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1985 TECHNICAL COEFFICIENTS FOR INPUTS TO ENERGY TECHNOLOGIES

JOAN LUKACHINSKI AND RAYMOND G. TESSMER, JR.

June 1976

ECONOMIC ANALYSIS DIVISION
NATIONAL CENTER FOR ANALYSIS OF ENERGY SYSTEMS

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This report is a revision of two earlier reports, "Technical Coefficients for Inputs to Energy Supply Sectors from Non-Energy Sectors", and "Technical Coefficients for Inputs to New Energy Technologies", by Mark Swift (January 1975 & April 1975), initially issued by the Center for Advanced Computation, University of Illinois at Urbana-Champaign, as CAC Technical Memoranda Nos. 46 & 49. This revision supercedes those reports and includes respecification of input-output coefficients for compatability with a 110 sector version of the combined energy optimization/input-output model developed jointly by CAC and BNL.

ABSTRACT

This report describes the incorporation of input-output technical coefficients for five new energy supply and conversion technologies as estimated by the MITRE Corporation into a 110 sector Energy I-O Model. The five new technologies are solvent-refining of coal, oil shale mining and retorting, high temperature gas-cooled reactor electricity generation, high BTU coal gasification, and COGAS combined cycle electricity generation. Incorporation of seven existing energy supply and conversion technologies is also described: crude oil and gas extraction, coal mining, refined petroleum products, pipeline gas, fossil electric generation, and hydroelectric generation.

Non-energy input coefficients are given in units of 1967 \$/10⁶ BTU and represent the inputs in constant 1967 dollars from non-energy sectors (e.g. manufacturing, transportation, services) required per 10⁶ BTU of energy production by each of these energy supply technologies. The 90 non-energy sectors included are based on the Bureau of Economic Analysis 83 sector input-output structure for 1967 with minor disaggregations. Energy input coefficients are given in units of BTU/BTU.

TABLE OF CONTENTS

	Page
1. INTRODUCTION	1
2. COAL, CRUDE OIL & GAS, REFINED OIL PRODUCTS, AND PIPELINE GAS	2
3. FOSSIL ELECTRIC, LIGHT WATER REACTOR (LWR) ELECTRIC, and HYDROELECTRIC	4
3.1 Disaggregating Petroleum and Transportation Inputs	9
3.2 Process Vectors for Fossil Electric and Electric Overhead	10
3.3 Normalization	10
3.4 Adjustment of Process Coefficients	11
3.5 Reconciliation with BEA Electric Utility Sector Data	13
4. METHANE FROM COAL	13
4.1 Energy Supply Inputs	17
4.2 Energy Product Inputs	17
4.3 Non-Energy Inputs	17
5. SOLVENT-REFINED COAL	19
5.1 Energy Supply Inputs	19
5.2 Energy Product Inputs	19
5.3 Non-Energy Inputs	19
6. SHALE OIL	19
6.1 Energy Supply Inputs	21
6.2 Energy Product Inputs	21
6.3 Non-Energy Inputs	21

Table of Contents (Con't)	Page
7. HIGH TEMPERATURE GAS-COOLED REACTOR (HTGR) ELECTRIC	21
7.1 Electric Overhead and BEA Residual Allocation	23
7.2 Energy Supply Inputs	23
7.3 Energy Product Inputs	23
7.4 Non-Energy Inputs	23
8. COAL COMBINED CYCLE ELECTRIC	23
8.1 Energy Supply Inputs	25
8.2 Energy Product Inputs	25
8.3 Non-Energy Inputs	25
REFERENCES	27
APPENDIX: 1963-1967 Inflatons	29

LIST OF TABLES

		Page
Table 1	Alignment of BNL 110 with Other Classification Systems	3
Table 2	1985 Coal Mining Coefficients	5
Table 3	1985 Crude Oil & Gas Extraction Coefficients	6
Table 4	1985 Refined Oil Products Coefficients	7
Table 5	1985 Pipeline Gas Coefficients	8
Table 6	1967 Non-Energy Process Coefficients for Electricity	12
Table 7	1967 Electric Operating Transactions and Residuals, and Residual Allocation Coefficients	14 & 15
Table 8	1967 Fossil Electric, Light Water Reactor Electric, and Hydroelectric Coefficients	16
Table 9	1985 High BTU Coal Gasification Coefficients	18
Table 10	1985 Solvent-Refined Coal Coefficients	20
Table 11	1985 Shale Oil Coefficients	22
Table 12	1985 High Temperature Gas-Cooled Reactor Coefficients	24
Table 13	1985 Coal Combined Cycle Coefficients	26

1. INTRODUCTION

This memorandum describes the incorporation of input-output coefficients for the following new energy supply technologies into a 110 sector input-output model of the nation's economy:

1. Solvent-Refined Coal (SRC)
2. Shale Oil
3. High Temperature Gas-Cooled Reactor (HTGR)
4. Coal Combined Cycle Electricity Generation (CCC)
5. High BTU Coal Gasification (Methane from Coal)

These coefficients enable expansion of energy detail in an input-output model which was jointly developed by the University of Illinois and Brookhaven National Laboratory. Technical descriptions of the basic model are presented by C. W. Bullard in (1) and by D. J. Behling et al, in [2].

Besides the five new supply technologies listed above, the model includes the following seven existing energy supply sectors: coal, crude oil and gas, refined oil products, pipeline gas, fossil generated electricity, electricity generated by light water reactors, and hydroelectricity. Incorporation of I-O coefficients for these technologies is also described in the report.

There are three distinct types of inputs which are used in the model referenced above: energy supply, energy product, and non-energy. Energy supplies consist of energy resources, processed energy fuels and electricity. By definition, energy supply sectors distribute their output to only energy supply and/or energy product sectors. The flows of energy supplies from one sector to another include estimates of any losses involved in conversion and transmission. The output of these energy supply sectors are measured in British Thermal Units (BTU) per year.

Energy products are non-substitutable, end-use forms of energy. The model defines eight distinct energy products: coke (or ore reduction feedstocks), chemical feedstocks, motive power, process heat, water heat, space heat, air conditioning, and electric power. All energy inputs to a sector for final use by that sector and not for conversion to some other energy form are expressed in terms of energy products. That is, the energy products reflect the non-substitutable end-use demands for energy. For example, an oil refinery could use either oil or gas to meet its space heating needs, but it could not use motive power to do so. Its requirements for heating of office and manufacturing space is thus specified as a demand for space heat, not as a demand for either the oil or gas used to meet the demand. Output of energy

product sectors is also measured in BTU per year.

When calculating outputs of the energy product sectors, certain assumptions were made in the previous version of the I-0 model to exclude counting "free" by-products, such as waste heat from the energy supply sectors. In the current version of the I-0 model, waste heat from total energy systems is included in calculating the outputs of the space heat and air conditioning sectors. The new definition for space heat has also been made consistent with ERDA-48 [17], by dividing the space heat coefficients by 1.58.

There are 90 non-energy sectors consisting of a straightforward, partial disaggregation of 78 sectors in the input-output structure of the Bureau of Economic Analysis (BEA) [3]. Output of these sectors is measured in 1967 constant dollars. Table I lists the twelve energy supply sectors, the eight energy product sectors and the 90 non-energy sectors and also indicates the correspondence between these sectors and the BEA classification.

The primary data source for the new energy technology coefficients presented in this paper is a report by the MITRE Corporation [6]. The report gives detailed data on input requirements from the non-energy sectors and on the BTUs required from energy supply sectors. However, it gives almost no information on energy product requirements. The fuel needed for some motive power requirements is included and one process fuel requirement is identified as process heat, but no mention is made of such requirements as space heat, water heat, or lighting. These must be estimated from similar technology sector requirements as derived by Knecht [16].

2. COAL, CRUDE OIL & GAS, REFINED OIL PRODUCTS and PIPELINE GAS

These four input-output sectors represent existing energy supply technologies which correspond, on a one-to-one basis, to sectors 7.00, 8.00, 31.01 and 68.02 as defined by the Bureau of Economic Analysis (BEA) in [3]. The non-energy input coefficients for these existing energy supply sectors were derived from the Bureau of Labor Statistics 1985 134-order input-output forecast [15]. The 1985 134-order transactions matrix was inflated from 1963 \$ to 1967 \$ using the BLS supplied deflators, and then the 129-order transactions were aggregated to the 110-order BNL classification. Each of the resulting transactions elements was then divided by the corresponding 1967 domestic output in terms of BTUs (from [16]) to obtain coefficients in units of 1967 \$ per 10^6 BTU of energy output.

Table 1. Sectoral Classification of Energy Input-Output Model
and Alignment with Other Classification Systems

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	58.01	-	-	-
10	LWR electric	7	68.01	-	-	-
11	HTWR electric	-	-	68.1	92	101
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 ferroalloy ores mining	21	5	5	5	5
26	Nonferrous metal ores mining	22	6	6	6	6
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	25	11.01	11.1	11	12
30	New construction, nonresidential buildings	26	11.02	11.2	12	13
31	New construction, public utilities	25	11.03	11.3	13	14
32	New construction, highways	26	11.04	11.4	14	15
33	New construction, all other	26	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	26	12.02	12.2	17	18
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 selectec chemical products	41	27	27.1 27.2 27.3	34 35 36	35-36
51	Plastics and synthetic materials	42	28	28.1 28.2	37 38	37
52	Drugs, cleaning and toilet preparations	43	29	29	39	39-40
53	Paints and allied products	44	30	30	40	41
54	Paving mixtures and blocks	45	31.02	part 31	part 41	part 42
55	Asphalt felts and coatings	46	31.03	part 31	part 41	part 42
56	Rubber and miscellaneous plastic products	47	32	32.1 32.2 32.3	42 43 44	43-44
57	Leather tanning and industrial leather products	48	33	33	45	45
58	Footwear and other leather products	49	34	34	46	46
59	Glass and glass products	50	35	35	47	46
60	Stone and clay products	51	36	36	48	47-48

BNL 110	Sector	BNL 101	BEA	Battelle	A.Carter	BLS
61	Primary iron and steel manufacturing	52	37	37	49	49-50
62	Primary nonferrous metals manufacturing	53	38	38.1 38.2 39.3	50 51 52	51-57
63	Metal containers	54	39	39	53	58
64	Mating, 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
78	Household appliances	69	54	54	69	75
79	Electric lighting and wiring equipment	70	55	55	70	77
80	Radio, television and communications equipment	71	56	56	71	78-80
81	Electronic components and accessories	72	57	57.1 57.2 57.3	72 73 74	81
82	Miscellaneous elec. machinery, equipment & supplies	73	58	58	75	82
83	Motor vehicles and equipment	74	59	59	76	83
84	Aircraft and parts	75	60	60	77	84
85	Other transportation equipment	76	61	61	78	85-87
86	Professional, scientific & controlling inst. & supp.	77	62	62	79	88-89
87	Optical, ophthalmic, & photographic equip. & supp.	78	63	63	81	90-91
88	Miscellaneous manufacturing	79	64	64	82	92
89	Railroads and related services	80	65.01	65.1	83	93
90	Local, suburban & interurban highway pass. trans.	81	65.02	65.2	84	94
91	Motor freight transportation and warehousing	82	65.03	65.3	85	95
92	Water transportation	83	65.04	65.4	86	96
93	Air transportation	84	65.05	65.5	87	97
94	Pipe line transportation	85	65.06	65.6	88	98
95	Transportation services	86	65.07	65.7	89	99
96	Communications except radio & television broadcasting	87	66	66	90	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	-	-	136

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

Code BNL 110 - 110 sector version

BNL 101 - 101 sector version

BEA - Bureau of Economic Analysis, U.S. Dept. of Commerce

Battelle- Classification used in reference (7).

A.Carter- Professor Ann Carter, Brandeis University

BLS - Bureau of Labor Statistics, U.S. Dept. of Labor

Historical energy supply and energy product input coefficients for these sectors were derived at the University of Illinois for the year 1967 [16]. The energy product coefficients have been projected to 1985 by using certain projections for floor space, saturation, etc., contained in the "Energy Sourcebook". [18] Energy supply coefficients are not projected because they are endogenously determined by solving the combined I-O/LP model. The resulting A-matrix coefficients of production are presented in Tables 2-5.

3. FOSSIL ELECTRIC, LIGHT WATER REACTOR (LWR) ELECTRIC, and HYDROELECTRIC

The present model equates Nuclear Electricity with the Light Water Reactor (LWR) and Renewable Electricity with hydroelectric generation. James Just [6] gives a current 1974 vector for the LWR. Rudyard Istvan [13] lists 1963 vectors for fossil steam, other fossil, nuclear, and hydroelectric generation. He also gives vectors for transmission, distribution, and administration requirements. In addition, there exists the total transactions vector for inputs to electric utilities (from BEA [14]) which represents a set of 1967 control totals for all requirements of the electric utilities sector.

The Istvan vectors are listed in 1963 \$ transactions and have single, aggregated sectors for transportation (where BEA has seven separate sectors), and for petroleum products (where BEA has three separate sectors (number 6 corresponding to refined oil products; number 54, corresponding to asphalt paving; and number 55, corresponding to asphalt roofing and siding)). Converting Istvan's and Just's data to a form usable for our purposes thus involves five steps:

- Disaggregating Istvan's transactions data for transportation and petroleum
- Aggregating Istvan's process vectors to get transactions data for fossil electric (fossil steam & other fossil), hydroelectric, and electric overhead (distribution & transmission & administration).
- Normalizing the disaggregated transactions vectors with respect to domestic electricity generation in 1963 to get I-O coefficients in terms of 1963 $\$/10^6$ BTU; and multiplying these coefficients by inflators to convert them to 1967 $\$/10^6$ BTU.
- Comparing Istvan's fossil electric and hydroelectric coefficients with Just's LWR coefficients, and adjusting for comparability.
- Converting these 1967 $\$/10^6$ BTU process coefficients to

TABLE 2
1985 COAL MINING COEFFICIENTS

BNL 110	A MATRIX COEFFICIENTS		BNL 110	A MATRIX COEFFICIENTS	
1	0	BTU/BTU	56	.002392	1967\$/10 ⁶ BTU
2	0		57	0	
3	0		58	0	
4	0		59	0	
5	0		60	.000141	
6	0		61	.004562	
7	0		62	.000006	
8	0		63	0	
9	0		64	0	
10	0		65	0	
11	0		66	.001157	
12	0		67	.004883	
13	0		68	0	
14	.000004		69	.008829	
15	.000079		70	.000070	
16	.000527		71	.000460	
17	.000006		72	0	
18	0		73	.000231	
19	0		74	.001213	
20	.000133		75	0	
21	0	1967 \$/10 ⁶ BTU	76	0	
22	0		77	.000665	
23	0		78	0	
24	0		79	.001294	
25	.000004		80	0	
26	.000017		81	0	
27	.000062		82	.000083	
28	.000004		83	.000113	
29	0		84	0	
30	0		85	.000564	
31	0		86	0	
32	0		87	0	
33	0		88	0	
34	0		89	.001275	
35	.000450		90	0	
36	0		91	.001014	
37	0		92	.000044	
38	0		93	.000126	
39	0		94	.000010	
40	0		95	.000014	
41	0		96	.000577	
42	0		97	0	
43	.001340		98	.000139	
44	0		99	.005403	
45	0		100	.002861	
46	0		101	.005127	
47	.000092		102	0	
48	0		103	.004776	
49	.000004		104	.000783	
50	.003357		105	0	
51	0		106	.000175	
52	0		107	.000166	
53	0		108	.000042	
54	.000079		109	.000939	
55	.000029		110	.000049	

TABLE 3
1985 CRUDE OIL AND GAS EXTRACTION COEFFICIENTS

BNL 110	A MATRIX COEFFICIENTS		BNL 110	A MATRIX COEFFICIENTS	
1	0	BTU/BTU	56	.000699	1967\$/10 ⁶ BTU
2	.024703		57	0	
3	0		58	0	
4	0		59	0	
5	0		60	.001169	
6	0		61	.002112	
7	0		62	0	
8	0		63	0	
9	0		64	.001858	
10	0		65	0	
11	0		66	.000751	
12	0		67	.001308	
13	0		68	0	
14	.000003		69	.001555	
15	.000059		70	0	
16	.011095		71	0	
17	.000004		72	0	
18	0		73	.001670	
19	0		74	.000027	
20	.000799		75	0	
21	0	1967\$/10 ⁶ BTU	76	0	
22	0		77	.004485	
23	0		78	0	
24	0		79	.000020	
25	0		80	.000247	
26	.000006		81	.001938	
27	0		82	.000052	
28	0		83	.000027	
29	0		84	0	
30	0		85	0	
31	0		86	.000243	
32	0		87	0	
33	0		88	0	
34	0		89	.002074	
35	.007193		90	0	
36	0		91	.001649	
37	0		92	.000073	
38	0		93	.000205	
39	0		94	.000017	
40	.000146		95	.000024	
41	0		96	.000939	
42	0		97	0	
43	.000003		98	.000226	
44	0		99	.008787	
45	0		100	.004652	
46	0		101	.008338	
47	.000093		102	0	
48	0		103	.007767	
49	.000024		104	.001273	
50	.005400		105	0	
51	0		106	.000285	
52	0		107	.000271	
53	.000240		108	.000069	
54	.000132		109	.001527	
55	.000048		110	.000080	

TABLE 4
1985 REFINED OIL PRODUCTS COEFFICIENTS

BNL 110	A MATRIX COEFFICIENTS		BNL 110	A MATRIX COEFFICIENTS	
1	0	BTU/BTU	56	.000117	1967\$/10 ⁶ BTU
2	1.0004000		57	.000085	
3	0		58	.000064	
4	0		59	0	
5	0		60	.005162	
6	.030534		61	.000117	
7	0		62	.003951	
8	0		63	.012530	
9	0		64	.000664	
10	0		65	0	
11	0		66	.000610	
12	0		67	0	
13	0		68	0	
14	.000100		69	0	
15	.000006		70	.000546	
16	.043881		71	0	
17	.000004		72	.000010	
18	.000110		73	.000235	
19	.000136		74	.000021	
20	.002191		75	0	
21	0	1967 \$/10 ⁶ BTU	76	0	
22	0		77	0	
23	0		78	0	
24	0		79	0	
25	0		80	.000042	
26	0		81	0	
27	.007164		82	.000042	
28	.000053		83	.000010	
29	0		84	0	
30	0		85	0	
31	0		86	.000096	
32	0		87	.000149	
33	0		88	.000278	
34	0		89	.002698	
35	.010817		90	0	
36	0		91	.010024	
37	.001788		92	.003909	
38	0		93	.000257	
39	0		94	.013087	
40	.000010		95	.019631	
41	.000289		96	.004134	
42	0		97	0	
43	.000524		98	.002345	
44	.000021		99	.037131	
45	0		100	.025800	
46	0		101	.029109	
47	.009381		102	.000385	
48	.004690		103	.052457	
49	.000096		104	.000040	
50	.045795		105	0	
51	.000042		106	.000235	
52	.003973		107	.001285	
53	.001692		108	.000160	
54	.005537		109	.002934	
55	.002088		110	.000396	

TABLE 5
1985 PIPELINE GAS COEFFICIENTS

BNL 110	A MATRIX COEFFICIENT		BNL 110	A MATRIX COEFFICIENTS	
1	0	BTU/BTU	56	.000093	1967 \$/10 ⁶ BTU
2	.979534		57	0	
3	0		58	0	
4	0		59	0	
5	0		60	0	
6	0		61	0	
7	.032490		62	0	
8	0		63	0	
9	0		64	0	
10	0		65	0	
11	0		66	0	
12	0		67	0	
13	0		68	0	
14	.000004		69	0	
15	.000072		70	0	
16	0		71	0	
17	.000028		72	0	
18	.000467		73	0	
19	.000076		74	.000023	
20	.000224		75	0	
21	0	1967 \$/10 ⁶ BTU	76	0	
22	0		77	0	
23	0		78	0	
24	0		79	.000007	
25	0		80	0	
26	0		81	0	
27	0		82	.000046	
28	0		83	.000007	
29	0		84	0	
30	0		85	0	
31	0		86	0	
32	0		87	0	
33	0		88	0	
34	0		89	.000156	
35	.008602		90	0	
36	0		91	.001290	
37	0		92	.000602	
38	0		93	.000015	
39	0		94	.002776	
40	0		95	.004160	
41	.000156		96	.005481	
42	0		97	0	
43	0		98	.000250	
44	0		99	.005481	
45	0		100	.009947	
46	0		101	.007840	
47	.000555		102	0	
48	0		103	.033876	
49	.000054		104	.001610	
50	.000031		105	0	
51	0		106	.000328	
52	0		107	.003605	
53	0		108	.021974	
54	.000156		109	.005614	
55	.000054		110	.000336	

transactions; adjusting these transactions to account for the actual 1967 figures given by BEA; and recomputing final coefficients for fossil, LWR, and hydroelectric I-0 sectors.

3.1 Disaggregating Petroleum and Transportation Inputs

To disaggregate petroleum and transportation we will use the 1967 transactions data for inputs to the electric utilities sector which is available from BEA [14] and assume that all of Istvan's process vectors (Table 3-1 in [13]) use these inputs in the same proportions as they are used by the electric utilities sector as a whole. We note that the three petroleum sectors are 31.01, 31.02, and 31.03 in the BEA classification and the seven transportation sectors are 65.01, 65.02, 65.03, 65.04, 65.05, 65.06, and 65.07, while the electric utilities sector is 68.01. Letting $TT_{i,j}$ indicate the 1963 transactions, as given by BEA, for inputs from sector i to sector j , we can calculate, on the basis of the assumption above, the following fractions for disaggregating Istvan's sectors 31 and 65:

$$F_{31.01} = \frac{TT_{31.01, 68.01}}{TT_{31.01, 68.01} + TT_{31.02, 68.01} + TT_{31.03, 68.01}} = 1.0$$

$$F_{31.02} = \frac{TT_{31.02, 68.01}}{TT_{31.01, 68.01} + TT_{31.02, 68.01} + TT_{31.03, 68.01}} = 0.0$$

$$F_{31.03} = \frac{TT_{31.03, 68.01}}{TT_{31.01, 68.01} + TT_{31.02, 68.01} + TT_{31.03, 68.01}} = 0.0$$

$$F_{65.01} = \frac{TT_{65.01, 68.01}}{TT_{65.01, 68.01} + TT_{65.02, 68.01} + \dots + TT_{65.07, 68.01}} = .70972$$

and so on, resulting in the following remaining fractions:

$$F_{65.02} = 0.0$$

$$F_{65.03} = 0.19522$$

$$F_{65.04} = 0.09213$$

$$F_{65.05} = 0.00062$$

$$F_{65.06} = 0.00231$$

$$F_{65.07} = 0.0$$

Since $TT_{31.02, 68.01}$ and $TT_{31.03, 68.01}$ are both zero for 1963 and 1967 we end up simply allotting all of the transaction given by Istvan for sector 31 to sector 31.01.

Letting $ISTVAN_{i,j}$ represent the six electric transactions vectors taken from Istvan's work, and $ELTT_{i,j}$ the corresponding disaggregated transactions, we get:

$$ELTT_{31.01,j} = F_{31.01} * ISTVAN_{31,j} = ISTVAN_{31,j}$$

$$ELTT_{31.02,j} = F_{31.02} * ISTVAN_{31,j} = 0$$

$$ELTT_{31.03,j} = F_{31.03} * ISTVAN_{31,j} = 0$$

$$ELTT_{65.01,j} = F_{65.01} * ISTVAN_{65,j} = .70972 * ISTVAN_{65,j}$$

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$$ELTT_{65.07,j} = F_{65.07} * ISTVAN_{65,j} = 0.0$$

3.2 Process Vectors for Fossil Electric and Electric Overhead

We now add the vector for Other Fossil ($j=3$) to the vector for Fossil Steam ($j=1$) to get a total fossil fuel electric generation vector. Further, the vectors for transmission ($j=4$), Distribution ($j=5$), and Administration ($j=6$) are added to obtain an electric overhead transactions vector.

3.3 Normalization

We now have a three column matrix of 1963 dollar inputs to electricity production. The columns are: (1) Fossil fuel electricity generation, (2) Hydroelectric generation, and (3) Electric Overhead. To get the corresponding coefficients we normalize the elements of these columns by the appropriate domestic generation of electricity in 1963 for each column, expressed in 10^6 BTUs. The electric overhead requirements are assumed to apply to all electricity regardless of how it was generated and so are normalized by total domestic production of electric utilities for 1963. The figures for electric generation in 1963 are taken from the 1971 Statistical Yearbook of the Edison Electric Institute [8]:

$EGEN63_1 = \text{Total Fossil Generation} = 2.5523 \times 10^9 \text{BTU}$
 $EGEN63_2 = \text{Hydroelectric Generation} = .56572 \times 10^9 \text{BTU}$
 $EGEN63_3 = \text{Total Domestic Generation} = 3.1290 \times 10^9 \text{BTU}$

Letting $ELAA63_{i,j}$ denote the coefficients for inputs to the electric generation vectors in 1963 $\$/10^6$ BTU we can write the calculations as follows:

$$ELAA63_{i,j} = ELTT_{i,j} / EGEN63.$$

To convert these coefficients to 1967 $\$/10^6$ BTU we assume that the physical requirements maintained the same proportions to gross domestic outputs between 1963 and 1967 (equivalent to assuming constant technologies or production functions) and adjust the coefficients only on the basis of changes in relative prices. A vector of price inflators for 1963 to 1967, $MU6367_i$, is derived in the Appendix. Letting $ELAA67_{i,j}$ denote the 1967 input coefficients we perform the following operation:

$$ELAA67_{i,j} = ELAA63_{i,j} * MU6367_i$$

This assumes that the same changes in relative prices are experienced by all purchasing sectors.

We now have a matrix of input coefficients to electricity production in terms of 1967 $\$/10^6$ BTU which has three columns. By inserting the MITRE vector for the LWR into the second column and moving columns two and three to the right, we get a four column matrix whose columns are: (1) Fossil electric, (2) LWR or Nuclear Electric, (3) Hydroelectric, and (4) Electric Overhead.

3.4 Adjustment of Process Coefficients

Inspection of process coefficients for fossil electric, LWR electric and hydroelectric reveals inconsistencies between the Istvan and the Just data. These inconsistencies were resolved in three ways. For sectoral requirements identified by Istvan and not by Just, the fossil electric coefficient specified by Istvan was inserted into the LWR vector of coefficients. For sectoral requirements identified by Just and not by Istvan, the LWR coefficient was inserted into the fossil and hydroelectric vectors. Finally, adjustments were made to sectors in which fossil and LWR coefficients were clearly out of line with each other. Fossil versus nuclear coefficient ratios from Istvan, Table 3.5, were used as control ratios for this purpose. The resulting process coefficients for fossil electric, LWR electric, hydroelectric, and electric overhead are presented in Table 6. Coefficients which were adjusted to obtain comparability of vectors are so identified, and energy input coefficients are not listed because they have been obtained from another source.

TABLE 6
1967 NON-ENERGY PROCESS COEFFICIENTS FOR ELECTRICITY
(1967 \$/10⁶BTU)

<u>BNL-110</u>	<u>Fossil Electric</u>	<u>LWR Electric</u>	<u>Hydroelectric</u>	<u>Electric Overhead</u>
35	.10528	.08992*	.03421	.02435
41	.00018	.00093	.00018	.00115
43				.00025
47				.00090
49	.00051***	.00051	.00051***	.00097
50	.00012	.48736		.00038
52	.00042	.00630*	.00042	
53	.00014	.00014**	.00014	
56				.00055
62				.00098
64	.00391***	.00391	.00391***	
66	.00042*	.00423	.00066*	.00070
73	.00373***	.00373	.00373***	
77	.00764*	.00509	.00764*	.00027
79				.00377
81	.00260***	.00260	.00260***	
82	.00005	.00005**	.00005	
83	.00008	.00008**	.00008	
86	.00004	.00444	.00011	
88				.00021
89	.11246	.00714	.00004	
91	.03648	.00204	.00001	
92	.01413	.00092		
93	.00009	.00010		
94	.00032	.00010		
96	.00095	.00091	.00072	.01327
98	.00860	.00768		.00069
99	.00621*	.01241	.00310*	.00368
100	.01182***	.01182	.01182***	.03723
101	.00132***	.00132	.00039	.00096
102	.00165***	.00165	.00165***	
103	.00957***	.00957	.00957***	.06996
104	.00006***	.00006	.00006***	.00180
106	.00156***	.00156	.00156***	.00115
107	.00017***	.00017	.00017***	.01745
108				.00193
109	.00061*	.00119	.00078*	.01260
110	.00041	.00266	.00020	.00309

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- * Istvan's fossil steam/nuclear coefficient ratio from Table 3.5 in [13] used to reestimate this parameter.
 ** Same as Istvan for comparability.
 *** Same as Just for comparability.

3.5 Reconciliation with BEA Electric Utility Sector Data

We now have electric operating coefficients for each of three generating technologies: fossil-fueled, nuclear, and hydroelectric, and for overhead. Since these coefficients have been derived from independent studies, they will not generally be consistent with the figures from BEA for total requirements by the electric utility industry for 1967. To ensure consistency of our energy supply sector input transactions with those of other sectors in the model which are taken from the BEA data, we must control the transactions implied by our four electric coefficient vectors to those given by BEA for the electric utility industry.

The first step is to add the overhead coefficients to each of the three electric generation vectors. This gives total operating requirements per BTU of output for the three types of electricity generation. These coefficients are then converted to 1967 dollar transactions. They are multiplied by historical 1967 production of electricity for each process. Electric utility generation for 1967, taken from [8] and multiplied by the conversion factor, 3412.8 BTU/kw-hr., gives the following levels of production:

Fossil electric -- 3.362×10^{15} BTU
LWR electric -- $.026 \times 10^{15}$ BTU
Hydroelectric -- $.756 \times 10^{15}$ BTU
Total electric -- 4.144×10^{15} BTU.

Transactions for the three processes based on Just and Istvan data is presented in Table 7, and their total (Estimate Total) is compared with 1967 BEA transaction data (BEA Total) for sector 68.01, Electric Utilities. For sectors in which BEA Total is greater than the Estimate Total, the difference is listed in the Residual column. These sectoral residuals are allocated to the three processes in the following way. They are first divided by total 1967 output of electricity, giving coefficients with units of 1967 \$/10⁶BTU. These coefficients are then added to the total operating requirement coefficient vector for fossil, LWR, and hydroelectric. These are the final I-0 coefficients to be used in our I-0 model, and they are listed in Table 8.

Input coefficients for energy product sectors are taken from [16] and projected by BNL to 1985. Input coefficients for energy supply sectors are taken directly from [16], but not projected to 1985 because they are endogenously determined in an I-0/LP model solution.

4. METHANE FROM COAL

Lignite is used to produce a pipeline-quality gas which can substitute for natural gas. The technology examined in the

TABLE 7
1967 ELECTRIC OPERATING TRANSACTIONS AND RESIDUALS
(1967 Dollars)
AND RESIDUAL ALLOCATION COEFFICIENTS (1967 \$/10⁶ BTU)

BNL	Fossil	Nuclear	Hydro-	Estimate	BEA		Residual
110	Electric	LWR	Electric	Total	Total	Residual	Allocation
21-							Coefficient
24	0	0	0	0	0	0	0
25	0	0	0	0	.00030	.00030	.00007
26	0	0	0	0	.00070	.00070	.00017
27	0	0	0	0	.00010	.00010	.00002
28	0	0	0	0	.00010	.00010	.00010
29-							
34	0	0	0	0	0	0	0
35	.43585	.00298	.04427	.48310	.89380	.41070	.09910
36	0	0	0	0	.00020	.00020	.00005
37	0	0	0	0	.00150	.00150	.00036
38	0	0	0	0	.00030	.00030	.00007
39	0	0	0	0	.00180	.00180	.00043
40	0	0	0	0	.00290	.00290	.00070
41	.00447	.00005	.00101	.00553	.00640	.00087	.00021
42	0	0	0	0	0	0	0
43	.00084	.00001	.00019	.00104	.00090		0
44	0	0	0	0	0	0	0
45	0	0	0	0	.00010	.00010	.00002
46	0	0	0	0	0	0	0
47	.00303	.00002	.00068	.00373	.02740	.02367	.00571
48	0	0	0	0	.00260	.00260	.00063
49	.00498	.00004	.00112	.00614	.01570	.00956	.00231
50	.00168	.01274	.00029	.01471	.04430	.02959	.00714
51	0	0	0	0	.00210	.00210	.00051
52	.00141	.00016	.00032	.00189	.00570	.00381	.00092
53	.00047	0	.00011	.00058	.00010		0
54	0	0	0	0	0	0	0
55	0	0	0	0	0	0	0
56	.00185	.00001	.00042	.00228	.02090	.01862	.00449
57	0	0	0	0	.00010	.00010	.00002
58	0	0	0	0	0	0	0
59	0	0	0	0	.00150	.00150	.00036
60	0	0	0	0	.00070	.00070	.00017
61	0	0	0	0	.02150	.02150	.00519
62	.00330	.00003	.00074	.00407	.01090	.00682	.00165
63	0	0	0	0	0	0	0
64	.01315	.00010	.00296	.01621	.00010		0
65	0	0	0	0	.00030	.00030	.00007
66	.00311	.00013	.00103	.00493	.01780	.01287	.00377
67	.00041	0	0	0	.00170	.00170	0
68	.00022	0	0	0	.00090	.00090	0
69	.00022	0	0	0	.00090	.00090	0

TABLE 7 (Cont'd.)
1967 ELECTRIC OPERATING TRANSACTIONS AND RESIDUALS
(1967 Dollars)
AND RESIDUAL ALLOCATION COEFFICIENTS (1967 \$/10⁶ BTU)

BNL l10	Fossil Electric	Nuclear LWR Electric	Hydro- Electric	Estimate Total	BEA Total	Residual	Residual Allocation Coefficient
70	0	0	0	0	0	0	0
71	0	0	0	0	0	0	0
72	0	0	0	0	0	0	0
73	.01254	.00010	.00282	.01546	.02740	.01194	.00288
74	0	0	0	0	.00160	.00160	.00039
75	0	0	0	0	0	0	0
76	0	0	0	0	0	0	0
77	.02660	.00014	.00598	.03272	.04040	.00768	.00185
78	0	0	0	0	0	0	0
79	.01268	.00010	.00285	.01563	.03150	.01587	.00383
80	0	0	0	0	.00110	.00110	.00027
81	.00874	.00007	.00197	.01078	.00240		0
82	.00017	0	.00003	.00020	.00200	.00180	.00043
83	.00027	0	.00006	.00033	.00550	.00517	.00125
84	0	0	0	0	0	0	0
85	0	0	0	0	0	0	0
86	.00013	.00012	.00008	.00033	.00140	.00107	.00026
87	0	0	0	0	.00010	.00010	.00002
88	.00071	.00001	.00016	.00088	.00030		0
89	.37812	.00019	.00003	.37834	.45990	.08156	.01968
90	0	0	0	0	0	0	0
91	.12266	.00005	.00001	.12272	.12650	.00378	.00091
92	.04751	.00002	0	.04753	.05970	.01217	.00294
93	.00030	0	0	.00030	.00040	.00010	.00002
94	.00108	0	0	.00108	.00150	.00042	.00010
95	0	0	0	0	0	0	0
96	.04782	.00037	.01058	.05877	.06560	.00683	.00165
97	0	0	0	0	0	0	0
98	.03124	.00022	.00052	.03198	.01310		0
99	.03325	.00042	.00513	.03880	.18280	.14400	.03475
100	.16499	.00128	.03710	.20337	.12970		0
101	.00767	.00006	.00102	.00875	.06260	.05385	.01299
102	.00555	.00004	.00125	.00684	.02000	.01316	.00318
103	.26740	.00208	.06012	.32960	.24020		0
104	.00625	.00005	.00141	.00771	.04280	.03509	.00847
105	0	0	0	0	0	0	0
106	.00911	.00007	.00205	.01123	.01030		0
107	.05924	.00046	.01332	.07302	.09980	.02678	.00646
108	.00648	.00005	.00146	.00799	.00270		0
109	.04442	.00036	.01012	.05490	.07360	.01870	.00451
110	.01178	.00015	.00249	.01442	.02410	.00968	0

TABLE 8
1967 FOSSIL ELECTRIC, LIGHT WATER REACTOR ELECTRIC
AND HYDROELECTRIC COEFFICIENTS

BNL 110	FOSSIL	NUCLEAR LWR	HYDRO- ELECTRIC	BNL 110	FOSSIL	NUCLEAR LWR	HYDRO- ELECTRIC
BTU/BTU				1967 \$/10 ⁶ BTU			
1	2.12470	0	0	56	.00504	.00504	.00504
2	0	0	0	57	.00002	.00002	.00002
3	0	0	0	58	0	0	0
4	0	0	0	59	.00036	.00036	.00036
5	0	0	0	60	.00017	.00017	.00017
6	.27886	0	0	61	.00519	.00519	.00519
7	.84551	0	0	62	.00263	.00263	.00263
8	0	0	0	63	0	0	0
9	.08800	0	0	64	.00391	.00391	.00391
10	0	.08802	0	65	.00007	.00007	.00007
11	0	0	0	66	.00423	.00804	.00447
12	0	0	.08731	67	.00041	.00041	.00041
13	0	0	0	68	.00022	.00022	.00022
14	.00005	.00005	.00005	69	.00022	.00022	.00022
15	.00089	.00089	.00089	70	0	0	0
16	0	0	0	71	0	0	0
17	.00035	.00035	.00035	72	0	0	0
18	.00579	.00579	.00579	73	.00661	.00661	.00661
19	.00094	.00094	.00094	74	.00039	.00039	.00039
20	.00277	.00277	.00277	75	0	0	0
21	0	0	0	76	0	0	0
22	0	0	0	77	.00976	.00721	.00976
23	0	0	0	78	0	0	0
24	0	0	0	79	.00760	.00760	.00760
25	.00007	.00007	.00007	80	.00027	.00027	.00027
26	.00017	.00017	.00017	81	.00260	.00260	.00260
27	.00002	.00002	.00002	82	.00048	.00048	.00047
28	.00010	.00010	.00010	83	.00133	.00133	.00133
29	0	0	0	84	0	0	0
30	0	0	0	85	0	0	0
31	0	0	0	86	.00030	.00470	.00037
32	0	0	0	87	.00002	.00002	.00002
33	0	0	0	88	.00021	.00021	.00021
34	0	0	0	89	.13214	.02682	.01972
35	.22873	.21337	.15766	90	0	0	0
36	.00005	.00005	.00005	91	.03739	.00295	.00092
37	.00036	.00036	.00036	92	.01707	.00376	.00294
38	.00007	.00007	.00007	93	.00011	.00012	.00002
39	.00043	.00043	.00043	94	.00042	.00020	.00010
40	.00070	.00070	.00070	95	0	0	0
41	.00154	.00229	.00154	96	.01587	.01583	.01564
42	0	0	0	97	0	0	0
43	.00025	.00025	.00025	98	.00929	.00837	.00069
44	0	0	0	99	.04464	.05084	.04153
45	.00002	.00002	.00002	100	.04907	.04907	.04907
46	0	0	0	101	.01527	.01527	.01434
47	.00661	.00661	.00661	102	.00483	.00483	.00483
48	.00063	.00063	.00063	103	.07953	.07953	.07953
49	.00379	.00379	.00379	104	.01033	.01033	.01033
50	.00764	.49488	.00752	105	0	0	0
51	.00051	.00051	.00051	106	.00271	.00271	.00271
52	.00134	.00722	.00134	107	.02408	.02408	.02408
53	.00014	.00014	.00014	108	.00193	.00193	.00193
54	0	0	0	109	.01772	.01830	.01789
55	0	0	0	110	.00350	.00575	.00329

MITRE report [6] included only the processing of the coal to gas; so all coal gas produced goes to the pipeline gas sector for distribution in the I-0 model.

4.1 Energy Supply Inputs

The only input to this sector for processing of coal to gas from other energy supply sectors is the coal. Any other energy needs for the conversion process are produced from the coal and are included as part of the process technology. The report gives a coefficient for BTUs of coal input per BTU of gas output of 1.620743.

4.2 Energy Product Inputs

The only energy input other than coal shown in the MITRE report is refined oil. The total value of this input is given as \$48,880. The total energy content is given as 1.75×10^{10} BTUs. Although \$13,880 is indicated as being for "power generation", the text of the report states that this is "omitted fuel purchases". So this input probably represents lubricants used in the coal-fired power plant. The remainder is listed as being for "supplies" and probably is mostly for vehicle fuel and oil although some might be for other energy products such as water heat or space heat. Applying the dollar fractions to the total refined oil BTU content, the two parts consist of $.4969 \times 10^{10}$ BTUs and 1.253×10^{10} BTUs. Normalizing these with respect to the annual BTU coal gas output of the plant gives coefficients of $.30255 \times 10^{-4}$ BTU/BTU for chemical feedstocks (which includes lubricants) and $.83346 \times 10^{-4}$ BTU/BTU for other uses. The latter coefficient is ignored in view of the following.

Subjective evaluation of the coal gasification process makes it appear more similar to petroleum refining than to any of the other energy supply sectors examined by Bullard and Knecht [5] in terms of its requirements for energy products such as water heat or motive power. Examination of the motive power input coefficients for petroleum refining indicate the same general degree of fuel usage as indicated in the MITRE report. For lack of more complete data we will simply adopt the assumption that energy product use in the coal gasification sector is identical to that derived for refined petroleum except for chemical feedstocks and process heat requirements. The process heat requirements here are primarily included as part of the process and already counted in the coal input. Process heat input thus will be zero. For chemical feedstocks we use the coefficient derived above from the MITRE data.

4.3 Non-Energy Inputs

Non-energy inputs are aggregated directly from MITRE coefficients, [6, Vol. 1, pp. 62-65].

TABLE 9
1985 HIGH BTU COAL GASIFICATION COEFFICIENTS
(METHANE FROM COAL)

BNL 110	A MATRIX COEFFICIENTS		BNL 110	A MATRIX COEFFICIENTS
1	1.620743	BTU/BTU	56	.00015
2	0		57	0
3	0		58	0
4	0		59	.00002
5	0		60	.00008
6	0		61	.00016
7	0		62	.00045
8	0		63	.00024
9	0		64	0
10	0		65	0
11	0		66	.00011
12	0		67	0
13	0		68	0
14	.00003		69	.00043
15	.00001		70	.00004
16	0		71	.00009
17	0		72	.00026
18	.00011		73	.00016
19	.00014		74	0
20	.00219		75	0
21	0	1967 \$/10 ⁶ BTU	76	0
22	0		77	.00003
23	0		78	0
24	0		79	.00003
25	0		80	0
26	0		81	0
27	.01749		82	0
28	0		83	.00002
29	0		84	0
30	0		85	0
31	0		86	.00002
32	0		87	.00001
33	0		88	.00002
34	0		89	.00174
35	.00910		90	0
36	.00001		91	.00100
37	0		92	.00174
38	0		93	.00005
39	.00011		94	.00045
40	.00001		95	0
41	.00002		96	.00092
42	.00002		97	0
43	.00004		98	.01324
44	0		99	.00085
45	0		100	.02313
46	0		101	.00387
47	.00096		102	.00017
48	.00018		103	.00557
49	.00054		104	.00018
50	.00549		105	0
51	0		106	.00011
52	.00053		107	0
53	.00012		108	0
54	0		109	.00147
55	0		110	.00018

5. SOLVENT-REFINED COAL

Solvent-refined coal is an ashless, desulfurized fuel from coal intended for use primarily as a boiler fuel for electricity generation and as a feedstock for petrochemical industries. At room temperature it is a solid while under moderate heat (400°F) it becomes a liquid. Thus it can substitute for both regular coal and residual oil as a boiler fuel. In the I-0 sector model it can only be used as a boiler fuel at present, not as a chemical feedstock.

5.1 Energy Supply Inputs

As was the case for coal gasification, the only energy supply input to this technology is the coal consumed and converted in the process. The coefficient is 1.697 BTUs of coal input per BTU of solvent refined coal output.

5.2 Energy Product Inputs

The only energy product requirement explicitly indicated in the MITRE report was 1.04×10^{14} BTUs of natural gas for process heat. Assuming a burner efficiency of 64% (as used in reference [5]), this amounts to $.6656 \times 10^{14}$ BTUs of process heat. Normalizing by the total output of solvent refined coal, and then adjusting the process heat coefficient by .90 to project to 1985, we get a coefficient of .058068 BTU/BTU for process heat requirements.

The remaining energy product coefficients must be approximated by some known set as was done previously. Again, of all previously examined energy supply technologies, petroleum refining seems to be the most similar. So we will assume energy product coefficients for solvent-refined coal identical to those for refined petroleum for all energy products except process heat and chemical feedstocks. For feedstocks, we will use the coefficient from the coal gasification technology.

5.3 Non-Energy Inputs

Since the coefficients for inputs from the non-energy sectors are available directly from the MITRE data in 10^6 $\$/10^{15}$ RTU [6, Vol. I, pp. 59-60] it was only necessary to multiply them by 10^3 to adjust the units to $\$/10^6$ BTU and then aggregate and re-order them to correspond to our 90 non-energy sectors. The coefficients are listed in Table 10.

6. SHALE OIL

The technology represented here includes mining of the shale and retorting it to a high-grade, low sulfur crude oil. This processing is assumed to be done at the mine-mouth (but not in situ), and the crude oil is shipped to refineries for further refining.

TABLE 10
1985 SOLVENT REFINED COAL COEFFICIENTS

BNL 110	A MATRIX COEFFICIENT		BNL 110	A MATRIX COEFFICIENT	
1	1.697000	BTU/BTU	56	0	1967 \$/10 ⁶ BTU
2	0		57	0	
3	0		58	0	
4	0		59	0	
5	0		60	.000662	
6	0		61	0	
7	0		62	0	
8	0		63	0	
9	0		64	.004507	
10	0		65	0	
11	0		66	.002775	
12	0		67	.001177	
13	0		68	0	
14	.000030		69	.000306	
15	.000006		70	.000720	
16	.058068		71	0	
17	.000004		72	0	
18	.000110		73	.005373	
19	.000136		74	0	
20	.002191		75	0	
21	0	1967 \$/10 ⁶ BTU	76	0	
22	0		77	.000039	
23	0		78	0	
24	0		79	.002359	
25	0		80	0	
26	0		81	0	
27	0		82	0	
28	0		83	0	
29	0		84	0	
30	0		85	0	
31	0		86	.001414	
32	0		87	0	
33	0		88	0	
34	0		89	.000146	
35	.004824		90	0	
36	0		91	.000083	
37	0		92	.000146	
38	0		93	.000004	
39	0		94	.000037	
40	0		95	0	
41	0		96	0	
42	0		97	0	
43	0		98	.002193	
44	0		99	.001842	
45	0		100	0	
46	0		101	0	
47	0		102	.000155	
48	0		103	.003606	
49	0		104	0	
50	.000503		105	0	
51	0		106	0	
52	0		107	0	
53	0		108	0	
54	0		109	0	
55	0		110	.000401	

6.1 Energy Supply Inputs

Since this technology represents resource extraction and not conversion there is no supply entry similar to that found in the previous two technologies. However, there is indicated the use of 6.78×10^{11} BTUs of natural gas for "methane reforming" in the processing of the shale to a crude oil. This is a feedstock use of the methane but evidently a non-substitutable one. As such it should enter as a supply coefficient rather than as an energy product since the latter formulation would enable the model to substitute feedstocks other than methane. The coefficient indicated by the MITRE data is .006405 and will be an input from the natural gas sector to the shale oil sector. At the present time this use of natural gas is not incorporated in the 110 sector model.

6.2 Energy Product Inputs

The only energy product input given in the MITRE report is a small amount of refined petroleum for vehicle fuel. This technology seems to have some of the characteristics of coal mining or stone quarrying, or crude oil extraction, and of oil refining. As a first approximation we will assume that the energy product requirements for mining and retorting a ton of shale are equal to the requirements for mining a ton of coal. This enables us to calculate the energy product coefficients for the shale oil sector by multiplying the energy product coefficients of the coal sector by the ratio of the BTU content of a ton of shale [7] to the BTU content of a ton of coal. (Ref. [7] gives shale yield of 35 gal. of crude oil per ton of shale; at 5,800,000 BTU/bbl. of crude and 42 gal./bbl. this converts to 4,833,333 BTU/ton of shale versus 26,200,000 BTU/ton of coal.)

6.3 Non-Energy Inputs

As with solvent-refined coal, the shale oil coefficients are directly available from the MITRE data [6, Vol. I, pp. 56-57] and need only be adjusted for unit, aggregation and ordering differences. The coefficients are printed in Table 11.

7. HIGH TEMPERATURE GAS-COOLED REACTOR (HTGR) ELECTRIC

The technology represented here includes the generation of electricity by a high temperature gas-cooled nuclear reactor (HTGR) as well as the transmission and distribution of the electricity generated and the administration of the entire range of activities. These non-generating, or overhead, activities are included so that the sector will parallel the BEA sector for electric utilities and our previous disaggregation of that sector in section 3.

The MITRE data includes only the inputs required for

TABLE 11
1985 SHALE OIL COEFFICIENTS

BNL 110	A MATRIX COEFFICIENT		BNL 110	A MATRIX COEFFICIENT	
1	0	BTU/BTU	56	.002057	1967 \$/10 ⁶ BTU
2	0		57	0	
3	0		58	0	
4	0		59	0	
5	0		60	0	
6	0		61	0	
7	0		62	0	
8	0		63	0	
9	0		64	.000872	
10	0		65	.001104	
11	0		66	.000520	
12	0		67	.000890	
13	0		68	0	
14	.000001		69	.006994	
15	.000015		70	.000854	
16	.000097		71	0	
17	.000001		72	0	
18	0		73	.002496	
19	0		74	0	
20	.000025		75	0	
21	0	1967 \$/10 ⁶ BTU	76	0	
22	0		77	.002246	
23	0		78	0	
24	0		79	0	
25	0		80	.000821	
26	0		81	0	
27	0		82	0	
28	0		83	.000618	
29	0		84	0	
30	0		85	0	
31	0		86	.000619	
32	0		87	0	
33	0		88	0	
34	0		89	.000443	
35	.008060		90	.000253	
36	0		91	.000443	
37	0		92	0	
38	0		93	.000013	
39	0		94	.000114	
40	0		95	0	
41	0		96	.001189	
42	0		97	0	
43	0		98	.001878	
44	0		99	.003786	
45	0		100	.025971	
46	0		101	.022496	
47	0		102	.000149	
48	0		103	.007763	
49	.000154		104	.002639	
50	.030320		105	0	
51	0		106	.001139	
52	0		107	0	
53	0		108	0	
54	0		109	.001713	
55	0		110	.000173	

generation and none of the overhead requirements. Thus in addition to the data restructuring done for the previous two technologies, we also must calculate and add on a vector of coefficients for inputs to the overhead activities, and for residual BEA sectoral transactions.

7.1 Electric Overhead and BEA Residual Allocation

In section 3 of this report, using the MITRE data for electricity generation by a Light Water Reactor (LWR) and BEA and Istvan data for electric utilities, a vector of coefficients was obtained for the LWR which included transmission, distribution and administration requirements as well as the generation requirements. Assuming that all electric generation technologies have the same requirements for transmission, distribution and administration and that all of the generation process vectors developed by MITRE are consistent in their treatment of these overhead requirements, then we can simply take the electric overhead coefficients presented in Table 6 and the residual allocation coefficients presented in Table 7 and add them to the MITRE coefficients.

7.2 Energy Supply Inputs

Since the MITRE data did not explicitly derive energy supply or energy product data, the vector just calculated has no energy supply or product coefficients.

The HTGR will have no energy supply inputs for conversion because the nuclear fuel used in the conversion to electricity is a product of the chemical sector (sector 50) and not of an energy supply sector. However, transmission and distribution of electricity is assumed to consume 9% of all electricity generated. So there will be a selfuse coefficient of .09.

7.3 Energy Product Inputs

Again, the MITRE data indicates only lubricants and vehicle fuel. Here we have a very similar technology, in terms of its energy product requirements, to draw on. We can assume that the energy product inputs to the HTGR are identical to those derived for the LWR in Table 8.

7.4 Non-Energy Inputs

The vector for the generating requirements of the HTGR obtained from the MITRE data must be modified as with the previous technologies: adjusting the units, aggregating, and reordering to our 90 sectors. Then the electric overhead coefficients and BEA residual allocation coefficients must be added. The final vector for the HTGR is given in Table 12.

8. COAL COMBINED CYCLE ELECTRIC

This is actually the combination of two processes into a

TABLE 12
1985 HIGH TEMPERATURE GAS-COOLED REACTOR COEFFICIENTS

BNL 110	A MATRIX COEFFICIENTS		BNL 110	A MATRIX COEFFICIENTS	
		BTU/BTU			1967 $\$/10^6$ BTU
1	0		56	.00504	
2	0		57	.00002	
3	0		58	0	
4	0		59	.00036	
5	0		60	.00017	
6	0		61	.00519	
7	0		62	.00263	
8	0		63	0	
9	0		64	.00488	
10	0		65	.00007	
11	.090000		66	.00913	
12	0		67	.00041	
13	0		68	.00022	
14	.00005		69	.00022	
15	.00089		70	0	
16	0		71	0	
17	.00035		72	.01180	
18	.00578		73	.00734	
19	.00094		74	.00039	
20	.00277		75	0	
		1967 $\$/10^6$ BTU			
21	0		76	0	
22	0		77	.00839	
23	0		78	0	
24	0		79	.00760	
25	.00007		80	.00027	
26	.00017		81	.00410	
27	.00002		82	.00043	
28	.00010		83	.00125	
29	0		84	0	
30	0		85	0	
31	0		86	.00573	
32	0		87	.00002	
33	0		88	.00021	
34	0		89	.02813	
35	.12700		90	0	
36	.00005		91	.00332	
37	.00036		92	.00391	
38	.00007		93	.00015	
39	.00043		94	.00022	
40	.00070		95	0	
41	.00102		96	.01611	
42	0		97	0	
43	.00025		98	.00937	
44	0		99	.05340	
45	.00002		100	.05229	
46	0		101	.01538	
47	.00661		102	.00532	
48	.00063		103	.08337	
49	.00411		104	.01039	
50	.56070		105	0	
51	.00051		106	.00302	
52	.00092		107	.02413	
53	0		108	.00193	
54	0		109	.01857	
55	0		110	.00732	

single I-0 sector. The first process is low BTU gasification of coal. The second process uses this gas in a second generation COGAS combined cycle generating plant. The MITRE report gives vectors for each of these processes.

To combine these two processes into a single technology, Coal Combined Cycle Electric (CCC), we first multiply the MITRE coefficients for input requirements to the low BTU gasification process by the BTUs of gas required by the COGAS plant to get the dollar (for non-energy sectors) and BTU (for energy sectors) inputs required by the gasification process. Multiplying the MITRE coefficients for inputs to the COGAS plant by the BTUs of electricity generated gives the inputs required by the COGAS generating process. The sum of these two gives the total inputs required by the combined technology. To get coefficients for this combined technology we divide these inputs by the BTUs of electricity generated. Using values for annual production taken from the MITRE report the above operation can be written for each sector, i , as

$$CCC(I) = (LOWGAS(I) * 3.83897 \times 10^7 + COGAS(I) * 2.092238 \times 10^7) / 2.092238 \times 10^7$$

This gives us a vector of coefficients for the combined processes at the same level of aggregation and in the same ordering as the MITRE data.

8.1 Energy Supply Inputs

The operation just described results in a coefficient of 2.10972 for BTUs of coal input per BTU of electricity output. There is also some electricity consumed by the coal gasification process. We assumed this will be consumed from the output of the CCC plant and is a non-substitutable selfuse of electricity. The coefficient for this consumption derived from the MITRE data is .0583749. To this must be added the transmission and distribution loss coefficient of .09 to get the total selfuse coefficient for CCC of .148375.

8.2 Energy Product Inputs

Again, the MITRE data is sketchy and incomplete so we will simply assume that energy product requirements are the same as for regular fossil electric generation as presented in Table 8.

8.3 Non-Energy Inputs

After aggregating and reordering the vector derived from the MITRE data, we must add on the overhead vector derived previously. Since the output of the combined processes is generated electricity, we must add the electric overhead coefficients (Table 6) and the BEA residual allocation coefficients (Table 7) so that this electric generation technology will parallel the other generating sectors. The final vector is given in Table 13.

TABLE 13

1985 COAL COMBINED CYCLE ELECTRIC COEFFICIENTS

BNL 110	A MATRIX COEFFICIENTS		BNL 110	A MATRIX COEFFICIENTS	
1	2.10872	BTU/BTU	56	.00528	1967 \$/10 ⁶ BTU
2	0		57	.00002	
3	0		58	0	
4	0		59	.00039	
5	0		60	.00029	
6	0		61	.00546	
7	0		62	.00327	
8	.14837		63	.00041	
9	0		64	0	
10	0		65	.00007	
11	0		66	.00541	
12	0		67	.00041	
13	0		68	.00022	
14	.00005		69	.00022	
15	.00089		70	.00008	
16	0		71	.00015	
17	.00035		72	.00043	
18	.00578		73	.00315	
19	.00094		74	.00039	
20	.00277		75	0	
21	0	1967 \$/10 ⁶ BTU	76	0	
22	0		77	.00274	
23	0		78	0	
24	0		79	.00766	
25	.00007		80	.00027	
26	.00017		81	0	
27	.00002		82	.00043	
28	.00010		83	.00128	
29	0		84	0	
30	0		85	0	
31	0		86	.00088	
32	0		87	.00004	
33	0		88	.00025	
34	0		89	.02136	
35	.18863		90	0	
36	.00005		91	.00096	
37	.00036		92	.00304	
38	.00007		93	.00002	
39	.00060		94	.00012	
40	.00072		95	0	
41	.00139		96	.01780	
42	.00003		97	0	
43	.00029		98	.01320	
44	0		99	.05543	
45	.00002		100	.04931	
46	0		101	.01652	
47	.00813		102	.00331	
48	.00092		103	.07370	
49	.00365		104	.01040	
50	.00761		105	0	
51	.00051		106	.00123	
52	.00614		107	.02391	
53	.00019		108	.00193	
54	0		109	.02117	
55	.00001		110	.00405	

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APPENDIX: 1963-1967 INFLATORS

This appendix describes the construction of a vector of inflators for converting 1963 dollar transactions into equivalent 1967 dollar transactions for each sector. The data used comes from unpublished reports of the Bureau of Labor Statistics and neither they nor we guarantee its accuracy. (9) The data consists of the 1967 total output for each of 134 sectors expressed in 1967 dollars, $x_k^{67,67}$; 1967 total output for these sectors expressed in 1963 dollars, $x_k^{67,63}$, and an inflator coefficient for each of these sectors, μ_k .

Table 1 in the text presents the correspondence between the BLS sectors and our 110 sector model: column two gives the sector name; column one lists the 110 order sector number; column four lists the corresponding BEA sector number; and column seven gives the associated BLS sector or sectors.

The mapping from the 134 BLS sectors to our 110 sectors is sometimes one-to-many and frequently many-to-one. Letting the subscript k denote the 134 BLS sectors and the subscript i denote our 110 sectors we can simply write

$$\mu_i^{63,67} = \mu_k^{63,67}$$

when there is a one-to-one mapping from k to i . When the mapping is one-to-many, as in the case of $k = 42$ which corresponds to $i = 6, 54$, and 55 we assume that the inflator value for a sector is valid for all subsectors. This implies

$$\mu_i^{63,67} = \mu_k^{63,67}$$

for every i associated with k . When the mapping is many-to-one and there are many different inflation rates which must be combined to yield a single coefficient, we must return to the equation relating the coefficients to total outputs:

$$\mu_k^{63,67} = x_k^{67,67} / x_k^{67,63}.$$

For the case where there are many sectors k associated with a single sector i , we then get

$$\mu_i^{63,67} = \sum_{k \rightarrow i} x_k^{67,67} / \sum_{k \rightarrow i} x_k^{67,63}.$$

There is one special case where one k sector and part of another are mapped into one sector i , while the remainder of the second k sector is mapped into a different i . This occurs with sectors $k = 27$ and $k = 28$. All of 27 and 91.29% of the 1967 total

output in 1967 \$ of sector 28 are associated with sector $i = 43$.
 The remaining 8.71% of the total output of 28 is associated with
 $i = 44$ In a parallel to the above equation we can see that

$$\mu_{43}^{63,67} = (x_{27}^{67,67} + (.9129) x_{28}^{67,67}) / (x_{27}^{67,63} + (.9129) x_{28}^{67,63})$$

and

$$\mu_{44}^{63,67} = (.0871) x_{28}^{67,67} / (.0871) x_{28}^{67,63} = \mu_{28}^{63,67}.$$