Livestock and livestock products
	22	Other agricultural products
	23	Forestry and fishery products
	24	Agricultural, forestry and fishery services
	25	Iron and ferroalloys ores mining
	26	Nonferrous metal ores mining
	27	Stone and clay mining and quarrying
	28	Chemicals and fertilizer mineral mining
	29	New construction, residential buildings
	30	New construction, nonresidential buildings
	31	New construction, public utilities
	32	New construction, highways
	33	New construction, all other
	34	Maintenance and repair construction, residential
	35	Maintenance and repair construction, all other
Manufacturing	36	Ordnance and accessories
	37	Food and kindred products
	38	Tobacco manufactures
	39	Broad and narrow fabrics, yarn and thread mills
	40	Misc. textile goods and floor coverings
	41	Apparel
	42	Misc. fabricated textile products
	43	Lumber and wood products, except containers
	44	Wooden containers
	45	Household furniture
	46	Other furniture and fixtures
	47	Paper and allied products except containers and boxes
	48	Paperboard containers and boxes
	49	Printing and publishing
	50	Chemicals and selected chemical products
	51	Plastics and synthetic materials
	52	Drugs, cleaning and toilet preparations
	53	Paints and allied products
	54	Paving mixtures and blocks
	55	Asphalt felts and coatings
	56	Rubber and miscellaneous plastics products
	57	Leather tanning and industrial leather products
	58	Footwear and other leather products
	59	Glass and glass products
	60	Stone and clay products
	61	Primary iron and steel manufacturing

Table C-1 (Cont'd)

62	Primary nonferrous metals manufacturing
63	Metal containers
64	Heating, plumbing and fabricated structural metal products
65	Screw machine prod., bolts, nuts, etc. & metal stampings
66	Other fabricated metal products
67	Engines and turbines
68	Farm machinery
69	Construction, mining, oil field machinery equipment
70	Materials handling machinery and equipment
71	Metalworking machinery and equipment
72	Special industry machinery and equipment
73	General industrial machinery and equipment
74	Machine shop products
75	Office, computing and accounting machines
76	Service industry machines
77	Elec. trans. & dist. eq. & elec. industry apparatus
78	Household appliances
79	Electric lighting and wiring equipment
80	Radio, television and communication equipment
81	Electronic components and accessories
82	Miscellaneous elec. machinery, equipment & supplies
83	Motor vehicles and equipment
84	Aircraft and parts
85	Other transportation equipment
86	Professional, scientific & controlling inst. & supp.
87	Optical, opthalmic, & photographic equip. & supp.
88	Miscellaneous manufacturing
Transportation (for hire)	
89	Railroads and related services
90	Local, suburban & interurban highway pass. trans.
91	Motor freight transportation and warehousing
92	Water transportation
93	Air transportation
94	Pipe line transportation
95	Transportation services
96	Communications except radio & television broadcasting
97	Radio and TV broadcasting
98	Water and sanitary services
99	Wholesale and retail trade

Table C-1 (Cont'd)

100	Finance and insurance
101	Real estate & rental
102	Hotels & lodging; pers. & repair serv., except auto repair
103	Business services
104	Automobile repair & services
105	Amusements
106	Medical, educ. services & nonprofit inst.
107	Federal government enterprises
108	State and local government enterprises
109	Business travel, entertainment & gifts
110	Office supplies

Table C-2

Total Primary Fuel Purchases by Interindustry Sector
(10^{15} BTU)

Sector	1967	1985	2000	1967-1985 Growth Rate %/Year	1985-2000 Growth Rate %/Year
21	.2965	.5143	.7227	3.1	2.3
22	.7212	.6938	1.1528	-0.2	3.4
23	.0383	.0611	.0782	2.6	1.6
24	.0099	.0093	.0149	-0.3	3.2
25	.0806	.1176	.1751	2.1	2.7
26	.0822	.2466	.4572	6.3	4.2
27	.1297	.2335	.3859	3.3	3.4
28	.1363	.3056	.5935	4.6	4.5
29	.3572	.2614	.4803	-1.7	4.1
30	.3637	.5393	.9205	2.2	3.6
31	.1478	.3048	.5232	4.1	3.7
32	.1132	.2434	.4134	4.3	4.1
33	.0991	.0723	.1144	-1.7	3.1
34	.0653	.1424	.4353	4.4	7.7
35	.1733	.2654	.3171	2.4	1.2
36	.0996	.0706	.1245	-1.9	3.8
37	1.1159	1.6124	2.7734	2.1	3.7
38	.0225	.0248	.0406	0.5	3.3
39	.3385	.5064	.8563	2.3	3.6
40	.0572	.1179	.1981	4.1	3.5
41	.0879	.1120	.2640	1.4	5.9
42	.0246	.0503	.0833	4.0	3.4
43	.2325	.4097	.5959	3.2	2.5
44	.0051	.0055	.0091	0.4	3.4
45	.0293	.0504	.0827	3.0	3.4
46	.0196	.0305	.0488	2.5	3.2
47	1.3362	2.2177	3.7425	2.8	3.6
48	.0647	.1149	.1931	3.2	3.5
49	.1030	.1818	.3020	3.2	3.4
50	3.3634	7.5172	15.1631	4.6	4.8
51	.6399	2.0540	5.0102	6.7	6.1
52	.1049	.2521	.4350	5.0	3.7
53	.0445	.0841	.1474	3.6	3.8
54	.2594	.6300	.9158	5.0	2.5
55	.2047	.3507	.0215	3.0	3.9
56	.2534	.4868	1.3660	3.7	7.1
57	.0207	.0035	.0055	-9.4	3.0
58	.0181	.0327	.0519	3.3	3.1
59	.2755	.4255	.6312	2.4	2.7
60	1.4039	1.8564	3.2111	1.6	3.7
61	2.6649	4.3999	7.5713	2.8	3.7
62	1.0560	2.4712	4.7033	4.8	4.4
63	.0323	.0611	.1052	3.6	3.7
64	.1170	.2808	.4596	5.0	3.3
65	.0931	.1030	.1682	0.6	3.3

Table C-2 cont'd.

Total Primary Fuel Purchases by Interindustry Sector
(10^{15} BTU)

Sector	1967	1985	2000	1967-1985 Growth Rate %/Year	1985-2000 Growth Rate %/Year
66	.1512	.2839	.4738	3.6	3.5
67	.0374	.1091	.1826	6.1	3.5
68	.0436	.0357	.1090	-1.1	7.7
69	.0642	.0985	.1560	2.3	3.6
70	.0116	.0278	.0445	5.0	3.2
71	.0567	.0815	.1311	2.0	3.2
72	.0324	.0603	.0959	3.5	3.1
73	.0634	.1291	.2099	4.0	3.3
74	.0395	.0645	.1088	2.8	3.5
75	.0227	.0638	.1120	5.9	3.8
76	.0280	.0878	.1471	6.6	3.5
77	.0870	.2044	.3534	4.8	3.7
78	.0544	.1115	.1933	4.1	3.7
79	.0343	.0943	.1551	5.8	3.4
80	.0702	.1457	.2362	4.1	3.3
81	.0638	.1704	.3022	5.6	3.9
82	.0272	.0577	.0992	4.3	3.7
83	.3030	.5522	.9281	3.4	3.5
84	.1351	.1649	.2772	1.1	3.5
85	.0536	.1034	.1806	3.7	3.8
86	.0276	.0598	.0950	4.4	3.1
87	.0221	.0882	.1048	8.0	1.2
88	.0466	.0883	.1428	3.6	3.2
89	.5822	.4543	.6715	-1.4	2.6
90	.2060	.6108	.8583	6.2	2.3
91	.4461	.4689	.6830	0.3	2.5
92	.6182	.3926	.5418	-2.5	2.2
93	1.1194	2.2618	3.1408	4.0	2.2
94	.0726	.0671	.0898	-0.4	2.0
95	.0014	.0039	.0060	5.8	2.9
96	.1275	.3633	.5499	6.0	2.8
97	.0285	.0351	.0574	1.2	3.3
98	.0800	.1324	.1892	2.8	2.4
99	2.5719	4.6103	7.2325	3.3	3.0
100	.2756	.5508	.8581	3.9	3.0
101	.2386	.4437	.6401	3.5	2.5
102	.7101	1.0268	1.5389	2.1	2.7
103	.2544	.5520	.7718	4.4	2.2
104	.5150	.3016	.4186	-2.9	2.2
105	.0669	.0930	.1557	1.8	3.5
106	1.0223	2.2397	3.5687	4.4	3.2
107	.0883	.2038	.3015	4.8	2.6
108	.2947	.5912	.8328	3.9	2.3
109	0.0	0.0	0.0	0.0	0.0
110	0.0	0.0	0.0	0.0	0.0

Source: BNL Combined IO/LP Runs of 5/8/75, 3/22/77.

Table C-3

Growth Rates in Non-Energy Total Output, by Sector: 1967-1985, 1985-2000 (%/Year)

Sector Number	1967-1985	1985-2000
21	2.6	3.3
22	3.0	3.7
23	5.0	2.5
24	1.6	3.7
25	2.5	2.1
26	6.7	3.6
27	3.9	2.9
28	5.2	4.0
29	2.8	3.4
30	4.5	2.9
31	7.3	3.0
32	-1.4	3.3
33	0.7	2.5
34	4.7	6.9
35	3.9	0.5
36	-1.7	3.4
37	2.5	3.2
38	1.1	3.1
39	2.5	3.0
40	4.5	3.0
41	3.2	3.1
42	4.1	3.1
43	3.5	2.1
44	0.4	2.9
45	2.7	3.1
46	2.5	2.8
47	3.5	3.1
48	3.5	3.1
49	2.9	3.2
50	5.0	4.4
51	7.3	3.5
52	5.5	3.3
53	3.9	3.6
54	5.5	2.5
55	3.4	3.9
56	6.5	3.5
57	-6.6	2.8
58	-1.1	2.7
59	3.0	2.2
60	3.5	3.2
61	1.7	2.9
62	5.1	3.4
63	3.9	3.2
64	5.1	2.9
65	0.7	2.9
66	3.9	3.0
67	6.5	3.1

Table C-3 cont'd.

Sector Number	1967-1985	1985-2000
68	1.4	4.4
69	2.6	2.8
70	5.0	2.9
71	2.0	2.9
72	3.5	2.8
73	4.1	2.9
74	2.7	3.1
75	5.6	3.5
76	6.7	3.1
77	4.8	3.3
78	4.3	3.3
79	5.8	3.0
80	3.9	3.0
81	5.5	3.5
82	4.4	3.2
83	3.6	3.0
84	1.0	3.1
85	4.0	3.2
86	3.8	3.3
87	5.9	3.4
88	3.4	3.0
89	1.8	3.1
90	0.9	4.2
91	3.7	3.0
92	1.0	2.6
93	7.8	2.7
94	0.4	1.9
95	5.2	2.9
96	5.9	3.2
97	1.1	3.2
98	2.5	3.1
99	3.7	3.2
100	4.0	3.1
101	3.2	3.2
102	2.1	3.3
103	4.4	3.2
104	2.7	3.2
105	2.2	3.3
106	4.4	3.2
107	4.7	3.2
108	3.5	3.2
109	3.2	3.1
110	1.7	3.3

Source: BNL Combined I/O-LP model runs 5/8/75, 3/22/77

Table: C-4

Growth Rates of Energy Input per Unit of Output by Interindustry Sector
(%/Yr)

Sector	1967-1985 Growth Rate	1985-2000 Growth Rate	Sector	1967-1985 Growth Rate	1985-2000 Growth Rate
21	0.5	-1.0	66	-0.3	0.5
22	-3.2	-0.3	67	-0.4	0.4
23	-2.4	-0.9	68	-2.5	3.3
24	-1.9	-0.5	69	-0.3	0.4
25	-0.4	0.6	70	0.0	0.3
26	-0.4	0.6	71	0.0	0.3
27	-0.6	0.5	72	0.0	0.3
28	-0.6	0.5	73	-0.1	0.4
29	-4.5	0.7	74	0.1	0.4
30	-2.3	0.7	75	0.3	0.3
31	-3.2	0.7	76	-0.1	0.4
32	5.7	0.8	77	0.0	0.4
33	-2.4	0.6	78	-0.2	0.4
34	-0.3	0.8	79	0.0	0.4
35	-1.5	0.7	80	0.2	0.3
36	0.2	0.4	81	0.1	0.4
37	-0.4	0.5	82	-0.1	0.5
38	-0.6	0.2	83	-0.2	0.5
39	-0.2	0.6	84	0.1	0.4
40	-0.7	0.5	85	-0.3	0.6
41	-1.8	2.8	86	0.6	0.2
42	-0.1	0.3	87	2.1	-2.2
43	-0.3	0.4	88	0.2	0.2
44	0.0	0.5	89	-3.2	-0.5
45	0.3	0.3	90	5.3	-1.9
46	0.0	0.4	91	-3.4	-0.5
47	-0.5	0.5	92	-3.5	-0.4
48	-0.3	0.4	93	3.8	-0.5
49	0.3	0.2	94	-0.8	0.1
50	-0.4	0.4	95	0.6	0.0
51	-0.6	2.6	96	0.1	-0.4
52	-0.5	0.4	97	0.1	0.1
53	-0.3	0.2	98	0.3	-0.7
54	-0.5	0.0	99	-0.4	-0.2
55	-0.4	0.0	100	-0.1	-0.1
56	-2.8	3.6	101	0.3	-0.7
57	-2.8	0.2	102	0.2	-0.6
58	4.4	0.4	103	0.0	-1.0
59	-0.6	0.5	104	-5.6	-1.0
60	-1.9	0.5	105	-0.4	0.2
61	1.1	0.8	106	0.0	0.0
62	-0.3	1.0	107	0.1	-0.6
63	-0.3	0.5	108	0.4	-0.9
64	-0.1	0.4	109	-3.2	-3.1
65	0.1	0.4	110	-1.7	-3.3

Source: Tables C-2, C-3.