BNL 50608

MASTER

INPUT-OUTPUT CAPITAL COEFFICIENTS FOR ENERGY TECHNOLOGIES

RAYMOND G. TESSMER, JR.

December 1976

Prepared for the
ADMINISTRATOR FOR PLANNING, ANALYSIS, AND EVALUATION
UNITED STATES ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

ECONOMIC ANALYSIS DIVISION
NATIONAL CENTER FOR ANALYSIS OF ENERGY SYSTEMS

BROOKHAVEN NATIONAL LABORATORY
ASSOCIATED UNIVERSITIES, INC.
UNDER CONTRACT NO. EY-76-C-02-0016 WITH THE
UNITED STATES ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

DISCLAIMER

BNL 50608
[General, Miscellaneous, and
Progress Reports (Nonnuclear) - TID-4500]

INPUT-OUTPUT CAPITAL COEFFICIENTS FOR ENERGY TECHNOLOGIES

RAYMOND G. TESSMER, JR.

December 1976

Prepared for the
ADMINISTRATOR FOR PLANNING, ANALYSIS, AND EVALUATION
UNITED STATES ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

ECONOMIC ANALYSIS DIVISION
NATIONAL CENTER FOR ANALYSIS OF ENERGY SYSTEMS

BROOKHAVEN NATIONAL LABORATORY
UPTON, NEW YORK 11973

Printed in the United States of America
Available from
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road
Springfield, VA 22161
Price: Printed Copy $4.00; Microfiche $3.00

January 1977 260 copies

Abstract

Input-output capital coefficients are presented for five electric and seven non-electric energy technologies. They describe the durable goods and structures purchases (at a 110 sector level of detail) that are necessary to expand productive capacity in each of the twelve sectors. Coefficients are defined in terms of 1967 dollar purchases per 10^6 Btu of output from new capacity, and original data sources include Battelle Memorial Institute, the Harvard Economic Research Project, The Mitre Corp., and Bechtel Corp.

Table of Contents

List of Tables

I. Introduction

An input-output model of the United States organizes a mass of factual data to describe the interworkings of the economy. It is particularly useful for estimating detailed production, employment and capital requirements to meet a forecasted level of Gross National Product (GNP), or final demand. Brookhaven National Laboratory and the University of Illinois have expanded the capability of such of model to answer many energy policy questions by adding an optimization model of the nation's energy system. (1) A key feature is expansion of productive energy sectors from five to twelve, and measurement of their output in physical units (British Thermal Units, or Btu) instead of in dollars. The 110 sectors of the Energy Input-Output Model are listed in Table 1.

One element of the GNP forecast that drives the I-O model is Gross Private Capital Formation (or sales to business on capital account). This must be specified at the 110 sector level of detail. After solving the model, one can check the accuracy of this forecast with the aid of a capital coefficient matrix. Such a matrix is composed of a column, or vector, of coefficients for each sector which describes all capital purchases required to support a unit expansion in output. With this matrix one can determine whether or not the estimate of capital formation is sufficient to support the increase in sectoral levels of production (from the model solution) over those of a prior year plus replacement of worn out capacity.

The purpose of this report is to present a consistent set of capital coefficients for each of the twelve energy sectors in the Energy Input-Output Model. To handle both traditional and emerging energy technologies, four basic data sources are used--Fisher and Chilton (2), Just (3), Istvan (4), and Bechtel Corp. (5). The problems encountered in combining and reconciling these data sources lead to a set of recommendations that can improve the usefulness of future capital coefficient estimates.

II. Methodology and Data Comparability

The basic capital coefficient matrix used in the BNL model was developed by Fisher and Chilton at Battelle Memorial Institute (2). Non-energy Battelle sectors correspond directly to or are simple disaggregations of BNL sectors, as shown in Table 1. Upon aggregating where necessary and inflating from 1958 to 1967 dollars,* they can be directly used in BNL's model. Non-energy sector coefficients are expressed in terms of 1967 $/1967 $.

Battelle coefficients are also the basis for four of the energy sectors--coal, crude oil and gas, refined oil products, and pipeline gas. Since our model expresses the output of these sectors in Btu's, capital coefficients are converted to units of 1967 $/$10^6$ Btu output** by multiplying by the average 1967 price of each fuel form, expressed in $/$10^6$ Btu.

Coefficients developed by James Just at The Mitre Corporation (3) are used for the other three non-electric energy sectors-shale oil, methane from coal, and solvent refined coal. Coefficients are estimated from pilot plant and technical data sources, and they are presented in terms of 1967 $/$10^6$ Btu. In certain cases they have been rescaled to reflect a different plant operating factor or a different measurement definition for output Btu.

Now, the sum of each capital coefficient vector equals the capital/output ratio for that sector. Just does not

---

*Inflators are from the U.S. Bureau of Labor Statistics, Washington, D.C.

**All capital purchases are from non-energy sectors; so the numerators of all coefficients are always measured in dollar terms in the BNL model.

Table 1

Cross Classification of Energy Input-Output Model Sectors

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	-	-	-	-	-
4	Methane from coal	3	-	-	-	-
5	Solvent refined coal	-	-	-	-	-
6	Refined oil products	4	31.01	part 31	part 41	part 42
7	Pipeline gas	5	68.02	68.2	93	102
8	Coal combined cycle electric	-	-	-	-	-
9	Other fossil electric	6	68.01			
10	LWR electric	7	68.01	68.1	92	101
11	HTGR electric	-	-			
12	Hydroelectric	8	68.01			
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		11.01	11.1	11	12
30	New construction, nonresidential buildings		11.02	11.2	12	13
31	New construction, public utilities	25	11.03	11.3	13	14
32	New construction, highways		11.04	11.4	14	15
33	New construction, all other		11.05	11.5	15	16
34	Maintenance and repair construction, residential	26	12.01	12.1	16	17
35	Maintenance and repair construction, all other		12.02	12.2	17	
36	Ordnance and accessories	27	13	13	18	18-19
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 38
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	
59	Glass and glass products	50	35	35	47	46
60	Stone and clay products	51	36	36	48	47-48
61	Primary iron and steel manufacturing	52	37	37	49	49-50
62	Primary nonferrous metals manufacturing	53	38	38.1 38.2 38.3	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 prod., 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, opthalmic, & 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	
96	Communications except radio & television broadcasting	87	66	66	90	99
97	Radio and TV broadcasting	88	67	67	91	100
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.

deflate the components of his vectors which represent certain labor and interest payments during construction. Capital/output (K/O) ratios estimated by the Bechtel Corporation (5) are therefore used in conjunction with Just's coefficients. The difference between a Bechtel K/O ratio and the sum of Just's coefficients for each energy technology is added to the capital coefficient for sector 30, new construction/nonresidential buildings, in accordance with Bureau of Economic Analysis (BEA) accounting procedures. For example, even if a public utility uses its own employees to install a steam turbine in a new plant and directly pays for interest during construction, BEA reassigns these payments to a construction sector and treats them as purchases by a construction sector instead of a public utility sector. The sum of each adjusted capital vector thus equals the K/O ratio estimated by Bechtel for these three non-electric sectors.

These three sectors are different from all other I-O sectors in that no administrative or management functions are included. They are strictly defined for a specific technological process. The way in which the BNL model picks up all overhead functions is by having them sell all their output to traditionally defined I-O sectors, gas utilities (called "pipeline gas" in the BNL model), or refined oil products.

Rudyard Istvan's work for the Harvard Economic Research Project forms the basis for defining five electric utility sectors in our model. He has taken the traditional electric utility I-O sector and disaggregated it into seven "processes"-fossil steam generating plants, hydroelectric generating plants, nuclear electric plants, electrical peaking facilities (internal combustion engines and gas turbines), electrical transmission facilities, electrical distribution facilities, and administrative overhead. Istvan's capital coefficients for the latter three processes, TD&A, are applied to all five BNL electric sectors. His hydroelectric vector is added to TD&A to form BNL's hydtroelectric sector, and his fossil and peaking vectors are added to TD&A to form BNL's fossil electric sector.

For BNL's light water reactor (LWR) electric sector and high temperature gas-cooled reactor (HTGR) electric sector, Just's capital coefficients for an LWR plant and an HTGR plant are added to Istvan's TD&A coefficients. As before, rescaling is required in order to account for a different plant operating factor than that assumed by Just. Also, an addition is made to each of Just's capital coefficients for sector 31-new construction, public utilities. The adjusted vectors then sum to the K/O ratios for LWR and HTGR plants as estimated by Bechtel Corporation.

The coal combined cycle electric sector combines Just's coefficients for low Btu coal gasification and the combined cycle power plant with Istvan's TD&A coefficients. Again, Just's coefficients are rescaled to different plant operating factors and aligned to Bechtel's K/O ratios for these two processes by increasing the capital coefficients for sector 31-new construction, public utilities.

In assembling data from several data sources it was found that differing procedures and classification schemes reduced comparability of the estimates. The level of detail varies considerably, with Just providing the most extensive disaggregation of capital purchases. In contrast to U.S. Bureau of Economic Analysis (BEA) accounting conventions, Istvan and Just break out value added payments of each energy industry (i.e., its own labor and interest during construction) and do not reassign them to purchases from a construction sector. This would be extremely useful for a dynamic I-O model requiring both current and capital inputs to capital formation. But non-energy sector capital formation has not been treated in this fashion by any modeller; so it cannot be used. The problem, then, lies in restructing production functions for "new construction" sectors to accurately reflect those other capital inputs not identified by the detailed capital coefficients. Neither Just, Istvan or Bechtel have done this. As shown in Table 2, a large portion of capital purchases still remains in two new construction sectors which are not technology-specific.*

Another serious problem with some of the data sources is that of deflation. With Istvan and Just it is a problem with the value added payments of the energy industries-those that should be reallocated to new construction for comparability with Battelle and BEA conventions. Istvan's data must be inflated from 1958 to 1967 dollars for our model, and Just's data must be deflated from 1971 or 1973 to 1967 dollars. The problem is serious enough that aggregate capital/output ratios cannot be computed and seriously compared. Between the times

*Data shown is from capital coefficients developed in later sections of this report.

Table 2

Construction Inputs to Capital Formation, 1967 $\$/10^6$ Btu

Energy Sector	New Construction, Non-Res Bldgs Input	New Construction, Public Utility Input	Other Inputs	Total K/O Ratio
Coal	0.02		0.23	0.25
Crude Oil and Gas	0.01		0.56	0.57
Shale Oil	4.3	0.1	1.1	5.5
Methane from Coal	4.7		1.0	5.7
Solvent Refined Coal	5.1		0.6	5.7
Refined Oil Products	.6		0.2	0.8
Pipeline Gas		1.4	0.5	1.9
Coal Combined Cycle Electric		30.5	8.8	39.3
Fossil Electric		13.4	13.6	27.0
LWR Electric		18.0	12.6	30.6
HTGR Electric		17.2	13.4	30.6
Hydroelectric		19.2	8.5	27.7

that Istvan and Just developed their coefficients, there were large increases in short term interest rates and the price of labor, lengthening construction schedules, and significant design changes in plants due to such things as pollution control equipment and new federal regulations. The data they present provides no basis for separating real effects (say, increased interest payments due to longer construction times) from monetary effects (say, increased interest rates). The problem is just as great with Bechtel data where everything is expressed in 1975 dollars and not deflated to either 1967 or 1972 dollars. Although capital estimates of Bechtel may be the most recent, it is extremely difficult to judge what they represent in terms of real shifts in capital formation from a statistical base year and in terms of purely inflationary effects. This capital information is for energy sectors only, and it must be combined with non-energy sector information estimated in prior year dollars (1958 or 1967). The 1967 aggregate capital output ratios developed in this report are, thus, very arbitrary and should be subject to close scrutiny in future research on capital formation.

Finally a limitation of the coefficients imposed by the plant factor assumptions must be noted. Specific plant factors are assumed for each energy sector. If any one is changed, the entire column of capital coefficients should be renormalized. In the electric sectors for example, all plants except internal combustion and gas turbine peaking plants have plant factors of 55%. This presumes a normal utility reserve margin of about 20%. Also, although one might assume that all nuclear plants will be base loaded with, say, a 65% plant factor, nuclear and fossil plants are treated alike in order to prevent bias in comparative analyses of the two. Options with respect to plant factors could be incorporated into the I-O model, but it was felt that data uncertainty and the way in which the model was to be used did not warrant such complexity.

III. Capital Coefficients for Non-Electric Sectors

Estimates of Fisher and Chilton (2) are used for four non-electric sectors -- coal, crude oil and gas, refined oil products, and pipeline gas. Presented in 1958 dollars, they are inflated to 1967 dollars with a set of inflators supplied by the U.S. Bureau of Labor Statistics. They are then renormalized to a Btu output basis by multiplying by implicit I-O prices for each fuel. Each fuel price was calculated by dividing total sectoral output in dollar terms as reported by BEA (6) by total sectoral output in Btus as estimated by Bullard (7). The calculated prices are:

coal	.2137	67$/$10^6$ Btu
crude oil and gas	.3541	"
refined oil products	.9892	"
pipeline gas	.7629	"

Capital coefficients are presented in Table 3, with the sum of coefficients in each column equaling the capital/output ratio for that sector.

Coefficients for the other three non-electric sectors are also listed in Table 3 -- shale oil, methane from coal, and solvent-refined coal. These data have been estimated by Just (3) from engineering and pilot plant studies.

Shale oil coefficients in the table have been rescaled from a 100% to a 90% plant factor and from a shale oil input Btu basis to a shale oil output Btu basis for conformity with the output unit of measurement in the Energy I-O Model. Just's coefficients for methane from coal are used without modification.

TABLE 3

Capital Coefficients for Non-Electric Energy Sectors, 1967 $\$/10^6$ Btu

BNL Sector	Shale Oil	Methane From Coal	Solvent Refd. Coal	Coal	Crude Oil & Gas	Refined Oil Prds.	Pipeline Gas
27	.001838						
30	4.305273	4.704733	5.128309	.023712	.006907	.577212	.043176
31	.085740					.002282	1.406063
33	.021300			.007006	.465705		
40	.000010			.000076	.000024		.000049
43	.000001			.000007	.000002	.000741	.000005
45	.000012			.000120	.000038		.000075
46	.000272			.002855	.000900	.000240	.001803
50	.055673	.015076	.012173				
56	.002347			.001313	.000507		.003650
58	.000001			.000025	.000008		.000016
60	.036290	.002104	.016012			.002095	
63					.000019	.000179	
64	.264997	.447364	.109078	.016867	.006517	.029584	.046880
66	.165520	.121554	.067166	.001792	.004181	.008514	.016133
67	.057581	.052683	.028483	.004879	.005313	.002968	.010609
69	.063882	.026738	.007405	.083078	.029948	.000046	.037054
70	.049447	.015144	.017430	.009987	.003859	.006709	.027758
71	.000365	.000891		.001755	.000235	.000838	.005889
72	.000498	.000934		.001403	.001674	.062861	.006160
73	.114140	.150118	.130038	.011822	.004568	.045281	.034522
75	.002973			.002064	.006490	.011100	.011139
76	.004393	.022117		.004198	.002908	.004118	.006914
77	.081003	.058900	.009482	.003738	.004712	.016504	.123694
79	.018753	.003332	.057100	.000076	.000096	.000234	.002515
80	.001866				.000903	.000790	.000552
81					.000012		
82	.000477			.000148	.000186	.000481	.004890
83	.012202			.029431	.001359	.012557	.003925
84	.009865				.000704		.000077
85	.000217			.017933	.001772	.000056	.001203
86	.020868	.013854	.034216	.001118	.001287	.020350	.025179
87	.000099			.000848	.000269	.002072	.001872
88	.004454			.006089	.002353		.016924
89	.008058	.007393	.003759	.001472	.001277	.006261	.003220
91	.011232	.010700	.005441	.001549	.001478	.015582	.006118
92	.000408	.000389	.000198	.000026	.000026	.000093	.000079
93	.000996	.000973	.000495	.000013	.000011	.000241	.000068
95	.000011			.000017	.000018	.000464	.000227
99	.076390	.065684	.043396	.016355	.010908	.003944	.048666
100			.008102				
101		.000281					
103		.002021	.044700				
Total (K/O Ratio)	5.479452	5.722983	5.722983	.251772	.567173	.834397	1.897104
Assumed Plant Factor	90%	90%	90%	--	--	--	--

They are derived in terms of high Btu coal gas output and a 90% plant factor. Just's coefficients for solvent refined coal are rescaled to reflect a 90% instead of a 91% plant factor.

If one adds up Just's coefficients, the sums are significantly less than the capital/output ratio for each process. This is because value added payments have not been deflated to 1967 dollars and reallocated as inputs from the new construction, non-residential buildings sector. Rather than attempt to do this from Just's data, the decision was made to use more recent K/O ratio estimates of Bechtel Corp.(5):

shale oil plant capital cost	$\$900 \times 10^6$ (75\$), 250×10^9 Btu/day crude
coal gasification plant capital cost	$\$940 \times 10^6$ (75\$), 250×10^9 Btu/day gas
coal liquefaction plant plant capital cost	$\$940 \times 10^6$ (75\$), 250×10^9 Btu/day crude.

These are deflated to 1967 dollars with the Handy-Whitman electric light and power construction cost index (1967=100, 1975=200).* Use of this index is somewhat arbitrary, but it is about equal to the average of Engineering News Record cost indices for buildings and construction. Each resulting Bechtel K/O ratio is shown in Table 4, along with the total for Just's coefficients and the increase that must be added to sector 30, new construction, non-residential buildings.

---

*U.S. Bureau of Domestic Commerce, "Construction Review."

Table 4

Non-Electric Capital Coefficient Adjustments, 1967$/$10^6$Btu

	Sum of Just's K/O Coefficients	Adjustment to Sector 30	Bechtel K/O Ratio
Shale Oil	1.606835	3.872617	5.479452
Methane from Coal	1.157510	4.565473	5.722983
Solvent Refined Coal	.882458	4.840525	5.722983

IV. Capital Coefficients for Electric Sectors

Because Battelle estimates capital coefficients for only a single electric utility sector, their data cannot be used in the Energy Input-Output Model which includes five such sectors. Estimates of Just and Istvan are therefore used. Power plant information for three sectors is taken from Just's work, while power plant information for two sectors plus transmission, distribution and administration information for all five electric sectors is taken from Istvan.

The seven "processes" into which Istvan disaggregates the electric utility sector are fossil steam generating plants, hydroelectric generating plants, nuclear electric generating plants, electrical peaking facilities (internal combustion engines and gas turbines), electrical transmission facilities, electrical distribution facilities, and administrative overhead. The first step in using his 1980 projection is to convert capital process proportional distributions (4, pp. 60-62) from 1958 to 1967 dollars, using price deflators from the U.S. Bureau of Labor Statistics. Each of the seven proportional distribution vectors break out relative purchases from each I-O sector for one dollar of total capital expenditure.* They are inflated by multiplying each coefficient by the inflator for the sector from which the capital purchase was made and by dividing each coefficient by the relative price of electricity in 1967 versus 1958 (assumed to be 1.0, indicating no change in the price of output from

*Capital coefficients are calculated from the proportional distributions by multiplying each vector by that process's capital/output ratio.

electric utilities over this time period). For value added coefficients, a price inflator of 1.144 is used,* for lack of a better figure. The coefficients in each vector are then renormalized, or divided by their sum, so that they again sum to 1.0 and represent a proportional breakdown of one 1967 dollar of capital expenditure. They are listed in Table 5.

Istvan does not present capital/output ratios for his seven process vectors; so appropriate ones must be calculated from the breakdown of capital expenditures by process which he envisions for 1980 (4, p. 65). Calculations are shown in Table 6. Investment in the four types of power production is estimated first using the capital cost (suitably deflated) and capacity addition estimates of Istvan. This represents 49.05% of capital investment; so total 1980 investment can be estimated as 19.0511 x 10^9 1967 dollars. Allocation of this total to transmission, distribution, and administration is then made on the basis of Istvan's proportional split as shown in the first column of Table 6. His 1980 capacity addition assumptions (in kW) are converted to annual Btu's of generated electricity by assuming a 55% load factor for fossil, nuclear, and hydro plants and a 10% load factor for peaking plants. Capital/output ratios in terms of 1967 $/$10^6$ Btu are then calculated directly. For T, D & A, the total annual output from the four power types is used as the divisor. The 55% load factor presumes excess reserve capacity of about 20%. Although one might expect nuclear plants to always be base loaded and to have a higher load factor than 55%, the same factor is used for all three in order to avoid bias in studies which com-

*This is the BLS price inflator for sector 31, new construction, public utilities.

TABLE 5

Capital Process Proportional Distributions for Electric Utilities, 1967 $/1967 $

BNL Sector	Fossil Steam	Nuclear Steam	Hydro-Electric	Peaking Facilities	Trans-Mission	Distri-Bution	Adminis-Tration
31	.153868	.222348	.417775	.004358	.191817	.248717	.476469
40	--	--	--	--	--	--	.004880
43	--	--	--	--	.032657	.029069	.019154
45	--	--	--	--	--	--	.001590
46	.000256	.002258	.013607	--	--	--	.031737
47	--	--	--	--	--	.003021	--
51	--	.000125	--	--	--	--	--
60	--	--	--	--	.004302	.005391	--
61	--	--	--	--	.010608	.003859	--
62	--	--	--	--	.065536	.055857	--
64	.267511	.180699	--	.003169	.035947	.013822	.009184
66	.071608	.017089	.001730	.024659	.002315	.002789	.000219
67	.084245	.163253	.166684	.582257	--	--	.003171
69	--	--	--	--	--	--	.031335
70	.004517	.002106	.010413	.000028	--	--	.009751
71	.001490	.000419	--	--	--	--	.020132
72	--	.023586	--	--	--	--	--
73	.062317	.023711	.004355	.011208	.000834	.000125	.005401
74	--	--	--	--	--	--	.001014
75	--	--	--	--	--	--	.010728
76	--	.002686	--	--	--	--	.003509
77	.084501	.032162	.009863	.216305	.099656	.201255	.040793
79	.006053	.009183	.000665	.008845	.020231	.045644	.002869
80	.000338	--	--	.000074	.008532	.016094	.084547
81	--	--	--	--	--	--	.001279
82	--	--	--	--	.002191	.000143	--
83	--	--	--	--	--	--	.119318
84	--	--	--	--	--	--	.008389
86	--	.007005	--	--	--	--	.008334
89	.012794	--	.003586	.015499	.007331	.009468	.017165
91	.018518	--	.005191	.022432	.010610	.013704	.024844
92	.000673	--	.000189	.000816	.000386	.000498	.000903
93	.001684	--	.000472	.002039	.000964	.001246	.002258
99	.008175	--	.002608	.012293	.009925	.011095	.011770
100	--	.012368	--	--	--	--	--
101	.000073	.000187	.006147	.000202	.001812	.000383	.000841
102	--	.000143	--	--	--	--	--
103	.004755	.051169	.002430	.000156	.028648	.005382	.002586
Value Added	.216624	.249503	.354285	.095660	.465698	.332438	.045830
Total	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000

Table 6

Capital/Output Ratios for Istvan's Electric Process Vectors

Type	Proportion of Total Investment	Capital Cost, * 1967 $/kw	1980 Capacity Addition, 10^6kw	Investment, 10^9 1967 $	Annual Output, 10^{15} Btu	K/O Ratio, 1967 $/$10^6$ Btu
Power Production	.4905					
fossil		155.1	15.0	2.3265	.2466	9.4349
nuclear		216.2	25.0	5.4050	.4110	13.1517
hydro		244.4	5.7	1.3931	.0937	14.8671
peaking		84.6	2.6	.2200	.0078	28.3046
Transmission	.1997			3.8045	.7590	5.0123
Distribution	.2767			5.2714	.7590	6.9449
Administration	.0331			.6306	.7590	.8308
Total	1.0000			19.0511		

*Istvan's estimates (1968 $) deflated by the Handy-Whitman public utility, electric light & power price index, 0.94.

pare alternative power production types.

Capital coefficients for the seven processes can now be calculated using the proportional breakdowns presented in Table 5 and the K/O ratio in Table 6, with the value added coefficients reassigned to sector 31. The T, D, & A coefficients are added together to form a general overhead vector for use with any power production vector, and this is listed in Table 7.

Fossil and peaking coefficients are combined for use in the single BNL sector 9 and in the ratio of .863 fossil, .137 peaking. This is based on the "Electrical World" forecast for new additions of these two plant types between 1976 and 1995. (7) The combined coefficients for fossil and peaking plants are listed in Table 7 as well as the calculated capital coefficients for hydroelectricity.

The remaining three sets of power production coefficients - LWR, HTGR, and Coal Combined Cycle - come from Just. (3) Nuclear coefficients from Just are used in place of Istvan's because they are more recent and are derived in much greater detail.* Just's coefficients are rescaled to a 55% plant factor, and the coal combined cycle coefficients presented in Table 7 combine his low Btu coal gas vector and his combined cycle power plant vector.

Just does not present deflators for value added components of capital construction (interest during construction, labor supplied by the energy industries, etc.); so one cannot easily

---

*The LWR capital coefficient for sector 50 is adjusted upward by 1.494374 1967$/$10^6$ Btu, and the HTGR capital coefficient for sector 50 is adjusted upward by 1.717671 1967 $/$10^6$ Btu, to account for initial fuel cores.

TABLE 7

Capital Process Coefficients
for Electric Utilities, 1967 $/10^6 Btu

BNL Sector	Tran, Distr & Admin	Fossil & Peaking	Hydro-Electric	LWR Electric	HTGR Electric	Coal CMBND Cycle
22				.000092	.000093	
24				.000093	.000148	
27				.000560	.000962	
31	7.765640	3.404496	11.478277	2.543670	3.903821	.941163
33						.192688
36				.001537		
39					.000053	
40	.004054				.000032	
43	.381481			.003264	.005343	
45	.001321					
46	.026366	.002084	.202296	.016179	.003352	.000852
47	.020981			.000087	.000295	
50				1.494481	1.717671	
51					.000678	
53				.001632	.003215	
54				.000563	.000760	
56				.000821	.001677	
59				.000071	.000120	
60	.059003			.031692	.530695	.130653
61	.079971			.021471	.383504	
62	.716407			.061320	.220254	.017716
64	.283799	2.190443		1.107020	.611117	.537947
65				.000135	.000215	
66	.031155	.678674	.025720	.611660	.763196	.195639
67	.002634	2.943766	2.478104	.816298	.798429	.911179
69	.026032			.000065	.000107	.004950
70	.008101	.036887	.154811	.035711	.191783	.014576
71	.016725	.012132				.001808
72				.203469	.216982	
73	.009535	.550865	.064746	.981144	.964510	.148473
74	.000842			.000058	.000096	
75	.008913			.084106	.135802	.012512
76	.002915				.030372	
77	1.931094	1.526798	.146634	.561906	.835912	.601688
78					.000055	
79	.420781	.083584	.009887	.125244	.054604	.142167
80	.224776	.003039		.000871	.002533	.001911
81	.001279				.011919	
82	.011968			.000707	.000122	
83	.099127					
84	.006969					
86	.006924			.121178	.215528	.025711
88				.000531	.000793	.000672
89	.117454	.164273	.053313	.032298	.053276	.015795
91	.168993	.237764	.077175	.046747	.091947	.022861
92	.006144	.008644	.002810	.001700	.002903	.000831
93	.015361	.021618	.007017	.004250	.006880	.002078
96				.000493	.000791	
99	.136579	.114232	.038773	.341104	.477201	.148305
100				.000714	.001124	.106053
101	.012441	.001378	.091388	.851876	.001382	
103	.183118	.039322	.036127	.002103	.003559	.487674
104				.000535	.000889	
106				.000115	.000179	
107				.000040	.000068	
108				.000042	.000065	
109				.000834	.001301	
110				.000426	.000066	

calculate K/O ratios for his processes. Instead, Bechtel estimates are used as controls with the difference between the sum of Just's capital coefficients and the deflated Bechtel K/O ratio added to the capital coefficient for sector 31, new construction, public utilities. The Handy-Whitman public utility electric-light and power index* is used to deflate Bechtel ratios from 1975 to 1967 dollars.

This adjustment scheme is the same as that used for Just's three non-electric process vectors in section III. Bechtel K/O ratios are also used as a control on the fossil and peaking vector derived from Istvan. Here it is assumed that new fossil plants will be 70% coal-fired and 30% oil-fired. Bechtel's K/O ratio for a hydroelectric plant is not used as a control, however, because it is lower than their K/O ratio for coal steam electric plants. Historically, capital costs for hydroelectric plants have been higher than for fossil-fired plants. Table 8 shows the addition to the capital coefficient for sector 31 that is made in order for the sum of the capital coefficients to equal Bechtel's K/O ratio for each electric generation vector.

Table 8

Adjustment to Electric Generation Vectors, 1967 $\$/10^6$ Btu

	Bechtel K/O Ratio	Sum of Just or Istvan Coefficients	Adjustment to Sector 31 Purchases
fossil electric	14.2302	12.0201	2.2101
LWR electric	17.7930	10.1109	7.6821
HTGR electric	17.7930	12.2564	5.5366
Coal Combined Cycle	26.4798	4.6659	21.8139

*This price index for 1975 versus 1967 is 2.0.

The final capital/output coefficients for the five electric sectors are listed in Table 9. Here, the T, D, & A coefficients in Table 7 have been added to each of the five electric generation vectors in that table. Also, coefficients for sector 31 have been adjusted upward by the amounts shown in Table 8. The sums shown at the bottom of each column are the estimated K/O ratios for that sector.

A check can be made on the reasonableness of these ratios by comparing them with Battelle's single forecasted 1975 K/O ratio for the electric utility sector. Their ratio, inflated to 1967 dollars and converted to a Btu basis by the implicit 1967 I-O price of electricity (4.74 1967 $/10^6$ Btu), is 28.19 1967 $/10^6$ Btu. The estimates developed in this report are right in the same ballpark; so there should be good conformity between energy sector capital requirements estimated with these coefficients and non-energy sector capital requirements estimated with Battelle coefficients.

TABLE 9

Capital Coefficients for Electric Sectors, 1967 $/10⁶ Btu generated electricty

BNL Sector	Fossil Electric	Hydro-Electric	LWR Electric	HTGR Electric	Coal CMBND Cycle
22			.000092	.000093	
24			.000093	.000148	
27			.000560	.000962	
31	13.380265	19.243917	17.991453	17.206135	30.520687
33					.192688
36			.001537		
39				.000053	
40	.004054	.004054	.004054	.004086	.004054
43	.381481	.381481	.384745	.386824	.381481
45	.001321	.001321	.001321	.001321	.003121
46	.028450	.228662	.042545	.029718	.027218
47	.020981	.020981	.021068	.021276	.020981
50			1.494481	1.717671	
51				.000678	
53			.001632	.003215	
54			.000563	.000760	
56			.000821	.001677	
59			.000071	.000120	
60	.059003	.059003	.090695	.589698	.189698
61	.079971	.079971	.101442	.463475	.079971
62	.716407	.716407	.777727	.936661	.734123
64	2.474242	.283799	1.390819	.894916	.821746
65			.000135	.000215	
66	.709829	.056875	.642815	.794351	.226794
67	2.946400	2.480738	.818932	.801063	.913813
69	.026032	.026032	.026097	.026139	.030982
70	.044988	.162912	.043812	.199884	.022677
71	.028857	.016725	.016725	.016725	.018533
72			.203469	.216982	
73	.560400	.074281	.990679	.974045	.158008
74	.000842	.000842	.000900	.000938	.000842
75	.008913	.008913	.093019	.144715	.021425
76	.002915	.002915	.002915	.041287	.002915
77	3.457892	2.077728	2.493000	2.767006	2.532782
78				.000055	
79	.504365	.430668	.546025	.475385	.562948
80	.227815	.224776	.225647	.227309	.226687
81	.001279	.001279	.001279	.013198	.001279
82	.011968	.011968	.012675	.012090	.011968
83	.099127	.099127	.099127	.099127	.099127
84	.006969	.006969	.006969	.006969	.006969
86	.006924	.006924	.128102	.222452	.032635
88			.000531	.000793	.000672

Table 9 (Continued)

Capital Coefficients for Electric Sectors, 1967 $\$/10^6$ Btu generated electricty

BNL Sector	Fossil Electric	Hydro-Electric	LWR Electric	HTGR Electric	Coal CMBND Cycle
89	.281727	.170767	.149752	.170730	.133249
91	.406757	.246168	.215740	.260940	.191854
92	.014788	.008954	.007844	.009047	.006975
93	.036979	.022378	.019611	.022241	.017439
96			.000493	.000791	
99	.250811	.175352	.477683	.613780	.284884
100			.000714	.001124	.106053
101	.013819	.103829	.864317	.013823	.012441
103	.222440	.219245	.185221	.186677	.670792
104			.000535	.000889	
106			.000115	.000179	
107			.000040	.000068	
108			.000042	.000065	
109			.000834	.001301	
110			.000426	.000066	
TOTAL (K/O Ratio)	27.019011	27.655961	30.581936	30.581936	39.268711

V. Recommendations for Future Research

A number of problems were encountered in coordinating and combining capital coefficient information from different original sources. The following recommendations are made so that future research on this subject will be both useful and compatible with that already done.

- Estimation of capital coefficients for technological <u>processes</u> should not be carried out in isolation. Corresponding adjustments should be made to the remaining capital requirements of the input-output <u>sector</u> in which BEA classifies that process. An example of this is the work of Istvan which examines all capital requirements of the electric utility sector, not just those for power plants.

- Coefficients should be estimated within the framework of some set of coefficients for the whole economy, such as Battelle's. Use of the same classification conventions, the same level of detail, and the same year dollars will ensure compatability of estimates and prevent definitional inconsistency.

- Coefficients should accurately reflect the composition of current inputs used by the construction sectors to produce buildings and structures. The processes investigated in this report, for example, all require large capital purchases from one or two new construction sectors. Yet, the I-O table of current (vs. capital) transactions which is used with the capital coefficients says that exactly the same set of inputs are used to construct nuclear plant buildings, fossil plant buildings, etc.

- All capital payments as defined by BEA (including construction and installation labor and interest during construction) should be deflated so that estimated coefficients can be used with historical input-output tables. In this way one can separate real effects in the structure of production from purely monetary effects that have occured between the date of the historical I-O table and the date of the technology represented by the capital coefficients.

·The level of detail incorporated in process coefficients should be compatable with that of the sectoral coefficients with which they are to be used. For example, Just pulls many purchases out of what BEA and Istvan would include in new construction purchases, and he identifies them by sector. This has not been done for fossil plants or T, D & A; so model runs that contrast sectoral investment requirements in fossil capacity versus nuclear capacity are not fully comparable.

REFERENCES

1. Behling, D. J., Marcuse, W., Swift, M., and Tessmer, R., "A Two-level Iterative Model for Estimating Interfuel Substitution Effects," BNL 19863. Paper presented at 1975 Summer Computer Simulation Conference, San Franscisco, July 1975.

2. Fischer, W. H., and Chilton, C. "An Ex Ante Capital Matrix for the United States 1970-1975," final report to Scientific American, Battelle Memorial Institute, Columbus Laboratories, March 31, 1971.

3. Just, J., Borko, B., Parker, N., and Ashmore, A., "New Energy Technology Coefficients and Dynamic Energy Models," Energy Research and Development Administration, ERDA-3 (2 volumes plus corrected tables), January 1975.

4. Istvan, R., "1980 Inputs for Private Electric Utilities," Harvard Economic Research Project, Cambridge, Mass., August 1971.

5. Bechtel Corporation, "The Energy Supply Planning Model," San Francisco, California, July 1975.

6. U.S. Department of Commerce, Bureau of Economic Analysis, "Survey of Current Business," Vol. 54, No. 2, pp. 24-56, February 1974.

7. 27th Annual Electrical Industry Forecast, "Electrical World," September 15, 1976 (pp. 43-58).